Research article

Changes in Planting Dates and Planted Areas for Rainfed Rice Cultivation in Northeastern Thailand Over Several Decades

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Abstract Northeast Thailand is a crucial rice-producing region, hosting 60% of the nation's rice paddies, yet over 90% of its fields are rain-fed, rendering them susceptible to variations in precipitation. Therefore, there is an acute need to study the impact of changes in precipitation on rice cultivation in the region. While numerous studies have examined how climate change affects rice production, most have focused on yield variations, neglecting the fluctuation in planted areas. Additionally, previous studies have often relied on fixed planting dates without considering annual or regional variations. This leads to an overestimation of rice production, especially in rain-fed fields where the extent of the planted area is strongly influenced by the volume of precipitation. In this study, we developed a model that estimates planted areas in Northeast Thailand by a water balance approach, integrating meteorological, elevation, and surface water level data. The model not only predicts the planted area but also the planting date, incorporating daily precipitation data to anticipate the spatiotemporal expansion of planted areas. The model calculates the surface water level, designating the day it exceeds 50 mm as the planting date. Model parameters were calibrated using observed data from 2004 and 2005. We then assessed the impact of precipitation changes on planted area extents by inputting climate data from 1981-2017. In analyzing the temporal changes in planted area and planting date, the model revealed significant differences between past and recent practices. Specifically, when comparing decadal shifts in planted areas from 1981-1990 and 2008-2017, the model revealed that during the former period, many areas were planted in June, while during the latter period, planting dates had become more variable. Furthermore, a comparative analysis of four periods of 1981-1990, 1991-2000, 2001-2010, and 2008-2017 indicated a progressive delay in the planting date over time, due to the increasing uncertainty of precipitation during the early part of the rainy season.

Keywords climate impact, water balance model, topographic effect, rain-fed rice

INTRODUCTION

The world population has seen a significant increase from 3 billion in 1960 to 6 billion in 2000 and is projected to reach around 9.5 billion by 2050 (United Nations, 2022). Despite advancements in grain production due to improved crop varieties, chemical fertilizers, and expanded irrigated farmland, the United Nations Food Security Information Network (FSIN) and Global Network Against Food Crisis estimates that 330 million people currently face high levels of food insecurity (FSIN and Global Network Against Food Crisis, 2023). Asia, which makes up 24% of the world's land area, is home to 4.3 billion of the global population of approximately 7.9 billion. Largely due to the humid environment and the cultivation of rice as a staple crop (Taniguchi et al., 2009).

Thailand is a key player in global grain production, with about 10 million hectares of rice paddies producing 33 million tons of rice annually (National Statistical Office, 2023). In the northeastern region of Thailand, which accounts for 60% of the country's rice paddies, fewer than 10% of these paddies are irrigated (National Statistical Office, 2023). Consequently, rice production there is largely dependent on precipitation compared to other regions in the country (Shiraiwa et al., 2001). For instance, Polthanee et al. (2014) have identified drought as a significant agricultural constraint in Thailand, primarily due to the erratic distribution of rainfall and frequent dry spells during the rainy season. The Intergovernmental Panel on Climate Change (IPCC) 2023 report predicts that global warming, particularly in tropical regions, may lead to a decline in food production and labor productivity, potentially raising food prices. This will be a critical issue for countries heavily reliant on food imports from tropical regions such as Thailand.

Studies have extensively investigated the impact of weather conditions on grain production. Research by Horie et al. (1993), Tanaka et al. (2011), and Masutomi et al. (2008) has focused on evaluating the potential production of rice across broad regions. However, these studies emphasize the need for models that reflect local farming systems and adaptive behaviors to climate change. Sujariya et al. (2019) and Babel (2011) developed models that quantitatively assess yield losses due to drought and predict a 24.34% decrease in yields by the 2080s under certain climate change scenarios. Tanaka et al. (2014) further highlighted the need to estimate not only the harvested area but also the area suitable for planting, given the variations in water availability. While numerous studies have been conducted on rice production forecasting in Thailand, many do not adequately account for the variability in planting areas and dates. However, since the most popular cultivar in Northeast Thailand has a photoperiod sensitivity, the delay in planting means a shorter cultivation period, which leads to less yield. That is why the cultivation period for rainfed rice varies annually and regionally, depending on rainfall patterns. Therefore, it is crucial to evaluate the impact of rainfall variability on both planting area and date for accurate rice production forecasts.

OBJECTIVE

Given these backgrounds above, the objective of this study was to develop a model for estimating the planting area and dates in Northeast Thailand and to quantitatively evaluate the changes from the past to the present.

METHODOLOGY

Planted Area Estimation Model

Daily precipitation data from the Thai Meteorological Department (TMD), monthly temperature data from the Climate Research Unit (CRU), elevation data from the United States Geological Survey (USGS), and land use data from the Land Development Department Thailand (LDD) were used for this study. Table 1 shows a list of the specifications of the data. The study considers the secondary data from 1981 to 2017 from TMD and CRU for precipitation and temperature data, respectively.

In this study, we developed a water balance model with Topographic Wetness Index (TWI) to estimate planting dates and planted areas in Northeast Thailand, using meteorological data, elevation data, and land use data. This model is chosen since it simply calculates water balance with limited available data. Also, TWI can explain how microtopography influences variations in water circulation. The rice planting starts when soil water content (SWC) in each paddy field grid exceeds a threshold. SWC is calculated by the equations below.

$$SWC\_(t-1/2) = SWC\_(t-1) + R\_t - ETP\_t \quad (1)$$

$$SWC\_t = SWC\_(t-1/2) - P\_t \quad (2)$$

$$P\_t = \max(0, SWC\_(t-1/2) - WR) * kP \quad (3)$$

$$kP = a/tan\beta \quad (4)$$

Where *SWC*: soil water content [mm]; *R*: rainfall [mm/day]; *ETP*: evapotranspiration [mm/day], calculated by the Thornthwaite method using monthly temperature; *P:* percolation [mm/day]; *t*: the *t*-th day from 5/20; *WR:* soil water retention, which was set as 30 mm; *kP*: percolation rate coefficient

[-]; $\tan\beta$: Topographic Wetness Index [-], a larger value showing flatter areas, which makes percolation speed slower; a: a fitting parameter.

Table 1 Specifications of the data

Data	Source	Temporal resolution	Spatial resolution
Precipitation	TMD	Day	10 km
Temperature	CRU	Month	110 km
Elevation	USGS	-	1 km
Land use	LDD	-	1 km

RESULTS AND DISCUSSION

Model Calibration

Sawano et al. (2008) conducted a field survey in Northeast Thailand and provided sufficient quantitative data on planting dates and planted areas in 2004 and 2005. In this study, the model parameters were calibrated using observed planted area change in 2004 and 2005, and then accuracy was assessed by Root Mean Square Error (RMSE).

Figure 1 shows the result of the model calibration. The unit for the planted area is the percentage of the paddy field grids to align with the calibration data. When a = 1.5 and the threshold for the start of planting = 50 mm, RMSE for 2004 and 2005 were 11.2% and 8.3%, respectively. Considering that the labor force becomes a limiting factor in planting after paddy has enough SWC, the planted rate in each grid increases by 2.25% per day, which is the highest rate observed in the wet year of 2004. In 2004, which was a wet year, there was heavy rain in early June, which made estimated planting dates too early. In 2005, which was a dry year, estimated planting dates are well fit to observed data until 30th August. After that, there was heavy rain, which made the estimated planted area larger while farmers rarely continued planting in September. This result implies that SWC is a suitable indicator to estimate planting dates in a dry year, whereas other factors such as labor force can be better indicators in a wet year. Enhanced calibration could potentially be achieved by incorporating data on the maximum planting rate, which is 2.25% per day if it were to be obtained from future field surveys.

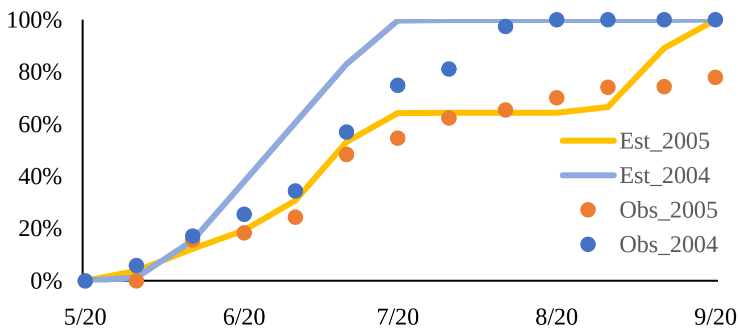

Fig. 1 Model calibration using 2004-2005 observation data

Figure 2 shows the spatiotemporal distribution of the planted area in 2004 and 2005. In 2004, a broad distribution of the planted area was observed across the region, with planting starting in most paddy by 20th June. On the other hand, in 2005, the planted area was predominantly located in the eastern part of the study area, an area characterized by relatively higher rainfall, while the planted area was not observed in the western part until August. This difference implies that the western part of the region is more vulnerable to the drought in planting season, compared to the eastern part of the region. These observations suggest that rice production in 2005 may be lower compared to 2004. This is attributed to two primary factors: a reduction in the planted area, as it is confined to a smaller region, and a shorter cultivation period due to the delayed onset of planting.

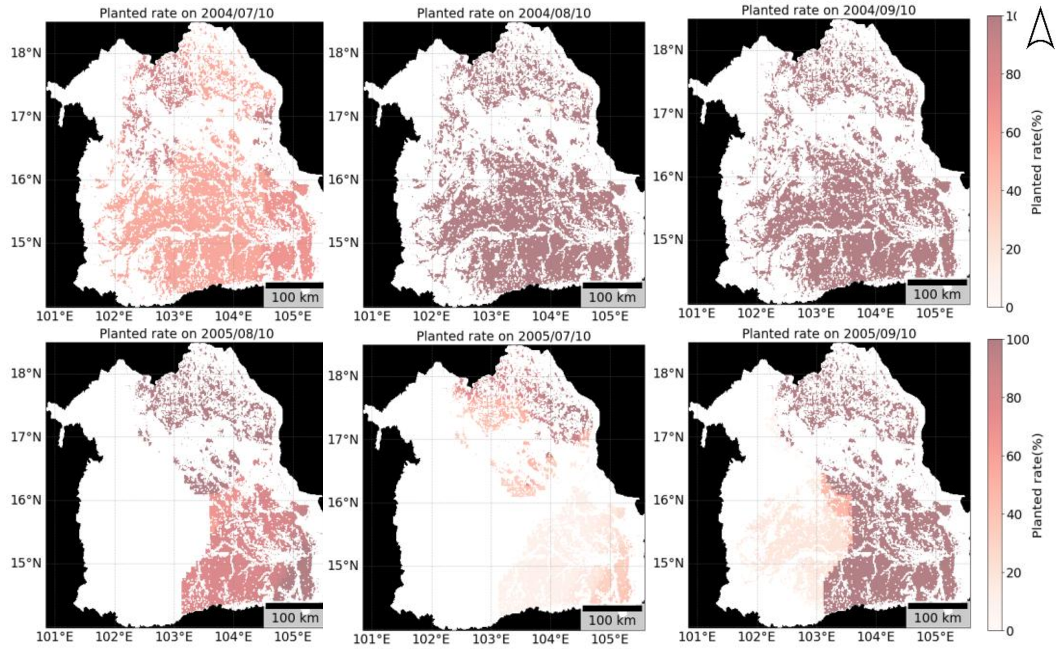

Fig. 2 Planted areas estimated by the model (2004, 2005)

Decadal Change of Planting Dates and Planted Area

Figure 3 shows the changes in planting area throughout four periods (a) 1981-1990, (b) 1991-2000, (c) 2001-2010, and (d) 2008-2017. As is evident from these figures, variability in planting dates has increased in recent decades relative to the earliest period. During the period (a), all ten years exhibited a significant increase in planted areas in June. In contrast, period (d) displayed a more unstable pattern, with some years showing an increase in June, others in July, and still others exhibiting similar increases in both June and July.

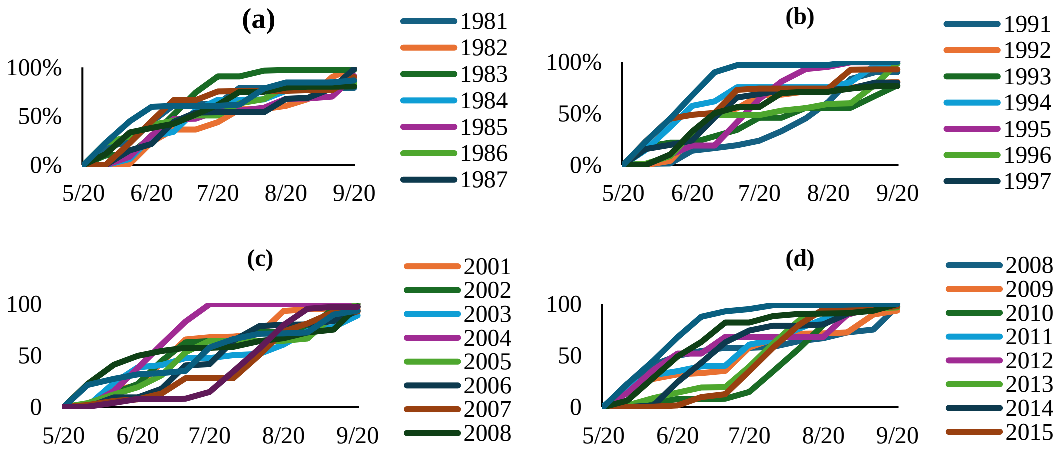

Fig. 3 Planting area on each day of four periods (a) 1981-1990, (b) 1991-2000, (c) 2001-2010, (d) 2008-2017

Figure 4 shows the average increment in planted area in four periods 1981-1990, 1991-2000, 2001-2010, and 2008-2017. In the past, the planted area has increased mainly in June, while in recent, the planting date has shifted to approximately one month later. The most popular cultivar in Northeast Thailand has photoperiod sensitivity. Thus, a delay in the planting date leads to a shorter cultivation period and less yield. This suggests farmers are recently struggling with determining planting dates, as the dates with sufficient soil moisture are unstable. In addition, there is a short period with a small increment in planting area in July in 1991-2000, 2001-2010, and 2008-2017. These short periods are thought to originate from dry spells, which are brief interruptions of the wet season, recently reported in Northeast Thailand.

Nodera et al. (2022) demonstrated the gap between changing rainfall trends and farmers' perception of climate in Northeast Thailand. According to the study, although annual rainfall has increased, more than 80% of farmers think rainfall has decreased. The estimated planting dates from this study imply this gap arises from the difficulties in planting experienced by farmers in the study area.

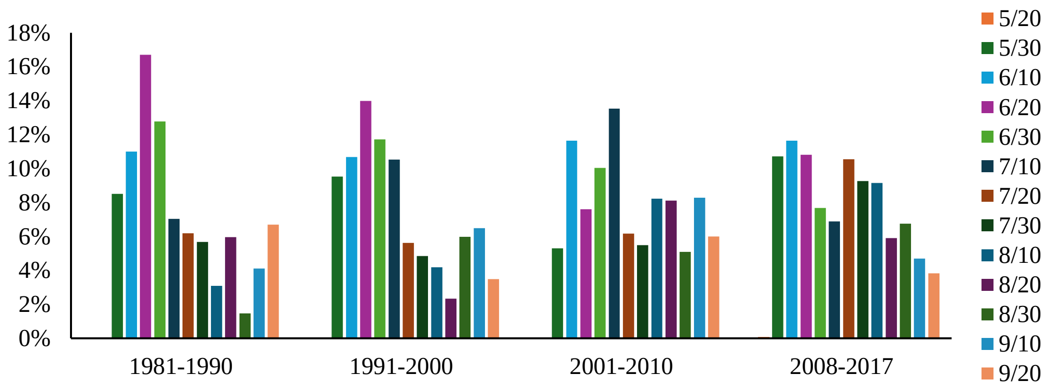

Fig. 4 Average increment in planted area of four periods

CONCLUSION

This study aimed to develop a model to estimate the planting area and dates for rainfed rice cultivation in Northeast Thailand, a region where agriculture is heavily influenced by rainfall patterns. By utilizing precipitation, temperature, elevation, and land use data, the research aimed to quantitatively evaluate the changes in planting practices from the past to the present. The model, calibrated by using field data from 2004 and 2005, incorporates daily precipitation to predict the temporal expansion of planted areas. It calculates soil moisture content and designates the day they exceed 50 mm as the planting date. However, the model's limitations became evident in wet years, where other factors like the labor force also influence planting dates. Despite these limitations, the RMSE of 11.2% for 2004 and 8.3% for 2005 indicate acceptable accuracy.

The findings from the model's analysis, covering the period from 1981 to 2017, revealed significant changes in planting dates and planted areas. In the past, specifically during 1981-1990, the increase in planted areas was consistently observed in June. In contrast, the more recent period of 2008-2017 showed greater variability, with planting occurring in June, July, or both. This shift indicates a change in precipitation patterns over the decades, implying the broader impact of climate change on agricultural practices. The study also noted a progressive delay in the planted date from past to present, attributed to the uncertainty of precipitation during the early part of the rainy season. This uncertainty presents challenges for farmers in planning their agricultural practices. Additionally, the research identified dry spells, and brief interruptions in the monsoon season, as a factor contributing to the variability in planting dates. This phenomenon has been increasingly observed in recent years in Northeast Thailand. The model's findings suggest that farmers in the region are facing challenges in determining optimal planting dates due to the unstable weather conditions. This could potentially lead to reduced yields, especially given the photoperiod sensitivity of popular rice cultivars in the area. In conclusion, the developed model serves as a valuable tool for estimating planting areas and dates, helping to understand the impact of these changes on agricultural practices.

This study has two major limitations. One is the ability to estimate the planting dates in a wet year. The fact that the model has relatively large errors in a wet year of 2005, implies there are other factors determining planting dates. A questionnaire survey about planting dates to farmers is planned to be conducted to improve the model. The other limitation is the ability to quantitatively assess the effect of the delay in planting on rice production. Incorporating the model proposed in this study into a crop growth model will be conducted to evaluate the relation between the delay in planting and rice production. This will be crucial for improving agricultural planning and management in the face of climate variability.

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