Risk Assessment of Agricultural Areas in Chon Buri, Thailand: A Composite Index on Sub-District Level

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Abstract

Climate variability and natural disasters are some of the main problems affecting agricultural land worldwide. In this study, climatic data, natural disaster data, and agricultural data were used to assess the climate risk of agricultural areas at sub-district level in Chon Buri province, Thailand. The data were aggregated using a composite index, the Agricultural Risk Index (ARI). The ARI values were scaled into three classes: low (<0.2500), medium (0.2500-0.5000), and high (>0.5000) risk. The results showed that the highest ARI value (0.6322) was found in Khokploh sub-district, which is a result of the high water consumption, the high number of agricultural areas, and the great distance from water resources. This index can be used for decision makers and government authorities to evaluate and monitor the risks in agricultural areas.

1 Introduction

The agricultural sector is more likely to face risks than other sectors because its products and services are related to natural processes, biological assets, and plant and animal diseases (GIRDZIUTEA 2012). Decreasing water supply as a result of climate change (PEREZ-BLANCE & GOMEZ 2014) and natural disasters affects the agricultural areas worldwide. The current climate of the world is likely to change in a negative manner, which directly affects the water cycle, i.e. the amount of water vapour in the atmosphere, the pattern of rainfall (BATES et al. 2008, QUEVAUVILLER 2011), and the water quantity. Especially in Thailand, water is an important resource for agriculture, in which the rain-fed agriculture constitutes approximately 78% of all agricultural lands. Furthermore, changes in rainfall can directly influence crop yields (CHIKOZHO 2010, VERMEULEN et al. 2012).

There are several methods for assessing the risk to climate hazards and natural disasters, for example the Livelihood Vulnerability Index (LVI) (HANH et al. 2009), Environmental Sensitive Area Index (ESAI) (SALVATI & CARLUCCI 2010), Vulnerability Index (HELTBERG & BONCH-OSOLOVSKIYV 2013), Sensitivity Index of Agricultural Land (SIAL) (MAZZOCCHIA 2013), Drought Risk Index (DRI) (ELAGIB 2014), and Hunger and Climate Vulnerability Index (KRISHNAMURTHY 2014). In this study, an Agricultural Risk Index (ARI) was calculated and visualized for sub-districts in Chon Buri province, Thailand. ARI adopts the methodology of the LVI to combine data for assessing the risk of agricultural areas.

Data that were used to calculate the ARI are comprised of four components: temperature and natural disasters, agricultural areas, water sufficiency, and distance from water resour-

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ces. The selected data differ from the LVI method as ARI uses climatic, disaster, agricultural, and hydrological data and integrates them in a GIS to assess the risk, while LVI uses primary household data i.e. the social, economic, health, and food of households (HANH et al. 2009). ARI helps planners and farmers to cope with climate hazard (e.g. lack of water), and provides government assistance with a practical tool to understand disaster, agricultural, and water resource factors to climate hazards at the sub-district level. Therefore it is extremely important to evaluate and manage agricultural risks and to select the best management methods.

2 Study Area

Chon Buri province is located in the eastern part of Thailand where it is the center of industry, services and tourism, and agriculture. Chon Buri has an area of 4,363 square kilometers. The province is subdivided into 11 districts. These are further subdivided into 92 sub-districts and 691 villages. This study only focuses on the mainland with its 91 sub-districts. The map of Chon Buri is shown in Figure 1.

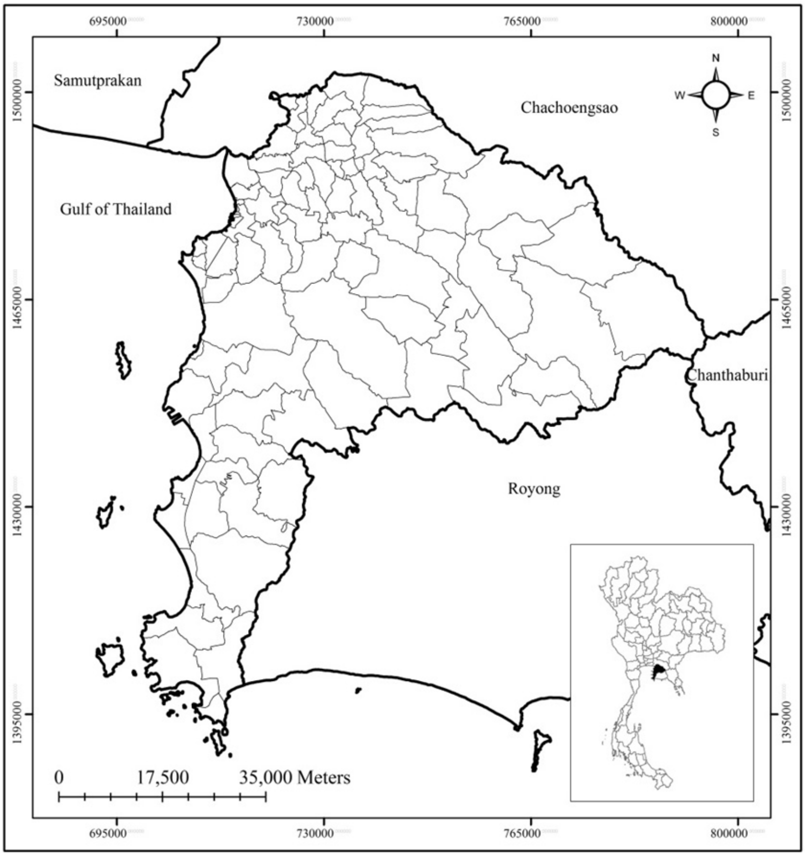

Fig. 1: Sub-districts of Chon Buri province, Thailand

3 Materials and Methods

3.1 Data and Preparation

The ARI was calculated of the following four components: temperature and natural disasters, agricultural areas, water sufficiency, and distance from water resources. These sub-components were identified on the basis of a literature review. For example, the LVI was calculated using seven components: socio-demographic profile, livelihood strategies, social networks, health, food, water, natural disasters, and climate variability (HANH et al. 2009). HELTBERG & BONCH-OSOLOVSKIYV (2013) used five components: agriculture, demographics, health, poverty, and disaster to calculate the vulnerability index, and ROHILLA (2009) used five components: climate, demographics, ecosystem, agriculture, and socio-economic structure for their vulnerability assessment. In this study, previous methods were combined and sub-components of agriculture, disaster, and water resources were selected to calculate the ARI. Table 1 shows the components, sub-components, and explanation of sub-components.

All sub-components were transformed into rasters with a grid size of 40×40 meters. Temperature and precipitation data were estimated using the Kriging Interpolation Technique, while distance from wells and water bodies was calculated using Euclidean Distance.

Table 1: Components and sub-components for the ARI calculation

Components	Sub-components	Explanation of Sub-components
Temperature and natural disasters	Monthly average of average maximum daily temperature	The average daily maximum temperature by month was averaged from 1982-2011.
	Average number of floods	The total number of floods was averaged from 2006-2011.
	Average number of droughts	The total number of droughts was averaged from 2006-2011.
	Average number of land slides	The total number of landslides was averaged from 2006-2011.
	Average number of storms	The total number of storms was averaged from 2006-2011.
Agricultural area	Percent of agricultural areas	Percentage of agricultural areas was calculated in each sub-district.
Water sufficiency	Agricultural water use from precipitation	Evapotranspiration of all plants was calculated and deducted by precipitation in each sub-district.
Distance from water resources	Average distance from wells	Average distance from wells was calculated in each sub district.
	Average distance from water bodies	Average distance from water bodies was calculated in each sub-district.

3.2 ARI Calculation

The ARI was calculated using a balanced weighted average approach where each sub-component contributes equally to the overall index even though each component was comprised of a different number of sub-components (SULLIVAN 2002, HANH et al. 2009).

Firstly, it was necessary to standardize the sub-components since each of them was measured on a different scale (equation 1).

$$Index_{S_t} = \frac{S_t - S_{min}}{S_{max} - S_{min}} \tag{1}$$

where $Index_{S_t}$ is the standardized value of sub-component S for sub-district t

S_t is the value of sub-component S for sub-district t

S_{min} and S_{max} are the minimum and maximum values of sub-component S for all sub-districts, respectively.

Secondly, the standardized sub-components were averaged to calculate the value of each component using equation 2.

$$C_t = \frac{\sum_{i=1}^{n} Index_{S_{t^i}}}{n} \tag{2}$$

where C_t is one of four components for sub-district t

$Index_{S_{t^i}}$ represents the sub-components S, indexed by i, that make up each component

n is number of sub-components in each component.

After each of the four components was calculated, they were used to average to obtain the ARI value in each sub-district using equation 3.

$$ARI_t = \frac{\sum_{i=1}^{4} W_{M_i} C_{t_i}}{\sum_{i=1}^{4} W_{m_i}} \tag{3}$$

where ARI_t is the Agricultural Risk Index for sub-district t

W_{M_i} is calculated by number of sub-components that make up each component and is included to ensure that all sub-components contribute equally to the overall ARI

C_{t_i} is one of four components for sub-district t.

4 Results and Discussion

4.1 Components and Sub-components

All components derived from secondary data and the ARI as a composite index are comprised of four components and nine sub-components. This part presents the details of all components and sub-components. The highest average daily temperature (30.81 degrees Celsius) was revealed in several sub-districts such as Bangsai, Bansuan, Bankhod, Makhamyong, and Bangplasoi, while the lowest was found in Pattaya with 29.71 degrees Celsius. The average number of floods between 2006-2011 for all sub-districts was 0.79 instances per year, and the highest and lowest average number of floods was 1 and 0.50 instances per year, respectively. Droughts were not reported in any of the sub-districts during the study period and landslides were found only once per year in 16 sub-districts (e.g. Watbot, Mappong, Bothong, and Sattahip). The average number of landslides for all sub-districts was 0.18 instances per year. The number of storms varied from 1-5 instances per year, for example, Khohchan (5 instances), Bothong (1 instance), and Pluangthong (3 instances), but most of the sub-districts did not report a storm between 2006-2011.

100% of agricultural areas were only present in Narerk, while no agricultural area was found in Pattaya, Bangsai, Bankhod, Makhamyong, and Bangplasoi. However, a high percentage of agricultural areas (>50%) were reported in 74 sub-districts. Overall, the average percentage of agricultural area for all sub-districts was approximately 75.75%. For the water sufficiency component, the results showed that 71.43% of the whole study area or 65 sub-districts had enough water, while the others lacked water for cultivation such as Thakam, Banghak, and Napa. The areas with a lack of water were generally planted with eucalyptus, rubbers, irrigated rice, and fruits, which require more water than other cultivations. The longest distance from wells was 13,126.20 meters in Banghak, compared to the shortest distance of 761.64 meters in Naklue. Similarly, the longest distance from water bodies was 10,612.60 meters in Thakam, compared to the shortest distance of 291.89 meters in Phanasnikom. The average distance from wells and water bodies for all sub-districts was around 2,920.88 and 3,784.43 meters, respectively.

4.2 Composite Index

The ARI was scaled from 0-1 (low-high risk). Most of the sub-districts (95.60%) had a low-medium ARI value (0-0.5000), while only four sub-districts exceeded 0.5000. The four highest ARI values were found in Thakam, Watluang, Watbot, and Khokploh (0.5211, 0.6167, 0.6200 and 0.6322, respectively). Figure 2 shows the component scores of the four highest ARI values. Khokploh is located in Phanasnikom district in the north of the province, and it had the highest ARI representing more risk in terms of the water sufficiency, agricultural area and distance from water resources components (1.00, 0.97 and 0.56, respectively). Considering the sub-components of Kholkploh, the average maximum daily temperature was 30.39 degrees Celsius and is affected by floods and landslides once a year on average. 96.54% of the areas of Khokploh are irrigated rice fields, and therefore this sub-district has lacked water for rice cultivation. In addition, the average distance from wells and water bodies was 6,878.44 and 6,910.36 meters, respectively, which explains the high risk value for Khokploh. Similarly, the other high ARI value sub-districts, Watbot, Watluang, and Thakam, also showed more risk in terms of the water sufficiency, agricultural area, and distance from water resources components. For instance, the ARI value of Watbot is slightly lower than Khokploh because of a smaller percentage of agricultural areas and a shorter distance from wells and water bodies (0.96 and 0.41, respectively, Figure 2). However, the temperature and the number of natural disasters in Watbot was similar to Khokploh, and the average number of storms was once a year.

The lowest ARI value (0.0989) was found in Pattaya because of its low temperature, the relatively low amount of floods (0.67 times per year), and, especially, the absence of agricultural areas.

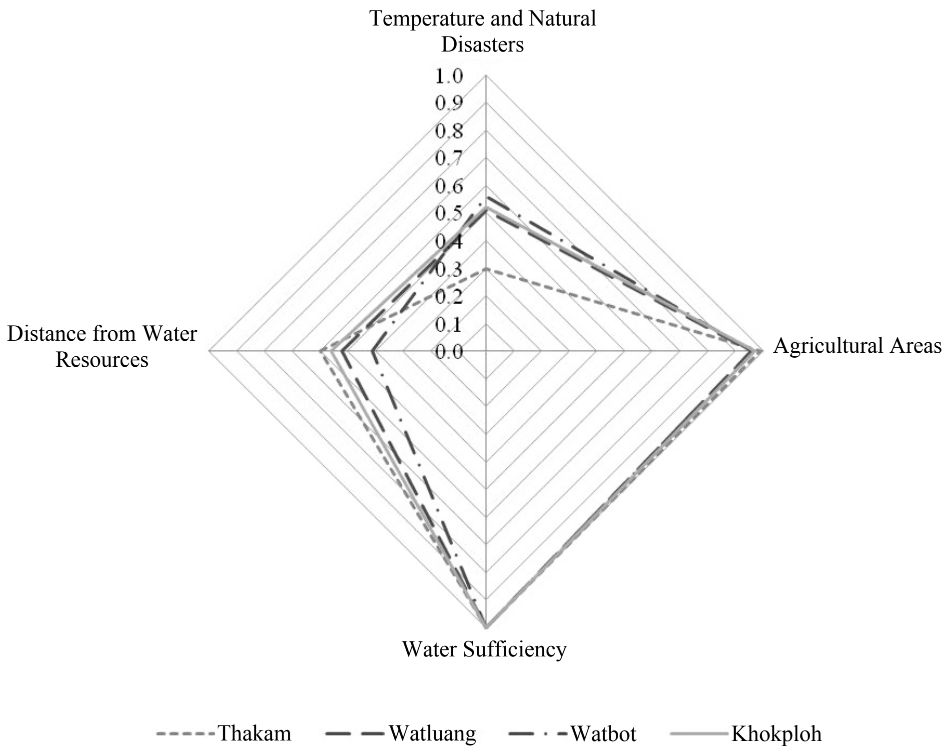

Fig. 2: The component scores for the four highest ARI sub-districts in Chon Buri

Figure 3 illustrates a map of the ARI. All four sub-districts with high ARI values are part of Phanasnikom district, which is located in the north of the province. These areas are mostly irrigated rice fields that need more water for cultivation than others. Similarly, these areas were affected by floods every year (2006-2011). Medium ARI values ranging from 0.2501-0.5000 can be found in the upper and lower part of the province. The values of components and sub-components varied in these areas, for example, the average number of disasters per year was 1-5 storms, 0.5-1 floods, and 0-1 landslides. Further, the percentage of agricultural area ranged from 0-100%, whereby 33 sub-districts showed a high percentage of agricultural areas (>90%). Nevertheless, this component did not significantly affect the overall ARI value, similar to the longest distance from a well, which was also found in this class. Most low ARI values (0-0.2500) can be found in the lower central and the eastern part of the province. These low ARI areas only faced an average of 0.5-1 flood occurrences per year. Furthermore, all sub-districts in this class had adequate water for the cultivation of cassava, sugar cane, and coconut, for instance.

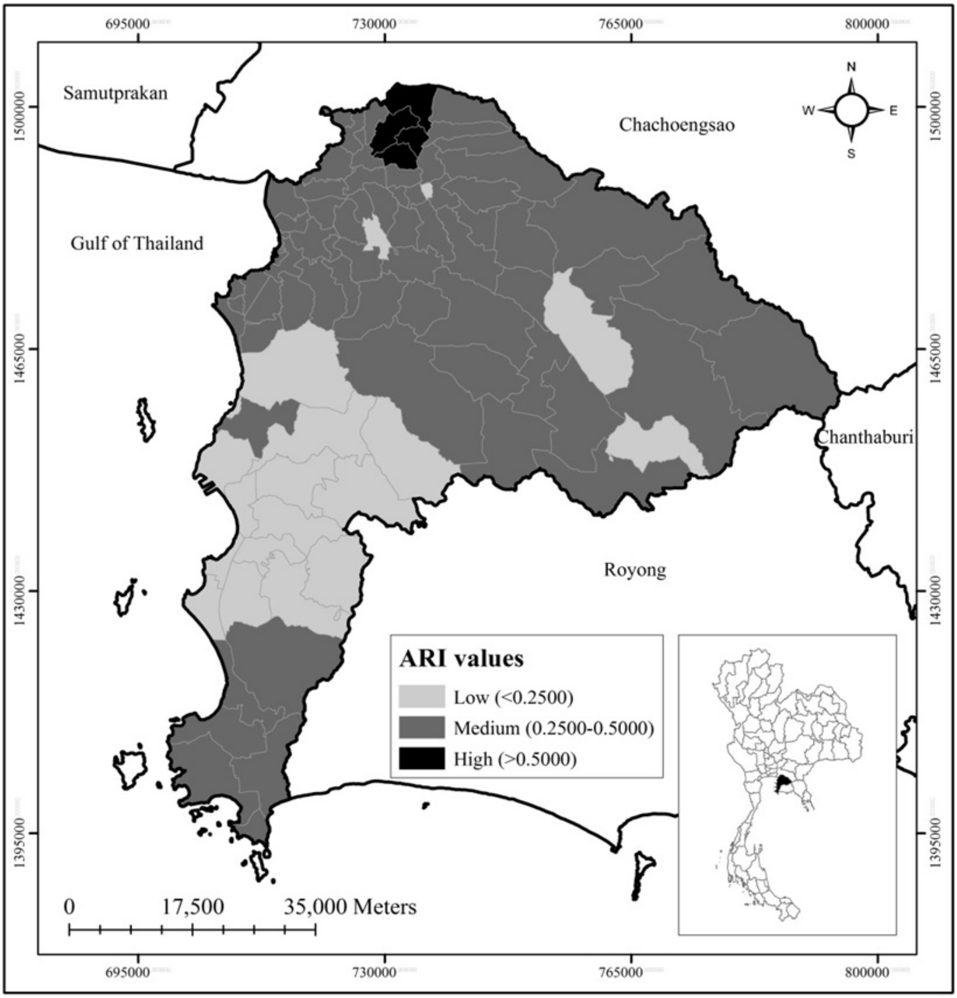

Fig. 3: Agricultural Risk Index map of sub-districts in Chon Buri province

5 Conclusion and Outlook

Agricultural areas in Thailand are affected by climate change and natural disasters. This paper compliments previous work by using a composite index approach for understanding the risk of climate change and natural disasters to agricultural areas. The Agricultural Risk Index was proposed as an alternative method for assessing the risk of agricultural areas related to climatic variability, natural disasters, and insufficient water supply. Most areas of the province showed low to medium ARI values, while high ARI values were present in four sub-districts. The ARI value varies according to water sufficiency, agricultural areas, and distance from water resources. Additionally, the ARI approach could be tested at the sub-district level in order to compare the risk among sub-districts within a district. The ARI can be used for decision makers or government authorities to evaluate these high-risk areas, and set up a plan for mitigating and monitoring agricultural areas in the future.

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