Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 25 No. 9
October 2025
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2025; 25(9): 27741-27771 https://doi.org/10.18697/ajfand.146.25850

Date	Submitted	Accepted	Published
	25th August 2025	6th October 2025	6th November 2025

ECONOMIC DAMAGE ASSESSMENT OF FLOOD-AFFECTED AREAS IN MAHASARAKHAM PROVINCE OF THAILAND: ASSESSING THE ELEMENTS OF ECONOMIC DAMAGE VALUES

Sawangloke W[1], Chanthes S[1], Phuakkhuntot C[1], Muangkhiew P[1]*, Luksamee-Arunothai M[2], Senbut P[3] and N Srimuangtong[1]

Muangkhiew Pornpiya

*Corresponding author email: pornpiya.m@acc.msu.ac.th
ORCID: https://orcid.org/0009-0004-4534-1236

[1]Mahasarakham Business School, Mahasarakham University, Thailand

[2]Department of Economics, Faculty of Economics, Kasetsart University (Bangkhen Campus), Thailand

[3]Parliamentary Budget Office, The Secretariat of the House of Representatives, Thailand

ABSTRACT

Natural disaster is among the causes that affect agricultural production, especially in agricultural land of Thailand. Flood damage is obviously recognized because of climate change. As a result, it negatively affects the food security through complex relationships between food production, distribution, consumption and waste with the flood. To prevent future destructions, this research assesses the preliminary economic damage from flooding and identifies factors that determine the value of damage from flooding in Mahasarakham province, Thailand, in 2022. The areas of study cover Mueang District and Kantharawichai District. The area of study was chosen because of its densely populated area of agriculture households. The study employs a preliminary economic damage assessment methodology focusing on direct and indirect damages. It used quantitative and qualitative approaches to analyze the primary data collected through a questionnaire survey and semi-structured interviews from 242 flood-affected households. These families are primarily involved in agricultural farming. Factors determining flood damage values were analyzed using cross-sectional data analysis through a linear regression model. The investigation reveals that average total damage reached USD 3,726.69 per household, comprising direct damages of USD 3,520.52 per household and indirect damages of USD 206.17 per household. Flood victims received compensation from government and private sector sources averaging USD 530.80 per household, equivalent to 14.24 percent of the total average damage value. Analysis of factors affecting total flood damage value demonstrates predominantly positive correlations, with notable exceptions being the age of household heads in Kantharawichai District and the distance of residences from nearest rivers in Mueang District and overall analyses. Research limitations include delayed data collection following the flooding event, necessitated by interview form development and respondents' focus on home repairs, suggesting future studies should prioritize immediate data collection to minimize discrepancies. The findings provide practical implications to determine appropriate compensation for flood victims and develop guidelines for reducing factors contributing to economic damage which are 1) Implementation of comprehensive flood preparedness training programs, 2) Development of enhanced early warning systems, 3) Integration of adaptive management strategies in flood-prone areas. These can be useful for all stakeholders. The study contributes to existing literature through its comprehensive preliminary economic damage assessment across household, agricultural, and business sectors, coupled with analysis of factors affecting total economic damage values. Future research should focus on the longitudinal assessment of how effective a flood warning strategy is and the investigation of additional variables that influence community resilience to extreme flooding.

Key words: Damages, economic loss assessment, flooding disaster, total economic damage value

Citation: **Sawangloke W, Chanthes S, Phuakkhuntot C, Muangkhiew P, Luksamee-Arunothai M, Senbut P and N Srimuangtong** Economic Damage Assessment of Flood-affected Areas in Mahasarakham Province of Thailand: Assessing the Elements of Economic Damage Values. *Afr. J. Food Agric. Nutr. Dev.* 2025; **25(9):** 27741-27771. https://doi.org/10.18697/ajfand.146.26285

INTRODUCTION

Agricultural resources sustainability is a primary goal in agricultural land [1]. However, limitation of land, environmental changes and uncertainty of production results and limited access to resources directly impact the farmers' earnings [2].

Global climate change has accelerated an increase in the frequency, intensity, and duration of floods, which constitute a significant natural disaster. These events become visible when precipitation levels exceed normal parameters, either through heavy rainfalls or prolonged duration, resulting in flash floods, extensive inundation, and riverine overflow. The consequent impacts on communities and individuals are both substantial and multifaceted. Furthermore, flooding events immediately trigger and cause profound disruptions to human habitation, infrastructure, economic systems, and ecological frameworks that exceed conventional human adaptive capacity. One of the problems is soil erosion which mostly affects the rice fields [3]. Historical data analysis reveals that flooding is the leading cause of natural disaster damage in Thailand. Longitudinal assessment spanning 1989 through 2021 indicates that flood-induced damages totalled USD 3,315.40 million, representing 69.69 percent of aggregate natural disaster damages. In hierarchical order of magnitude, conflagration-related damages ranked second at USD 1,196.41 million (18.13 percent), followed by drought impacts of USD 622.92 million (9.44 percent). Further analysis reveals that windstorms resulted in damages of USD 171.04 million (2.59 percent), while winter-related hazards accounted for USD 9.29 million (0.14 percent) of total documented damages [4]

In Thailand, rice has been most important agricultural crops. However, those paddy fields located near river lines are risky to high flood [5]. Flood causation derives from a variety of circumstances. The primary contributory factors encompass south-eastern monsoon patterns, low-pressure meteorological systems, tropical cyclonic (including depressions, tropical storms, and typhoons), anthropogenic factors such as dam discharge, and structural failures or capacity exceedance in banks, reservoirs, and hydraulic infrastructure.

The meteorological genesis of Typhoon NORU can be traced to a low-pressure system that developed in the Pacific Ocean in September 2022, subsequently bringing heavy rains to many parts generating substantial precipitation across multiple regions of Thailand. The system exhibited intensified as it unfolded into Thailand, particularly in the Khong Chiam district. On September 28, 2022, the system a weakened a tropical depression upon reaching Ubon Ratchathani Province. The meteorological system subsequently traversed the provinces of Amnat Charoen, Yasothon, Roi ET, Mahasarakham, and Khon Kaen, ultimately fading into a low-pressure system over Chaiyaphum province on the evening of

https://doi.org/10.18697/ajfand.146.25850

September 29, 2022. This storm development resulted in average precipitation throughout the Northeastern region, with particularly much rainfall occurring in Mahasarakham Province, where precipitation levels exceeded normative values by 25.79 percent. The consequent flooding was worsened by the water volume in Ubonrat Dam, which surpassed 2,431.00 million cubic meters [6]. This necessitated increased discharge operations, initiating at 38 million cubic meters per day on October 5, 2022, later increased to 50 million cubic meters per day on October 8, 2022 [7].

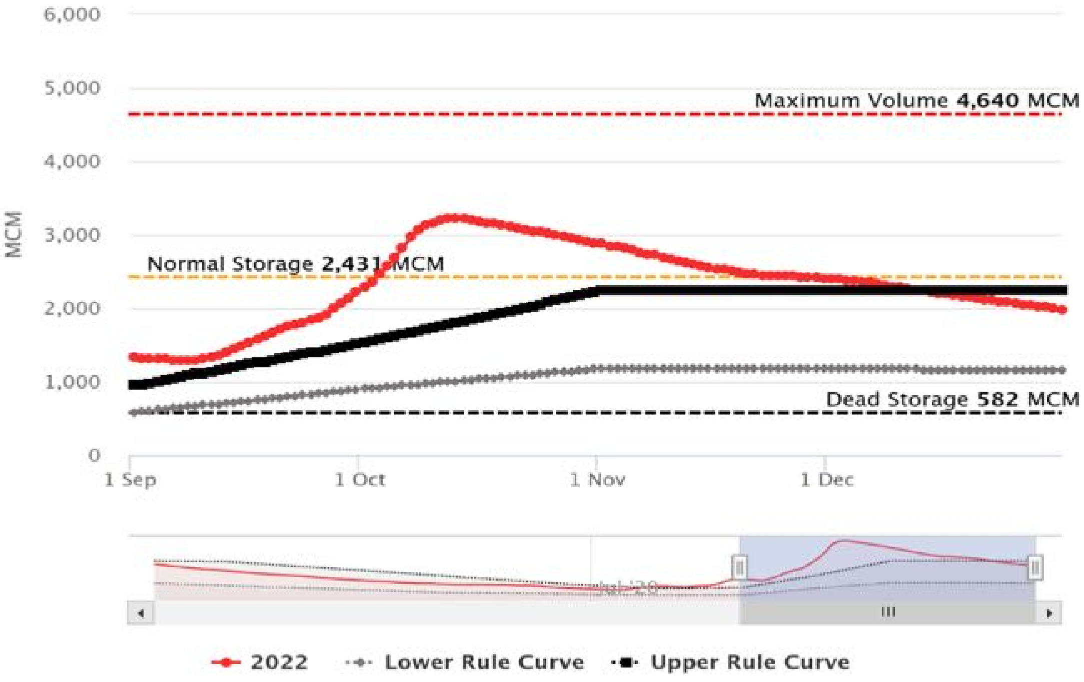

Figure 1: Water storage of Ubonrat Dam September to October 2022 [7]

The unprecedented flooding in Mahasarakham Province, unparalleled in magnitude over the past four decades, can be attributed to the convergence of two primary factors: unusually high rainfall and continued water discharge from Ubonrat Dam. This combination of events led to prolonged flooding in affected regions, spanning from late September to late November 2022. The resultant impact manifested in both direct and indirect adverse effects on the provincial population, encompassing both human welfare and material assets. Quantitative assessment reveals that the total inundated area encompassed 89,123.22 acres, affecting 2405 households. Of particular significance were the districts of Kantharawichai and Mueang which, owing to their status as vital economic nodes, sustained particularly severe impacts. Specifically, Kantharawichai District experienced inundation across 31,188.74 acres, constituting 35.00 percent of its territorial extent and affecting 1,770 households. Correspondingly, Mueang District witnessed flooding across 8,480.24

acres, representing 9.52 percent of its total area, with impacts extending to 365 households [8]. The dual causal factors of the flooding result in extensive devastation to both human welfare and material assets throughout the affected regions.

The present investigation examines the direct and indirect economic damages as well as determinant variables influencing the severity of floods within two critically impacted regions of Mahasarakham Province: specifically, Kantharawichai and Mueang Districts. caused by Typhoon NORU in Mahasarakham Province, Thailand, in 2022. During this period, the country experienced an average rainfall of 1848 millimetres, exceeding typical precipitation levels by 349 millimetres, an increase of 23 percent. The spatial extent of inundation encompassed 4.77 million acres, distributed across all regions, affecting 69 provinces, 619 districts, and 4115, sub-districts [9].

The selected empirical site of this research, which hosted the population and sampled households providing the primary data for the analysis, were agricultural households. They lived in the areas of the selected research site that were frequently affected by flooding, specifically in Mahasarakham Province, Thailand. The economic damage assessment of the elements and factors investigated by this research primarily focused on the areas of costs caused by floods, which affected the agricultural productivity of these households.

LITERATURE REVIEW

Direct damage

Flood events can cause key damage to both anthropogenic infrastructure and natural ecosystems. Within the theoretical framework of flood impact assessment, direct damage encompasses immediate physical impacts triggered by floodwater contact with structures, infrastructure systems, agricultural territories, and ecological environments. The temporal scope of such damage encompasses the entire flood timeline, including pre-event preparatory expenditures. Direct damage is characterized by its tangible and readily quantifiable nature in the immediate post-event period, distinguishing it from indirect damage, which manifests through subsequent economic disruptions, service interruptions, and extended temporal impacts [10].

The taxonomy of flood damage encompasses three fundamental categories: impacts on built infrastructure, agricultural systems, and natural environmental assets. These classifications justify detailed examination to outline the comprehensive nature of flood-induced damages. In the context of built environment impacts, structural assets demonstrate particular vulnerability to flood events, with heightened susceptibility observed in developments situated within flood-prone territories. Floodwater infiltration typically compromises structural integrity, degrades electrical infrastructure, and precipitates extensive damage to personal property. Research conducted by Apel *et al.* [11] demonstrates that residential structures within floodplain zones consistently sustain substantial damage, necessitating significant financial investment for remediation. Critical infrastructure systems, encompassing transportation networks, hydraulic structures, and utility services (including water distribution and sewerage systems), constitute fundamental societal components that exhibit pronounced vulnerability to flood-induced deterioration. The compromised functionality of transportation infrastructure significantly impedes communication networks and emergency response capabilities, thereby amplifying the flood event's cascading impacts [12]. Moreover, the restoration and reconstruction of such infrastructure systems typically necessitate extended temporal frameworks and substantial financial resources.

Within the agricultural sector, which represents a critical component of food security and economic sustainability, flood events can initiate catastrophic consequences. Hydrological impacts include topsoil erosion, crop destruction, and diminished soil fertility. Prolonged inundation frequently results in soil saturation conditions that impede both planting operations and harvest activities, potentially culminating in complete crop failure. Research by Soulibouth *et al.* [13] emphasizes that agricultural losses constitute a predominant component of flood damage in rural contexts, where agricultural activities represent the primary economic activity. These agricultural impacts extend beyond localized farmer communities, posing challenges throughout food supply chains and exhibiting broader economic implications.

Indirect damage

Indirect flood damages encompass the secondary socio-economic and environmental consequences that manifest after the primary flood event. They frequently present fewer tangible characteristics while potentially demonstrating greater pervasiveness and temporal persistence. These impacts include economic perturbations, commercial and livelihood disruptions, public health implications and mental health effects.

The economic ramifications of flood events often surpass-immediate physical destruction, manifesting through complex cascading effects across various sectors. Commercial entities often experience sustained operational disruptions caused by infrastructure degradation, supply chain challenges, and diminished consumer expenditure. Thieken *et al.* [14] empirically demonstrate that such economic disruptions can engender significant impacts on local and regional economic systems. Productivity and income losses represent substantial components of indirect economic damage, primarily through workforce displacement due to inundated workplaces and commercial operational cessation, thereby contributing to broader economic instability. Furthermore, the financial burden is intensified by expenditures associated with temporary commercial and residential relocation, coupled with extended sectoral recovery periods.

In addition, societal impacts of the floods are obviously seen through disruptions of established community structures and social networks. Population displacement, whether temporary or permanent, results in the dissolution of residential stability and compromises access to educational facilities and community infrastructure. The process of relocation introduces additional sociological challenges, as communities experience degradation of established social cohesion and support mechanisms. Furthermore, the psychological burden associated with displacement and material loss can precipitate significant mental health sequelae. Alderman *et al.* [15] document elevated incidence rates of anxiety disorders, clinical depression, and post-traumatic stress disorder (PTSD) among flood-affected populations. The indirect societal costs extend to increased pressure on institutional infrastructure, with healthcare systems, educational facilities, and emergency response services experiencing substantial strain during disaster response and recovery phases. Moreover, the floods generate extensive public health considerations in both short and long terms. A critical post-flood concern centers on water contamination, as flood waters frequently contain polluted, and hazardous chemical substances. Such contamination of water resources can be associated with the outbreaks of waterborne pathogenic conditions, including cholera, hepatitis, and various gastrointestinal infections.

Factors affecting the value of flood damage

The magnitude of flood-induced damage to household assets demonstrates significant spatial heterogeneity across affected regions, necessitating a comprehensive examination of the determining factors that influence damage valuation. This analysis systematically investigates the theoretical frameworks and empirical evidence pertaining to the key variables that moderate flood damage values. The identified determinant factors consist of demographic characteristics (specifically the age of the household head), agricultural parameters (plantation area), preventive measures (protection costs), geographical variables (proximity to riverine systems), and hydrological factors (water depth proximate to residential structures and flood duration).

Age of the Household Head

The age of the household head varied widely across in the assessment of flood damage vulnerability, manifesting through complex interactions between experiential knowledge and physical capability. Thieken *et al*. [14] posit that elderly household heads frequently demonstrate elevated vulnerability during flood events, primarily attributable to physiological limitations and increased health-related risks.

However, this exposure may be partially offset by accumulated experiential knowledge and enhanced risk awareness, potentially contributing to more effective preparatory and mitigation strategies. The relationship between age and flood damage exhibits notable paradoxical characteristics. While advanced age typically correlates with enhanced wealth accumulation and financial resources, potentially facilitating superior property protection measures and post-flood recovery capabilities, it simultaneously may impose physical constraints on implementing immediate protective interventions during acute flood events. Furthermore, Yin *et al.* [16] document that certain household heads, despite experiencing losses, opt for residential stability due to established economic opportunities, demonstrating a rational cost-benefit analysis of post-flood circumstances. The cumulative evidence suggests that extensive experiential knowledge enables household heads to conduct comprehensive analyses of post-flood implications, facilitating more effective adaptive responses and coping mechanisms.

Plantation Area

Plantation areas constitute critical economic and nutritional resources for households, particularly within rural and agrarian communities. The extent of flood-driven agricultural losses significantly influences aggregate flood damage valuation. The overflows of agricultural fields trigger substantial economic losses, with damage severity contingent upon flood intensity, crop typology, and seasonal timing. Risk mitigation strategies necessitate investment in flood-resistant crop varieties, advanced agricultural methodologies, and sophisticated hydrological management systems [17]. The sensitivity of rice cultivation to flooding presents particular significance in Southeast Asian economies, where rice exports constitute a primary source of national income. Contemporary research by Shrestha *et al.* [18] projects increased flood-prone areas under future climate scenarios, with corresponding implications for crop damage potential. Empirical evidence from the Solo River basin of Indonesia demonstrates substantial economic impacts, with rice crop damage valuations approximating 89.1 billion IDR. Beyond immediate crop destruction, flooding increases long-term soil-related effects that compromise agricultural productivity.

Protection Costs

Capital investment on flood protection infrastructure, including levee systems, flood barriers, and drainage networks, demonstrates a significant correlation with flood damage reduction estimates. Empirical evidence indicates an inverse relationship between protection costs and damage values, as protective measures effectively mitigate flood extent and severity [19, 20, 21]. The economic efficacy of such investments can be quantified through cost-benefit analyses, evaluating protective infrastructure expenditure against potential damage reduction coefficients [22].

Billings and Schnepel [23] demonstrate that adequate investment in protective infrastructure yields substantial reductions in flood damage while enhancing community resilience. Ward *et al*. [24] project escalating global flood protection costs correlating with increased greenhouse gas concentrations. Their analysis reveals that average costs across all Shared Socioeconomic Pathways (SSPs) demonstrate positive correlation with rising CO2-equivalent concentrations, emphasizing heightened future expenditure requirements under more severe climate scenarios. Nevertheless, the economic benefits derived from protection measures generally substantiate such investments.

Water Level around the House

A primary determinant of potential flood damage is the height of floodwater elevation to residential buildings. Empirical evidence demonstrates a positive correlation between height of water level and the severity of structural and personal property damage, demonstrating proactive action to manage effects of waterfloods, thereby directly influencing aggregate damage valuation. This relationship introduces prediction systems for flood levels in the residential areas during the flooding seasons. In regions where floodings occur repeatedly, architectural adaptations, such as elevated structures and flood-resistant construction materials, are applied to minimize the impacts, although higher associated costs [10, 14]. Zhai *et al.* [25] found that for communities proximate to reservoir systems, flood probability demonstrates strong correlation with reservoir water levels. Their research establishes that initial reservoir water levels significantly influence downstream flood profiles, with elevated initial levels corresponding to increased overflow volumes. The discharge rate, regulated by reservoir water levels, emerges as a critical factor in flood management efficacy. Enhanced discharge volumes can effectively mitigate downstream flood risk through reduction of dam overflow. Optimal flood control necessitates comprehensive consideration of initial water levels, discharge volumes, and flood event frequency distributions.

Flood Duration

The timeline of flood events emerges as a critical determinant of damage magnitude. Prolonged inundation periods engender extended water exposure, constituting severe structural deterioration, fungal proliferation, and elevated health risks [14, 15]. The economic implications extend beyond immediate physical damage to surrounding long-term disruptions of daily activities, loss of income, and rising rehabilitation expenditures. Community and household resilience can be enhanced through the high-level implementation of early warning systems, well-developed emergency response capabilities, and comprehensive recovery protocols [26].

https://doi.org/10.18697/ajfand.146.25850

MATERIALS AND METHODS

Research Hypotheses

H1: Older household heads (AGE) are associated with higher flood damage (TDF).
H2: Higher protection costs (PRO) are associated with lower flood damage (TDF).
H3: Higher water levels (LEV) lead to greater flood damage (TDF).
H4: Longer flood duration (DAY) increases flood damage (TDF).
H5: Greater distance from rivers (DIS) is associated with higher flood damage (TDF) due to lower risk perception.

Materials, Participants, and Procedures

The research was conducted in two districts of Mahasarakham Province of Thailand: namely Kantharawichai and Mueang. The study population consisted of 2,405 flood-affected families, affected between 27 September and 14 November 2022. The geopolitical distribution indicated that 1770 families lived in Kantharawichai District while the others were from Mueang District [8]. Sample size determination was conducted utilizing the Yamane [27] statistical formula. This methodological approach resulted in the expected sample size of 343 households. A convenience sampling approach was used. The sampling framework implemented a convenience sampling methodology to select flood-affected households within the specified districts of Kantharawichai and Mueang in Mahasarakham Province. Primary data collection was executed through structured interviews with the selected respondents.

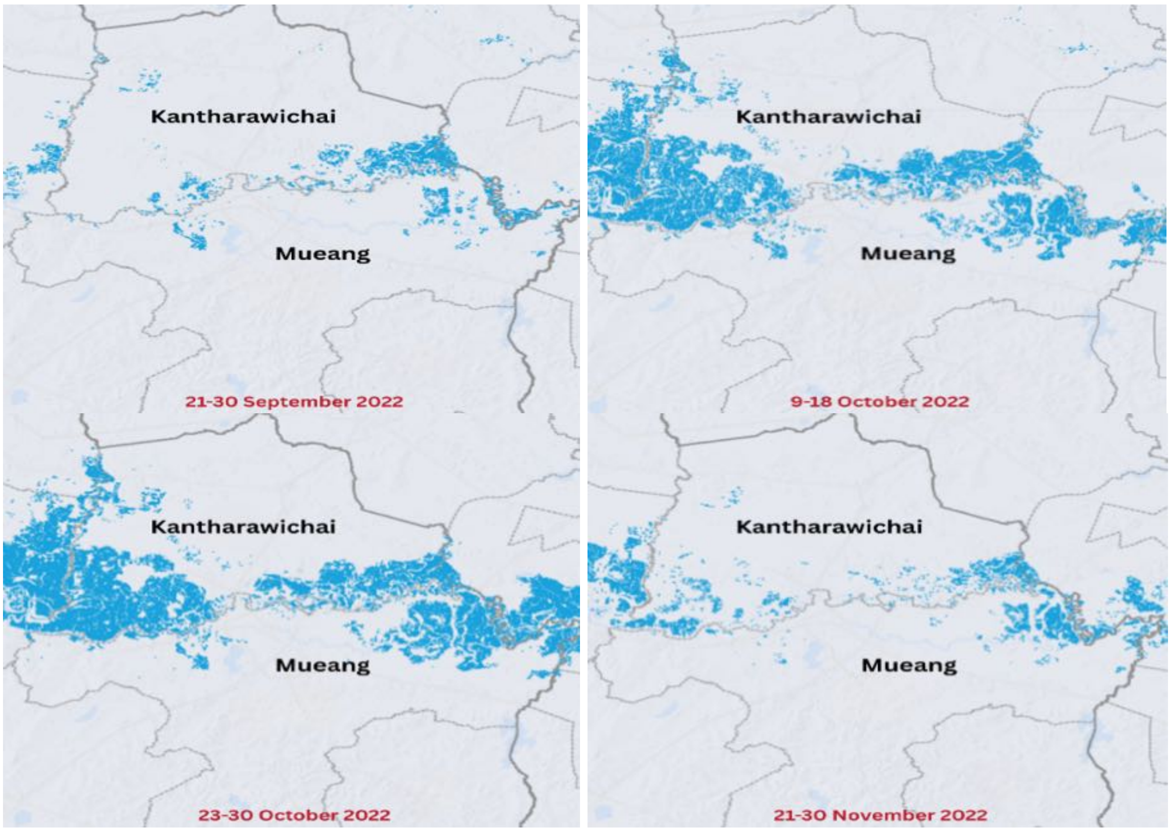

Figure 2: The Flood Map in Mahasarakham Province in Thailand [28]

The primary research instrument comprises a structured interview protocol designed to assess preliminary flood damage in Mahasarakham Province during 2022. It was adapted from the methodological framework established by Nabangchang *et al.* [10]. The instrument's content validity was evaluated through the Index of Item-Objective Congruence (IOC) methodology, with validation conducted by expert panels from three academic institutions: King Mongkut's University of Technology North Bangkok, Rajamangala University of Technology Thanyaburi, and Chandrakasem Rajabhat University, Thailand.

The interview protocol encompasses nine sections:

I. Demographic and Residential Characteristics - Respondent spatial location - Family composition and status - Gender identification - educational attainment - Occupational classification - Household composition - Residential characteristics

II. Pre-Flood Economic Parameters - Labor-derived income - Volunteer-related expenditures - Flood preparation material costs - Vehicle storage expenses - non-monetary volunteer contributions

III. Flood-Period Economic Impact - Relief-derived income - Accommodation expenditures - Water procurement costs - Food cost differentials - Flood mitigation equipment expenses - Transportation cost variations - Work disruption duration - Income loss quantification

IV. Post-Flood Recovery Assessment - Residential repair labor costs - Cleaning and restoration expenses - Vehicle and appliance repair costs - Flood depth measurements - Inundation duration - Flood response experience

V. Health Impact Analysis - Pharmaceutical expenses - Medical treatment costs - Patient quantification - Care provision duration

VI. Relief Compensation Assessment - Public and private sector assistance - Aid disbursement timeframes

VII. Agricultural Impact Evaluation - Affected land area quantification - Crop damage assessment - Production price metrics - Yield loss per affected area

VIII. Business Sector Impact Analysis - Operational disruption duration - Post-flood rehabilitation costs - Production/sales value assessment - Loss quantification - Repair expenditure evaluation

IX. Qualitative Assessment - Open-ended inquiry regarding challenges and recommendations

Regarding data analysis, the analytical framework encompasses two primary research objectives:

Objective 1: Preliminary Economic Damage Assessment - the initial objective entails a comprehensive assessment of preliminary economic damage precipitated by flood events in Mahasarakham Province. The analytical methodology employs a systematic classification framework to differentiate between direct and indirect damages, facilitating detailed damage categorization and valuation as presented in subsequent tabular analysis in Table 1.

Objective 2: Determinant Factor Analysis - the second objective focuses on the identification and analysis of factors influencing flood damage valuation through cross-sectional data analysis utilizing a linear regression model. The analytical framework can be expressed through the following econometric specification:

$$TDF = \beta_0 + \beta_1 AGE + \beta_2 PRO + \beta_3 LEV + \beta_4 DAY + \beta_5 DIS + \epsilon$$

Where the dependent and independent variables are defined as follows: TDF represents the total damage value due to flooding (measured in USD); AGE denotes the age of the household head (measured in years); PRO indicates the protection costs incurred (measured in USD); LEV represents the water level that floods homes (measured in centimetres); DAY signifies the number of days that houses are flooded (measured in days); DIS denotes the distance of residences from the

https://doi.org/10.18697/ajfand.146.25850

nearest rivers (measured in meters); and ε represents the stochastic error term. The subscript i denotes individual household observations.

RESULTS AND DISCUSSION

Data collection

Field data collection was conducted during January - February 2024, following the Ethical Approval granted by Mahasarakham University's Internal Review Board (IRB) on 26 January 2024, and the approval number was 030-004/2024. Providing the 343 household samples, the actual responses were 242, representing a response rate of 70.55 percent. Resource constraints, including temporal and budgetary limitations, influenced the final sample size. The investigation comprises two primary components: quantification of direct and indirect flood-related losses, and examination of factors that influence flood damage valuation. The areas of study cover the Kantharawichai and Mueang districts of Mahasarakham province, Thailand.

As seen in Figure 2, the studied areas of this study are by the riverside and experience recurring floods annually. They have experienced regular flooding incidents and already incur preventive expenses. Despite the prevention efforts and costs spent, the households reported being severely affected by the damage from the two major floods in Thailand, which occurred in 2011 and 2022.

As indicated above, the fieldwork of this study was conducted during January – February 2024, which was the period after the latest major flood experienced by the sampled households. It therefore took into consideration the natural circumstances of living within the flooding area of the households. As a result, it designed the questionnaire sections by adopting the items of expenses suggested by previous relevant studies, the Index of Item-Objective Congruence (IOC) methodology [29]. This study adopted items suggested by Nabangchang *et al.* [10], which apply to the living conditions of households in flood-affected areas, categorizing them into three sections: expenses before the flood, expenses during the flood, and expenses after the flood. Additionally, when categorizing expenditures incurred after being affected by the recent flood disaster of 2022, the costs were guided by multiple relevant studies, including Nabangchang *et al.* [10], Hallegatte *et al.* [19] and Jongman *et al.* [20] and Thieken *et al.* [21] to investigate items of flooding damages categorized into four extents, including health, household, agricultural, and business.

Values of the Economic Damages

Based on the assessment, the study results reveal total valuations of USD 3,266.30 and USD 3,301.10 for Kantharawichai and Mueang districts, respectively, categorized across seven distinct damage components, three concerning the preventive flooding expenditures of three period, pre-, during and post 2022 flooding disaster and the other four related to four extents of economic damages covering expenses relating to health, household, agriculture, and business matters.

Pre-, during, and post-flood expenditures analysis

Flooding preventive expenditures involve three periods: pre-, during, and post-flood. Results from the survey data concerning pre-flood preventive expenditure indicated higher precautionary investment in the Kantharawichai district (USD 50.32) than that of the Mueang district (USD 33.73). During the period of water coverage during the 2022 flood in October 2022, Kantharawichai households reported relocation expenses of USD 1.36, while Mueang residents documented no such expenditure. Consumer goods expenditure showed similar disparities. Kantharawichai households reported higher costs (USD 128.13) compared to Mueang residents (USD 118.81). Material and equipment acquisition during the flood event similarly reflected this pattern, with Kantharawichai residents incurring substantially higher costs (USD 47.94) relative to Mueang district residents (USD 22.99).

The results also showed substantial disparities between the two districts across multiple rehabilitation categories. Kantharawichai residents incurred significantly higher rehabilitation costs (USD 18.95) compared to Mueang residents (USD 5.95), representing a threefold difference in recovery expenditure. Vehicle damage assessments similarly proved higher values in Kantharawichai (USD 22.04) relative to Mueang district (USD 14.26). Housing-related expenses presented particularly marked variations, with Kantharawichai residents reporting substantially higher repair costs (USD 177.29) compared to Mueang residents (USD 40.71). Structural damage valuations further emphasized this disparity, with Kantharawichai properties sustaining greater damage (USD 231.60) than those in Mueang district (USD 87.52). Notably, the sole exception to this pattern emerged in residential cleaning expenses, where Mueang district residents reported marginally higher expenditure (USD 35.90) compared to Kantharawichai residents (USD 33.25). Analysis of health-related expenditures following the 2022 flood event reveals significant inter-district variation, with Kantharawichai residents incurring substantially higher health-related costs (USD 2.58) compared to Mueang residents (USD 0.52), representing an approximate fivefold difference in healthcare expenditure.

The flood event catalyzed considerable workforce disruption across both districts, though with notable variations in duration and economic impact. Kantharawichai residents experienced work interruption spanning 13.15 days, resulting in diminished monthly earnings of USD 19.04. In contrast, Mueang residents, despite experiencing longer work disruption (15.70 days), maintained substantially higher monthly earnings (USD 528.76). This marked disparity in income retention despite similar disruption durations suggests underlying socioeconomic differences between the districts.

Agricultural sector analysis

The study indicates significant spatial variation in flood impact. Mueang district experienced higher aggregate damage (USD 2,405.63), corresponding to an affected area of 5.83 acres and production losses of 567.17 kilograms per unit area. Comparatively, Kantharawichai district reported lower total damage (USD 1,983.99) across 4.49 acres, though with higher per-area production volume (656.51 kilograms). The flood event additionally influenced market dynamics, with Kantharawichai experiencing lower production prices (USD 0.27) relative to Mueang district (USD 0.29).

Business sector impact analysis

The assessment confirms correlation between flood duration and economic losses. Mueang district, experiencing longer inundation periods (45 days), reported higher total damages (USD 577.49) and reduced sales revenue (USD 12.83). Relative to Kantharawichai businesses, despite shorter flood duration (40.93 days), maintained marginally higher sales (USD 13.31) while incurring lower total damages (USD 544.84). This pattern suggests a direct relationship between flood duration and magnitude of business sector losses.

Comparative analysis of district characteristics, as presented in Table 3, reveals distinct spatial and demographic patterns. Kantharawichai district higher values across multiple parameters, including median age of population, expenditure on protective measures, and proximity to riverine systems. In contrast, Mueang district exhibits marginally elevated mean water levels during flood events. Notably, both districts display comparable flood duration patterns, with mean inundation periods approximating 48 days, suggesting consistent temporal exposure to flood conditions across the study area. These findings indicate significant spatial heterogeneity in demographic and protective measures, while temporal flood characteristics remain relatively uniform across districts.

Table 4 represents Collinearity assessment. It examines Variance Inflation Factors (VIF) for five predictor variables across three analytical domains: Mueang district, Kantharawichai district, and the aggregate dataset. The analysis reveals VIF values consistently below the conventional threshold of 10 across all variables and geographical subdivisions. These results indicate the absence of problematic multicollinearity among predictor variables, thereby validating the stability and reliability of subsequent regression analyses. The independence of predictor variables suggests that the estimated coefficients and their standard errors are not adversely affected by collinearity, enabling robust interpretation of the regression results across all spatial scales of analysis.

Diagnostic analyses presented in Table 5 reveal significantly inconsistent variability in both the Mueang district and aggregate datasets ($p < 0.05$), indicating violation of the homoscedastic error variance assumption fundamental to ordinary least squares regression. Furthermore, residual diagnostics demonstrate significant departures from normality, as evidenced by skewness and kurtosis test statistics ($p = 0.00$). These violations of classical regression assumptions potentially compromise the efficiency of parameter estimates and the validity of inferential statistics. To address these methodological challenges and enhance the robustness of statistical inference, the analysis employs heteroskedasticity-consistent standard errors. This approach, documented in Table 5, provides more reliable parameter estimates under conditions of non-constant error variance and non-normal residual distributions, thereby strengthening the validity of statistical conclusions drawn from the regression analysis.

Table 6 presents the empirical results of multiple linear regression analyses examining determinant factors of flood damage across three spatial domains: Mueang District, Kantharawichai District, and the aggregate dataset. The analytical framework employs heteroskedasticity-robust standard errors to account for non-constant variance in errors. Each regression specification presents parameter estimates and associated standard errors for the suite of independent variables, thereby elucidating the differential impact of predictor variables on total flood damage across spatial scales. This spatially disaggregated analysis enables the identification of both location-specific and general patterns in the determinants of flood damage valuation.

Analysis of the relationship between household head age (AGE) and flood damage reveals significant spatial heterogeneity across districts. In Mueang District and the aggregate analysis, results demonstrate a positive correlation between age and flood damage magnitude. This relationship may be attributed to diminished physical capacity for implementing protective measures among older residents, coupled with potential occupation of legacy structures characterized by reduced flood resilience. These findings align with research by Huang *et al.* [30] who demonstrate that advanced age can impede flood preparedness capabilities, potentially resulting in elevated damage due to constrained adaptive responses. Conversely, Kantharawichai District exhibits an inverse relationship between household head age and flood damage severity. This distinctive pattern suggests the potential influence of accumulated experiential knowledge and enhanced preparedness among older residents, possibly manifesting in improved structural adaptations developed over time. Poussin *et al.* [31] provide supporting evidence for this interpretation, documenting that prior flood exposure significantly influences adaptive behavior, particularly among older populations who may prioritize structural modifications for flood resilience.

Empirical analysis reveals a positive correlation between protection expenditure and flood damage magnitude. This counterintuitive relationship can be attributed to the unprecedented nature of the 2021 flood event in Mahasarakham province, which reached historically significant levels unprecedented in four decades. The severity of this event exceeded residents' risk assessment capabilities, particularly in flood-prone areas, resulting in substantial damage despite protective measures. Kreibich *et al.* [32] document similar patterns, where underestimation of flood intensity frequently results in the implementation of inadequate protection measures during extreme events. This phenomenon manifests in the current study through increased losses correlating with reactive, short-term protection investments. Di Baldassarre *et al.* [33] provide theoretical framework for understanding this relationship, describing a "levee effect" wherein reliance on protective infrastructure can generate feedback mechanisms that amplify vulnerability during extreme events that exceed design parameters. Ludy and Kondolf [34] further elucidate this phenomenon, demonstrating how protective infrastructure can induce false security perceptions, potentially encouraging increased investment in high-risk zones and consequently amplifying losses when protective measures fail.

These findings suggest the necessity for a paradigmatic shift toward proactive and adaptive flood management strategies. Although Nabangchang *et al.* [10] suggest the expenses to prevent flood damage for three periods, pre-, during, and post-flood, the results of this research contradict the suggestion. It revealed that these expenses added extra value to the economic damage assessment when the flood hit, and these preparations were destroyed, physically and hence economically. Considering the unusual flood being more severe than the recurring flood regularly experienced by the farming families living in the affected areas, this study suggested the infeasibility for the farmers to spend extra expenses for major flood incidents; only for those of recurring floods were sufficient and did not incur any additional costs to the economic damage in the case of a severe flood hit, especially the costs categorized for the agricultural and business matters, which suggested by previous studies [19, 21] to have the major costs damaging the agricultural sector in severe flood incidents.

Given these results, this paper provides empirical evidence to support the implementation of vertical evacuation protocols, particularly the relocation of valuable assets to elevated positions when initial flood indicators are detected. Poussin *et al.* [31] demonstrate the superior efficacy of preventive measures, such as vertical asset relocation and upper floor reinforcement, compared to conventional ground-level barrier systems in reducing flood-related losses.

The empirical analysis demonstrates a significant positive relationship between flood water levels and total damage valuations, with elevated inundation depths corresponding to increased severity of both structural and content damage. McGrath *et al.* [35] corroborate this finding, documenting that incremental increases in floodwater depth yield proportional increases in damage percentages for both building infrastructure and contents. Their research particularly emphasizes that seemingly minor elevations in water level can precipitate disproportionate increases in restoration and replacement costs. Further empirical support is provided by Boulange *et al.* [36] whose methodological assessment of flood damage evaluation frameworks identifies water depth as a crucial determinant in calculating expected annual damage. Their findings establish a robust correlation between inundation depth and magnitude of economic losses. This relationship finds additional validation in foundational research by Thieken *et al.* [37] who establish water depth as a fundamental predictor variable in flood damage assessment models. The consistency of these findings across multiple studies and methodological approaches reinforces the critical role of water level as a primary determinant of flood damage magnitude, suggesting its central importance in flood risk assessment and management strategies.

Analysis reveals that flood duration exhibits both direct and indirect effects on aggregate damage valuation through multiple mechanistic pathways. Extended inundation periods facilitate progressive water penetration into structural elements, precipitating material degradation and consequently elevating direct rehabilitation costs. Concurrently, prolonged exposure generates cascading indirect impacts through disruption of economic activities, extended operational cessation, and amplified public health risks. Dottori *et al*. [38] provide empirical evidence for this dual-pathway impact, demonstrating that increased flood duration correlates with escalating direct repair costs due to enhanced structural water penetration, while simultaneously generating compounding indirect impacts through prolonged business interruption and income diminution.

Empirical analysis reveals significant spatial heterogeneity in the relationship between riverine distance and flood damage across districts. In Kantharawichai District and the aggregate analysis, results demonstrate a positive correlation between distance from rivers and damage magnitude, suggesting potential risk perception disparities affecting preparedness behaviors. This spatial relationship indicates that increased distance may engender false security perceptions, potentially leading to suboptimal protective measures. Ludy and Kondolf [34] provide theoretical support for this finding, documenting reduced investment in protective measures among communities situated at greater distances from primary water bodies. This distance-based complacency effect is further corroborated by O'Neill *et* *al*. [39] who demonstrate that perceived reduced exposure due to spatial separation frequently results in inadequate protective measure implementation, thereby amplifying vulnerability. Di Baldassarre *et al.* [33] further elucidate this phenomenon, emphasizing how distance-based risk underestimation can exacerbate damage through insufficient protective infrastructure implementation.

Conversely, Mueang District exhibits an inverse relationship between riverine distance and flood damage, suggesting more sophisticated risk assessment practices. This differential pattern may be attributed to enhanced flood experience and risk awareness within the district, facilitating implementation of appropriate protective measures regardless of spatial proximity to water bodies. Thieken *et al.* [14] provide supporting evidence for this interpretation, demonstrating that communities with elevated flood awareness exhibit more comprehensive protective measure implementation across varying distances, resulting in reduced aggregate damage. Kellens *et al.* [40] further substantiate this finding, documenting that communities with recurrent flood exposure typically demonstrate enhanced risk awareness and more effective mitigation strategy implementation. These contrasting spatial relationships underscore the critical role of risk perception and experiential knowledge in moderating the relationship between geographic proximity and flood damage outcomes.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

This paper assesses the economic damage of flood-affected areas in Mahasarakham Province of Thailand. It categorized the items for assessment using the three periods of flood affection, namely pre-, during, and post-flood. Providing that the households of the studied areas were agricultural households, this paper formulated the assessment elements into four parts, including the area of health expenses of the farming household members, the area of household expenses, the area of agriculture expenses, and the area of farming business expenses.

The result of structured interviews and questionnaires from 242 flood-affected families showed that determinants of flood impacts are varied across different factors. The first factor is riverine proximity. The study found that a higher rate of damage was obvious in the areas of greater distance from rivers. This is potentially caused by risk underestimation and subsequent underinvestment in protective measures. The second factor is known as the age of household heads. The study found that older residents found it very difficult to handle situations involving flooding.

In comparison, the younger could improve their resilience capacity of experiential knowledge and adaptive behaviors. The third factor is protective expenditures. The study revealed that those who spent were less likely to help community members prevent themselves from flood damage. As a result, it threatened structural and economic losses.

The findings suggested significant policy implications. 1) Implementation of comprehensive flood preparedness training programs, 2) Development of enhanced early warning systems, 3) Integration of adaptive management strategies in flood-prone areas. Future research directions should focus on the longitudinal assessment of how effective a flood warning strategy is and the investigation of additional variables that influence community resilience to extreme flooding.

ACKNOWLEDGEMENTS

The authors would like to express their heartfelt gratitude to the Mahasarakham Business School, Mahasarakham University, Thailand, for funding this study. Additional thanks are expressed to the participants and the research assistants (Veeraya Chareonkhunmuang, Chanaphai Khieokha, Natthinan Chitpho, Duangkamol Phoombunchoo and Parichat Choeirot) who conducted data collection.

CONFLICT OF INTEREST

The authors declare unequivocally that there is no conflict of interest in this study.

Table 1: Preliminary assessment of economic damage from floods

Components of flood damage	Direct damage	Indirect damage	Calculation method
Expenses before the flood (A)	A1 = Materials/equipment for prevention before flooding occurs A2 = Parking rental fee	AA1 = Household labour expenses (Number of days x Minimum wage $^{1/}$) AA2 = Volunteer labour expenses (Number of volunteer labor x Minimum wage $^{1/}$)	Expenses before the flood = A1+A2+AA1 +AA2
Expenses during a flood (B)	B1 = Accommodation expenses (in case of moving accommodation) B2 = Increased expenses of consumer goods such as drinking water and food B3 = Expenses of protective materials/equipment during flooding	BB1 = Consumer goods expenses received from donations BB2 = Volunteer labor expenses (Number of volunteer labor x Minimum wage $^{1/}$) BB3 = Increased travel expenses for work (Increased expenses per day x number of days affected by flooding)	Expenses during a flood = B1+B2+B3 +BB1+BB2+ BB3
Expenses after the flood (C)	C1 = Expenses of materials/equipment for rehabilitation C2 = Vehicle damage value C3 = Housing repair expenses C4 = Value of damage to items within the home C5 = Expenses of cleaning the residence	CC1 = Volunteer labor expenses (Number of volunteer labor x Minimum wage $^{1/}$)	Expenses after the flood = C1+C2+C3+ C4+C5+CC1
Health expenses (D)	D1 = Medical expenses D2 = Expenses of medicine	DD1 = Opportunity cost of income of sick workers during the flood	Health expenses = D1+D2+DD1 +DD2

Components of flood damage	**Direct damage**	**Indirect damage**	**Calculation method**
		(Number of days x Minimum wage [1/]) DD2 = Opportunity cost of caregivers (Number of days x Minimum wage [1/])	
Household sector (F)	F1 = number of days unable to go to work F2 = number of normal working days per month F3 = Monthly income		Household sector = (F3/F2) x F1
Agricultural sector (G)	G1 = Damaged area (Acres) G2 = Amount of produce per area (Kilogram) G3 = Production price (USD)		Agricultural sector = (G1 x G2) x G3
Business sector (H)	H1 = number of days experiencing flooding H2 = Daily sales		Business sector = H1 x H2
Total average damage value	Direct damage =A1+A2 +B1+B2+B3+C1+C2+C3+C4+C5+D1+D2+F1+F2+F3+((G1 x G2) x G3) +(H1xH2)	Indirect damage = AA1+AA2 +BB1+BB2+BB3+CC1+DD1+DD2	Total average damage value = Direct damage + Indirect damage
Net damage value			Net damage value = Total average damage value - Compensation received from the government and private sector

[1/] Minimum daily wage is USD 9.18

Note: The local currency of Thailand is Baht. Since this study was conducted based on production data in 2022, the presentation in this paper used the average exchange rate of 2022, which was 35.0653 Baht/USD

Table 2: Preliminary assessment of economic damage from floods in Mahasarakham

Components of flood damage		Preliminary assessment of economic damage from floods	Mueang	Kantharawichai	Total
1. Expenses before the flood	Direct	Materials/equipment for prevention before flooding occurs (USD)	33.73	50.32	44.84
		Parking rental fee (USD)	0.07	0.93	0.65
	Indirect	Household labour expenses (USD)	0.36	3.75	2.63
		Volunteer labour expenses (USD)	39.39	86.01	70.60
Total (USD)			73.55	141.01	118.71
2. Expenses during flood flood	Direct	Accommodation expenses (in case of moving accommodation) (USD)	-	1.36	1.36
		Increased expenses of consumer goods such as drinking water and food (USD)	115.81	128.13	124.06
		Expenses of protective materials/equipment during flooding (USD)	22.99	47.94	39.69
	Indirect	Consumer goods expenses received from donations (USD)	52.60	146.21	115.26
		Volunteer labor expenses (USD)	-	-	-
		Increased travel expenses for work (USD)	2.61	9.17	7.00
Total (USD)			194.00	332.81	286.92
3. Expenses after the flood	Direct	Expenses of materials/equipment for rehabilitation (USD)	5.95	18.95	14.65
		Vehicle damage value (USD)	14.26	22.04	19.47
		Housing repair expenses (USD)	40.71	177.29	132.14
		Value of damage to items within the home (USD)	87.52	231.60	183.97
		Expenses of cleaning the residence (USD)	35.90	33.25	34.13
	Indirect	Volunteer labor expenses (USD)	3.43	14.26	10.68
Total (USD)			187.77	497.38	395.03

Components of flood damage		**Preliminary assessment of economic damage from floods**	**Mueang**	**Kantharawichai**	**Total**
4. Health expenses	Direct	Medical expenses (USD)	0.14	1.06	0.75
		Expenses of medicine (USD)	0.37	1.52	1.14
	Indirect	Opportunity cost of income of sick workers during the flood (USD)	-	-	-
		Opportunity cost of caregivers (USD)	-	-	-
Total (USD)			0.52	2.58	1.90
5. Household sector	Direct	Number of days unable to go to work (Day)	15.70	13.15	13.99
		Number of normal working days per month (Day)	22.00	22.00	22.00
		Monthly income (USD)	528.76	503.85	512.08
Total (USD)			377.34	301.12	325.68
6. Agricultural sector	Direct	Damaged area (Acres)	5.83	4.49	4.66
		Amount of produce per area (Kilogram)	567.17	656.51	644.86
		Production price (USD)	0.29	0.27	0.27
Total (USD)			2,405.63	1,983.99	2,046.02
7. Business sector	Direct	Number of days experiencing flooding (Day)	45.00	40.93	41.83
		Daily sales (USD)	12.83	13.31	13.21
Total (USD)			577.49	544.84	552.43
Total average direct damage value (USD)			3,717.93	3,544.33	3,520.52
Total average indirect damage value (USD)			98.39	259.40	206.17
Total average damage value (USD)			3,816.31	3,803.73	3,726.69
Compensation received from the government and private sector (USD)			515.21	537.43	530.77
Net damage value (USD)			3,301.10	3,266.30	3,195.92

1/ Minimum daily wage is USD 9.18

Note: The local currency of Thailand is Baht. Since this study was conducted based on the production data in 2022, the presentation of this paper used the average exchange rate as of 2022, which was 35.0653 Baht /USD

Table 3: Descriptive statistics

Variable	Mean	Std. dev.	Minimum	Maximum
Mueang				
AGE	52.16	10.54	32	80
PRO	56.72	99.08	0	661.62
LEV	86.98	28.61	30	150
DAY	48.28	17.74	2	90
DIS	467.65	178.49	50	1000
Kantharawichai				
AGE	60.59	11.38	33	88
PRO	98.26	138.67	0	661.62
LEV	73.07	42.47	3	272
DAY	47.72	20.58	6	90
DIS	342.18	260.73	10	1785
Total				
AGE	57.81	11.78	32	88
PRO	84.53	128.25	0	661.62
LEV	77.66	38.94	3	272
DAY	47.91	19.65	2	90
DIS	383.66	243.63	10	1785

Source: Researchers' computations

Table 4: Variance Inflation Factor (VIF)

Variable	Mueang	Kantharawichai	Total
AGE	1.15	1.10	1.05
PRO	1.12	1.16	1.08
LEV	1.24	1.22	1.11
DAY	1.12	1.22	1.09
DIS	1.12	1.16	1.05

Source: Researchers' computations

Table 5: White's test and skewness and kurtosis tests

Test	Mueang	Kantharawichai	Total
White's test for homoskedasticity	31.76 (0.04)	30.91 (0.05)	41.51 (0.00)
Skewness and kurtosis tests for normality	154.63 (0.00)	26.22 (0.00)	108.54 (0.00)

Source: Researchers' computations

Note: The figures in parenthesis () are p-values

Table 6: Linear regression results with robust standard errors

Variable	Mueang	Kantharawichai	Total
AGE	350.54***(103.72)	-420.27***(96.66)	334.16***(53.59)
PRO	3.24***(0.40)	4.16***(0.31)	4.44***(0.06)
LEV	101.5993**(48.63)	283.75***(36.64)	69.91***(19.12)
DAY	46.98 (34.86)	296.09***(40.13)	262.22***(30.95)
DIS	-77.68***(5.25)	28.04***(4.67)	-13.94***(3.24)
Constant	42716.99***(4405.18)	47219.22***(6921.25)	23479.51***(6734.24)
F-statistic	529.54***	62.83***	7591.76***
R-squared	0.90	0.62	0.93
Observations	80	162	242

Source: Researchers' computations

Note: Robust standard errors are in parenthesis, *p < 0.1 **p < 0.05 ***p < 0.01

https://doi.org/10.18697/ajfand.146.25850

REFERENCES

1. **Suardi IDPO, Widhianthini, Arisena GMK, Sukewijaya IM and AAK Krisnandika** Status of agriculture resources sustainability and agricultural policy in Denpasar City, Province of Bali, Indonesia. *Afr. J. Food Agric. Nutr. Dev.* 2023; **23(3)**: 22694-2271. https://doi.org/10.18697/ajfand.118.21875

2. **Darmawan DP, Arisena GM, Utami NW and AA Krisnandika** The Dynamics of the Social Network of Urban Farmers in Subak Sembung Denpasar. *AGRIS On-line Pap. Econ. Inform.* 2021; **13(2)**: 51-58. https://doi.org/10.22004/ag.econ.320257

3. **Suamba K, TikaW, Sumiyati, Sulastri NN, Arisena GMK, Wiguna PPK and Widhianthini** Evaluation of Erosion Rates as Indicators of Ecosystem Services in Bali's Subak Rice Fields: Insights from Tabanan Regency, Indonesia. *Int. J. Des. Nat. Ecodyn.* 2024; **19(3)**: 831-839. https://doi.org/10.18280/ijdne.190313

4. **Department of Disaster Prevention and Mitigation.** Disaster statistics for 2022. Ministry of Interior, Thailand. 2023.

5. **Budhathoki A, Tanaka T and Y Tachikawa** Developing flood risk curves of agricultural economic damage under climate change in the Lower Chao Phraya River Basin, Thailand. *J. Flood Risk Manag.* 2024; **17(4)**: e13031. https://doi.org/10.1111/jfr3.13031

6. **Hydro Informatics Institute.** Thailand Water Situation 2022 https://nehccinter.egat.co.th/gph_reservoir/news/ur-5-10-65.JPG *Accessed July,2023.*

7. **National Hydroinformatics Data Center.** Normal Water Level (NWL). 2023. https://www.thaiwater.net/water/dam/large *Accessed April, 2023.*

8. **Department of Disaster Prevention and Mitigation, Mahasarakham Province**. Disaster statistics. Ministry of Interior, Thailand. 2023.

9. **Climate Center.** Tropical cyclones moving into Thailand Period: 72 years (1951 – 2022). Meteorological Department, Thailand. 2023. http://climate.tmd.go.th/files/40 *Accessed April, 2023.*

10. **Nabangchang O, Allaire M, Leangcharoen P, Jarungrattanapong R and D Whittington** Economic costs incurred by households in the 2011 Greater Bangkok flood. *Water Resour. Res.* 2015; **51(1)**: 58-77. https://doi.org/10.1002/2014WR015982

11. **Apel H, Thieken A H, Merz B and G Blöschl** Flood risk assessment and associated uncertainty. *Nat. Hazards Earth Syst. Sci.* 2004; **4(2)**: 295-308. https://doi.org/10.5194/nhess-4-295-2004

12. **Yin J, Yu D, Lin N and RL Wilby** Evaluating the cascading impacts of sea level rise and coastal flooding on emergency response spatial accessibility in Lower Manhattan, New York City. *J. Hydrol.* 2017; 648-658.

13. **Soulibouth L, Hwang HS and DH Shin** The impact of flood damage on farmers, agricultural sector and food security in Laos: A regional case study of Champhone District, Savannaket Province. *J. Int. Dev. Coop.* 2021; **16(2)**: 151-170. https://doi.org/10.34225/jidc.2021.16.2.151

14. **Thieken AH, Kreibich H, Müller M and B Merz** Coping with floods: preparedness, response and recovery of flood-affected residents in Germany in 2002. *Hydrol. Sci. J.* 2007; **52(5)**: 1016-1037. https://doi.org/10.1623/hysj.52.5.1016

15. **Alderman K, Turner LR and S Tong** Floods and human health: A systematic review. *Environ. Int.* 2012; 37-47. https://doi.org/10.1016/j.envint.2012.06.003

16. **Yin Q, Ntim-Amo G, Xu D, Gamboc VK, Ran R, Hu J and T Hong** Flood disaster risk perception and evacuation willingness of urban households: The case of Accra, Ghana. *Int. J. Disaster Risk Reduct.* 2022; **78**: 103126. https://doi.org/10.1016/j.ijdrr.2022.103126

17. **Adger WN, Hughes TP, Folke C, Carpenter SR and J Rockstrom** Social-ecological resilience to coastal disasters. *Science*. 2005; 1036-1039.

18. **Shrestha BB, Rasmy M, Ushiyama T, Acierto RA, Kawamoto T, Fujikane M, Ito H and T Shinya** Assessment of flood damage to agricultural crops under climate change scenarios using MRI-AGCM outputs in the Solo River basin of Indonesia. *Proc. Int. Assoc. Hydrol. Sci.* 2024; **386**: 127–132. https://doi.org/10.5194/piahs-386-127-2024

19. **Hallegatte S, Green C, Nicholls RJ and J Corfee-Morlot** Future flood losses in major coastal cities. *Nat. Clim. Change.* 2013; **3(9)**: 802-806. https://doi.org/10.1038/nclimate1979

20. **Jongman B, Hochrainer-Stigler S, Feyen L, Aerts JC, Mechler R, Botzen WW and PJ Ward** Increasing stress on disaster-risk finance due to large floods. *Nat. Clim. Change*. 2014; **4(4)**: 264-268. https://doi.org/10.1038/NCLIMATE2124

21. **Thieken AH, Bessel T, Kienzler S, Kreibich H, Müller M, Pisi S and K Schröter** The flood of June 2013 in Germany: how much do we know about its impacts? *Nat. Hazards Earth Syst. Sci.* 2016; **16(6)**: 1519-1540. https://doi.org/10.5194/nhess-16-1519-2016

22. **Parker DJ, Green CH and PM Thompson** Urban flood protection benefits: A project appraisal guide. 1987.

23. **Billings SB and KT Schnepel** The value of a healthy home: Lead paint remediation and housing values. *J. Financ. Econ.* 2018; **127(2)**: 201-223. https://doi.org/10.1016/j.jpubeco.2017.07.006

24. **Ward PJ, Jongman B, Aerts J, Bates P Botzen W, Loaiza AD, Hallegatte S, Kind J, Kwadijk J and P Scussolini** A global framework for future costs and benefits of river-flood protection in urban areas. *Nat. Clim. Change.* 2017; **7(9)**: 642–646.

25. **Zhai YW, Jiang DG, Ji GL and ZY Lv** Study on the Impact of Flood Season Operating Water Level on Flood Control of the Three Gorges Reservoir. *Int. Hydropower Dev. Conf.* Singapore: Springer Nature Singapore. 2024; 88-104. https://doi.org/10.1007/978-981-97-9184-2_9

26. **Kundzewicz ZW and K Takeuchi** Flood protection and management: Quo vadimus? *Hydrol. Sci. J.* 1999; **44(3)**: 417-432. https://doi.org/10.1080/02626669909492237

27. **Yamane T** Elementary sampling theory. 1967. Prentice-Hall, Inc., Englewood Cliffs.

28. **Office of Space Technology and Geoinformatics Development (Public Organization).** Flood Map 2022. https://disaster.gistda.or.th/flood *Accessed August, 2025.*

29. **Turner RC and L Carlson** Indexes of item-objective congruence for multidimensional items. *Int. J. Test.* 2003; **3(2)** :163-71. https://doi.org/10.1207/S15327574IJT0302_5

30. **Huang SK, Lindell MK and CS Prater** Who leaves and who stays? A review and statistical meta-analysis of hurricane evacuation studies. *Environ. Behav.* 2016; **48(8)**: 991-1029. https://doi.org/10.1177/0013916515578485

31. **Poussin JK, Botzen WW and JC Aerts** Effectiveness of flood damage mitigation measures: Empirical evidence from French flood disasters. *Glob. Environ. Change*. 2015; **31**: 74-84. https://doi.org/10.1016/j.gloenvcha.2014.12.007

32. **Kreibich H, Bubeck P, Van Vliet M and H De** Moel A review of damage-reducing measures to manage fluvial flood risks in a changing climate. *Mitig. Adapt. Strateg. Glob. Change.* 2015; **20(6)**: 967-989. https://doi.org/10.1007/s11027-014-9629-5

33. **Di Baldassarre G, Viglione A, Carr G, Kuil L, Salinas J and G Blöschl** Socio-hydrology: conceptualising human-flood interactions. *Hydrol. Earth Syst. Sci.* 2013; **17(8)**: 3295-3303. https://doi.org/10.5194/hess-17-3295-2013

34. **Ludy J and G Kondolf** Flood risk perception in lands “protected” by 100-year levees. *Nat. Hazards.* 2012; **61(2)**: 829-842. https://doi.org/10.1007/s11069-011-0072-6

35. **McGrath H, Abo El Ezz A and M Nastev** Probabilistic depth–damage curves for assessment of flood-induced building losses. *Nat. Hazards.* 2019; **97**: 1-14. https://doi.org/10.1007/s11069-019-03622-3

36. **Boulange J, Hirabayashi Y, Tanoue M and T Yamada** Quantitative evaluation of flood damage methodologies under a portfolio of adaptation scenarios. *Nat. Hazards.* 2023; **118(3)**: 1855-1879. https://doi.org/10.1007/s11069-023-06017-7

37. **Thieken A, Müller M, Kreibich H and B Merz** Flood damage and influencing factors: New insights from the August 2002 flood in Germany. *Water Resour. Res.* 2005; **41(12)**: 1-16 https://doi.org/10.1029/2005WR004177

38. **Dottori F, Szewczyk W, Ciscar J, Zhao F, Alfieri L, Hirabayashi Y and L Feyen** Increased human and economic losses from river flooding with anthropogenic warming. *Nat. Clim. Change.* 2018; **8(9)**: 781-786.

39. **O'Neill E, Brereton F, Shahumyan H and J Clinch** The impact of perceived flood exposure on flood-risk perception: The role of distance. *Risk Anal.* 2016; **36(11)**: 2158-2186. https://doi.org/10.1111/risa.12597

40. **Kellens W, Terpstra T and P De Maeyer** Perception and communication of flood risks: A systematic review of empirical research. *Risk Anal.* 2013; **33(1)**: 24-49. https://doi.org/10.1111/j.1539-6924.2012.01844.x