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A Review-Based Agricultural Science Manuscript

Climate Resilience of Thailand's Agricultural Systems Under Climate Change: Impacts on Rice, Water Resources, Soil Health and Adaptation Strategies

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Abstract

Thailand is one of the world's important agricultural and rice-producing countries, but its farming systems are increasingly exposed to climatic variability, including drought, floods, heat stress, irregular rainfall and changing water availability. These pressures interact with soil constraints, crop water requirements, greenhouse-gas emissions, salinity and the socioeconomic vulnerability of smallholder farmers. This review synthesizes evidence on climate-related risks and adaptation opportunities in Thailand, with particular emphasis on rice-based systems, water management, soil health and climate-smart agronomy. Evidence from Thailand indicates that climate effects are spatially heterogeneous. In northeast Thailand, where a large proportion of rice is rain-fed, temperature trends and drought indices have been associated with variation in rice productivity, while drought and soil salinity can interact with nutrient limitations. Crop-modelling studies indicate that future warming and changing rainfall may increase irrigation requirements and reduce water productivity in some rain-fed systems, although projected effects differ by basin, crop, management practice and climate scenario. Recent research also indicates that management practices such as water-saving irrigation, crop diversification, improved soil management, organic amendments and better matching of crop calendars to climatic conditions can increase resilience. Rice remains central to the analysis, but cassava, maize, soybean and mung bean are also relevant to diversification strategies. The review argues that Thailand's agricultural adaptation should move from isolated farm-level responses toward integrated climate-smart systems combining water governance, crop and varietal diversification, soil-carbon management, improved weather information, precision agriculture and locally appropriate farmer support. The paper concludes that resilient agriculture in Thailand will depend on combining productivity objectives with efficient water use, soil conservation, greenhouse-gas mitigation and adaptive capacity at farm, watershed and policy levels.

Keywords: Thailand; agricultural science; climate change; rice; drought; flood; water management; soil health; climate-smart agriculture; crop diversification; irrigation; resilience

1. Introduction

Agriculture occupies a central position in Thailand's food system, rural economy and international agricultural trade. Rice is particularly important, while cassava, maize, sugarcane, rubber, fruits and other crops contribute to regional livelihoods and national agricultural value. The agricultural sector is highly dependent on climatic conditions because crop growth, water availability, pest pressure and farm operations respond directly to temperature, rainfall and extreme events. Climate change therefore presents both production and resource-management challenges.

Thailand experiences substantial geographic variation in agricultural conditions. Rain-fed systems are widespread in the northeast, while irrigated production is more prominent in parts of the central and lower northern regions. Coastal areas can face salinity and flooding risks, whereas inland farming areas can experience drought and high-temperature stress. The same climatic trend can therefore produce different consequences depending on soil type, crop, irrigation infrastructure, planting calendar and farm management.

Recent reviews identify drought, heat waves, irregular precipitation, floods, storms and changing pest pressure among the principal climate-related threats to Thai agriculture. A 2025 review of Thailand's agricultural sector concluded that adaptation measures include alternative farming techniques, crop diversification and improved water management. Evidence from crop and water modelling further indicates that future effects are likely to vary by location and management system rather than producing a uniform national response.

This review examines the scientific evidence concerning climate risks to Thailand's agricultural systems and evaluates adaptation approaches for crop productivity, water use, soil health and farm resilience. Particular attention is given to rice because of its importance and the relatively extensive Thailand-specific literature, while evidence for cassava and diversified cropping systems is also considered.

2. Review Methodology

This manuscript uses a narrative evidence-synthesis approach. Peer-reviewed agricultural, environmental and climate-impact studies focused on Thailand were considered, together with recent review literature and established international agricultural and climate references. Priority was given to studies examining rice yield, drought, flood, salinity, irrigation requirements, water footprints, soil organic carbon, crop diversification and adaptation practices.

The evidence was organized into six themes: climate hazards; crop productivity; water resources; soil and greenhouse-gas management; crop and farm diversification; and adaptation and policy. Model-based projections are reported as scenario-dependent findings rather than predictions of a single inevitable future. Because studies use different models, baselines, climate scenarios and spatial scales, their numerical outputs should not be directly pooled.

3. Climate Risks to Thai Agriculture

3.1 Temperature and heat stress

Increasing temperature can influence crop development, evapotranspiration, reproductive success and grain filling. Rice is especially sensitive to high temperature around flowering, when heat can reduce spikelet fertility and yield. A study of rice production in the Mun River Basin found that increasing maximum and minimum

temperatures were associated with modest yield losses over the historical period examined, while the authors noted that continued warming could produce more serious effects in the future.

3.2 Drought and rainfall variability

Drought is one of the most important constraints in rain-fed agriculture. In northeast Thailand, where a large share of rice production is rain-fed, short-term drought conditions can affect soil moisture and crop establishment. Research in the Mun River Basin found that the one-month Standardized Precipitation Evapotranspiration Index (SPEI-1) was more informative for rice yield variability than precipitation alone, highlighting the importance of indicators that incorporate both rainfall and atmospheric water demand.

3.3 Flooding

Flooding is a recurrent agricultural hazard in parts of Thailand, particularly in river basins and low-lying agricultural areas. The 2011 floods in the Chao Phraya River Basin demonstrated how extreme flooding can disrupt rice production, agricultural infrastructure, transport and trade. Flood impacts depend on timing: short periods of inundation may be tolerated by some rice varieties, whereas prolonged flooding during sensitive growth stages can substantially reduce productivity.

3.4 Salinity

Soil salinity is particularly relevant in parts of northeast Thailand. Field research in farmers' rice fields showed that drought and salinity can both reduce productivity, with drought producing very large yield losses under the conditions studied and salinity also affecting yield components. Salinity therefore needs to be considered alongside water availability and nutrient management rather than treated as an independent soil problem.

4. Climate Change and Rice Production

Rice is the most extensively studied crop in the Thailand-specific climate literature. Studies using crop-growth models have produced different results depending on location, climate scenario, irrigation status and management. Research in the Songkhram River Basin projected declining rain-fed rice yields under future climate conditions and identified irrigation and other management adjustments as potential adaptation measures. Research in the Nam Oon Irrigation Project likewise found that future climate could alter both rice yield and water footprint, with variety-specific differences.

A broader assessment of major crops in Thailand using CMIP6 climate projections found that responses vary by crop and location. In areas experiencing repeated drought and flood, rice, maize, soybean, mung bean and cassava showed different levels of resilience. Such evidence supports a shift from single-crop adaptation toward diversified farming systems that can distribute climate risk across crops and seasons.

Climate effects should also be evaluated through water productivity. A crop can maintain yield while requiring substantially more irrigation water, creating pressure on water resources. Conversely, a management system that slightly reduces yield but substantially improves water productivity may be more resilient under water scarcity. Agricultural adaptation should therefore evaluate yield, water footprint, soil health and farm profitability together.

5. Water Management and Irrigation

Water management is a central component of climate resilience in Thailand. Irrigation can reduce rainfall variability but may also increase competition for water among agriculture, domestic consumption, industry and

ecosystems. Climate-change studies in Thai river basins indicate that irrigation requirements may increase as temperature and evapotranspiration rise, even when annual rainfall does not decline substantially.

Water-saving practices can therefore have multiple benefits. Improved irrigation scheduling, alternate wetting and drying in rice where agronomically appropriate, land leveling, canal maintenance, soil-moisture monitoring and weather-informed irrigation can reduce unnecessary water application. However, the effectiveness of any intervention depends on infrastructure and local hydrology.

Large-scale farming and organized extension systems may provide greater capacity to implement coordinated water management. A Thailand study comparing large-scale and individual rice farming found differences in projected yield and water footprint under climate scenarios, suggesting that management organization can influence adaptive capacity. Such findings should not be interpreted as meaning that larger farms are inherently more resilient; rather, access to coordinated technical services and water management can be important.

6. Soil Health, Organic Matter and Greenhouse-Gas Management

Soil health is closely connected to climate resilience. Soils with greater organic matter can support water retention, aggregation and nutrient cycling, although the magnitude of these benefits depends on soil type and management. Thai research in rice systems has examined organic farming, soil organic carbon sequestration and carbon-footprint outcomes, providing evidence that production systems can be evaluated simultaneously for productivity and environmental performance.

Rice cultivation also contributes to greenhouse-gas emissions, particularly methane under flooded conditions, while nitrogen management can influence nitrous oxide emissions. A 2025 experimental study in central Thailand found that water scarcity reduced methane emissions under some conditions but increased nitrous oxide emissions, illustrating why climate-smart management should assess multiple greenhouse gases rather than assuming that reducing one emission automatically reduces total climate impact.

Organic amendments such as biochar are being investigated for their potential to modify soil properties, nutrient cycling, carbon storage and crop performance. Their use should be evaluated using locally appropriate feedstocks, application rates, economic costs and long-term soil effects. Climate-smart agriculture should avoid promoting an input solely because it is labeled 'organic' or 'carbon-negative'; environmental benefits must be demonstrated under field conditions.

7. Crop Diversification and Agricultural Resilience

Diversification can reduce dependence on a single climate-sensitive crop and may improve the timing and use of water and labor. In Thailand, rice-based systems can potentially incorporate maize, soybean, mung bean and other crops depending on soil, water availability, market conditions and seasonal climate. CMIP6-based research in areas affected by repeated drought and flood identified mung bean and cassava among crops projected to show comparatively strong resilience under some scenarios.

Cassava is particularly relevant because it is relatively tolerant of dry conditions compared with some annual crops. A Thailand panel study covering 1989–2016 found that rainfall and La Niña events influenced cassava harvested area and that climate variables affected production patterns. Diversification should nevertheless be based on economic as well as agronomic considerations because a crop that tolerates drought may not provide reliable income if markets, storage or processing infrastructure are inadequate.

Diversified rotations can also influence soil fertility and pest dynamics. Legume inclusion may contribute nitrogen through biological fixation, while rotations can interrupt pest and disease cycles. However, crop

diversification requires extension support, suitable seed systems, market access and knowledge of local agroecological conditions.

8. Adaptation Strategies for Thai Farmers

Adaptation strategy	Primary purpose	Important considerations
Climate-informed planting calendars	Reduce mismatch between crop stages and rainfall/temperature	Requires reliable seasonal forecasts
Drought-tolerant or locally adapted varieties	Maintain productivity under water stress	Seed availability and farmer acceptance
Improved irrigation scheduling	Increase water productivity	Requires infrastructure and monitoring
Alternate crops/rotations	Spread climate and market risk	Markets and agronomic suitability
Soil organic matter management	Improve soil function and resilience	Long-term management and local materials
Flood-tolerant varieties/field drainage	Reduce flood-related yield loss	Flood timing and duration matter
Integrated pest management	Reduce climate-related pest risks	Requires surveillance and farmer training
Weather and climate services	Support farm decisions	Forecast uncertainty must be communicated
Digital/precision agriculture	Improve input and water efficiency	Technology cost and digital access

Table 1. Major adaptation options for climate-resilient agriculture in Thailand.

Farmer adaptation is most effective when technical interventions are matched with socioeconomic conditions. A drought-tolerant variety has limited value if seed is unavailable; an irrigation recommendation has limited value where water infrastructure is inadequate; and crop diversification may fail if alternative crops lack stable markets. Adaptation policy should therefore combine agronomic innovation with financial, institutional and market support.

Systematic evidence from Southeast Asia indicates that farmers use combinations of crop diversification, water management, changes in planting practices, soil-management measures and livelihood adjustments. Thai adaptation strategies should consequently be evaluated as portfolios rather than single technologies.

9. Regional Agricultural Priorities in Thailand

Agricultural adaptation should be geographically differentiated. Northeast Thailand requires strong attention to rain-fed rice, drought, soil salinity and low water-storage capacity. The central plain and Chao Phraya system require integrated management of irrigation, flood risk and dry-season water allocation. Northern areas may require greater attention to drought, watershed management and crop diversification, while southern agricultural systems have distinct rainfall, flooding and perennial-crop considerations.

This regional approach is important because national averages can conceal local risks. A strategy that increases irrigation in one region may be inappropriate in another if groundwater is limited or if additional pumping increases environmental pressure. Similarly, a crop variety selected for drought tolerance may not perform well under prolonged flooding or salinity. Climate adaptation should therefore be based on agroecological zoning and local evidence.

10. Food Security and Agricultural Economics

Climate impacts on agriculture extend beyond yield. Changes in crop output affect food prices, farm income, labor demand, exports and household food security. Thailand's position as a major agricultural exporter means that production shocks can have consequences beyond farm communities. The economic effects of climate risk therefore need to be integrated with agronomic assessments.

Smallholder farmers may face particular constraints because they often have limited access to credit, irrigation, crop insurance, improved seed, machinery and technical information. Adaptation measures should be assessed for affordability and risk as well as biological effectiveness. Cost-benefit analysis, farmer participatory trials and value-chain analysis can help identify technologies that are both agronomically sound and economically feasible.

11. Research Priorities

Future research should combine field experimentation with crop and hydrological modelling. Models can explore long-term scenarios, but field observations are necessary to calibrate local responses to heat, drought, salinity, flooding and management interventions.

More research is needed on interactions among climate stressors. Farmers rarely experience drought, heat, pests and nutrient stress independently. Multi-stressor experiments can identify management practices that remain effective under realistic combinations of environmental pressures.

Research should also improve measurement of water productivity and greenhouse-gas emissions at farm scale. Yield alone is insufficient for judging resilience if production requires increasing amounts of water or produces large greenhouse-gas emissions.

Digital agriculture, remote sensing and low-cost weather stations could improve local decision-making, but research should assess data quality, accessibility, maintenance requirements and farmer usability. Technology adoption should be evaluated in real farm systems rather than only in demonstration settings.

12. Discussion

The evidence indicates that climate change is not simply a future threat to Thai agriculture; climate variability already influences production through drought, heat, flooding and water-resource uncertainty. However, the magnitude and direction of impacts vary strongly among locations and management systems. This variability explains why some crop models project increased yields under moderate climate scenarios while projecting substantial declines under more severe warming pathways.

Rice should remain a central research priority because of its importance, but resilience should not be equated with maintaining rice production under every circumstance. In water-limited areas, crop diversification may provide a more robust strategy than attempting to sustain continuous rice cultivation. Evidence from repeated drought-and-flood areas suggests that crops such as mung bean and cassava may offer useful alternatives under some future conditions.

The relationship between adaptation and mitigation also requires attention. Water management can alter both yield and methane emissions, while nitrogen management can influence nitrous oxide. Soil-carbon practices may improve soil function while affecting greenhouse-gas balances. Agricultural policy should therefore use multi-objective assessment rather than maximizing yield alone.

Thailand has substantial agricultural research capacity, irrigation infrastructure and farmer-extension institutions. A major opportunity is to integrate these resources with improved climate information and localized adaptation planning. The goal should be to move from reactive disaster response toward anticipatory farm management supported by seasonal forecasts, crop modelling, soil and water monitoring and farmer participation.

13. Limitations

This manuscript is a narrative review rather than a systematic review or original field investigation. It does not calculate a new national estimate of climate-related yield loss and does not pool model projections from different studies. The reviewed literature varies in geographic scale, climate scenario, crop model, baseline period and management assumptions. Consequently, future projections should be interpreted as scenario-dependent evidence rather than precise forecasts.

Some agricultural systems and crops have been studied more extensively than others. Rice receives substantial attention because of its economic and food-security importance, whereas evidence for some horticultural, livestock and perennial systems is less extensive in the literature synthesized here. Future reviews should use systematic database searches and quantitative evidence synthesis where comparable studies are available.

14. Conclusion

Thailand's agricultural sector faces interacting risks from rising temperature, rainfall variability, drought, flooding, salinity, changing water demand and climate-sensitive pests. Rice-based systems are particularly important, but resilience should be assessed across diversified farming systems rather than through rice yield alone. Evidence from Thai river basins indicates that climate effects vary spatially and depend strongly on water availability, crop choice and farm management. Climate-smart agriculture should therefore combine efficient irrigation, climate-adapted varieties, improved soil health, crop diversification, weather and climate services, integrated pest management and appropriate digital technologies. Adaptation should also consider greenhouse-gas emissions, farm profitability and long-term resource sustainability. The strongest pathway toward resilient Thai agriculture is likely to be an integrated approach connecting farm-level innovation with watershed management, extension services, agricultural markets and national climate policy.

15. Declarations

Conflict of interest: The authors declare no conflict of interest regarding this publication.

Ethics approval: Not applicable; this manuscript synthesizes published agricultural research.

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