

Rice Security Assessment Using Geo-Spatial Analysis

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Abstract

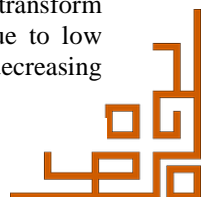
Rice is one of the most important food to half world's population. The agricultural administrative officer has strategies to change rice into other crops, while rice production was significantly decreased. This study aimed on identifying paddy rice field based on phenology in Landsat 5 of 2009 and Sentinel-2 images in 2017 and assessing rice security using spatial analysis techniques. Object-Based Image Analysis (OBIA) and hierarchy classification methods were applied to identify field by Normalize Different Vegetation Index (NDVI). Suitability area of rice growth with Analytic Hierarchy Process (AHP) statistical model was overlaid by soil properties, meteorology, distance from the water and road factors. The suitable areas and rice field were used to estimate production. Rice security was evaluated using rice yield and rice consumption. Rice maps were overall accuracy of 90 and 96%, kappa accuracy of 0.81 with 0.92. The spatial and spectral information of Sentinel-2 were better to demonstrate field objects than using Landsat 5 data and phenology feature of rice based on NDVI which were highly efficient to extract the field. The factors had higher weight of soil drainage, average rainfall and soil pH respectively, and higher rice growth area showed moderately more suitable than other classes. Yield estimation illustrated less percent of error, and this approach was agreed with physical properties in large area to define levels of rice growth. Rice security was the most stable in Kosum Phisai and Borabu districts in 2009 and 2017, and there was high quality of soil and water resources located in highly and moderately suitable for rice growing in current. The related agencies can apply the results to manage and plan rice cultivation.

1. Introduction

Rice is one of the most important crops and the mainly consumed food for half of the world's population which needs sufficiency of nutrients for healthy life (FAO, 2016, Milovanovic and Smutka, 2017). In Asia region, rice is produced and consumed over 90 percent. It is the stable food to drive quality of life and economic growth (FAO, 1994, FAO, 2011 and Abdullah et al., 2006). Recently, rice production in Asia has been increasing, together with its consumption, especially in Thailand that the people have been consuming rice production as stable food (United States Department of Agriculture, 2018 and Statistics, 2018). From 2015 to 2017, rice production contained 15,800 19,200 and 20,370 thousand metric tons. With this, population growth and urbanization were major causes to transform rice consumption to rice insecurity. It led people to have poor quality of life. Thailand's government has created strategies from one to twenty plants to develop agricultural technologies to improve the quality of life by

increasing the rice production (Office of The National Economic and Social Development Board, 2015).

According to National Statistical Office (2012) observed diet situation of females and children. The number of people in northeastern Thailand was more insufficient in nutrient than the other regions 18.9 percent causing to poor quality of life (Thai Health Promotion Foundation, 2014). Maha Sarakham province located in northeast of Thailand has topography as flat surface, weather, and soil characteristics which can be a suitable place for rice plantation (Jarvis et al., 2008 and Som-ard et al., 2018). Most people in the province were farmers, 96.26 percent, they planted the important crops such as rice, cassava, and sugarcane (Choenkhwat et al., 2014). Especially rice plantation, it is a main agriculture that most farmers consume and export. However, the government has encouraged farmers to transform paddy rice field into other plantations due to low price's situation. It has been significantly decreasing



in numbers of rice area. The report of statistical rice plantation of Office of Agricultural Economics (2017) represented the number of cultivation area from 2015-2016 as 3,353.97 and 3,434.14 square kilometers. Since, the number of population was rapidly growing and the rate of people consuming rice food was increasing. The disasters, including flood and drought, also occurred in agricultural cultivation in every year (Laosuwan et al., 2015). They obviously affected on insufficiency. The evaluated rice security is most required to help farmer in the world for planning and marketing decision.

In previous researches conducted by Yang et al., (2011), Moriondo et al., (2007) and Jin et al., (2016), they classified the crop areas using high resolution image and defined spectral value and environmental vegetation index (EVI) to extract the crop plantations. The accuracy was dependent on input image data that distorted the pixel values on atmosphere under their observation. The crop identification used OBIA with decision tree (DT) approaches, and NDVI to define the main group of crops. These methods were built by interpretable rules based on phenology properties of the crops study (Peña-Barragán et al., (2011), Singha et al., (2016), Immitzer et al., (2015) and Ferrant et al., (2017) applied Sentinel-2 images with new satellite data and high resolution (R, G, B, NIR; 10x10 meters: m) to classify crop areas by OBIA techniques, including Large Scale Mean Shift (LSMS); Multiresolution segmentation; Gray-Level Co-Occurrence Matrix (GLCM) and supervised object-based classification. The methods are highly potential and accurate for crop mapping. Moreover, analyzed rice growth developed by GIS model with influence factors, including soil properties, meteorology, and topography. The model was practiced by overlaying analysis to find out rice suitable area for growth (Choenkhwat et al., 2014 and Vanwambeke et al., 2007). In this case, the levels of rice growth were related to the production as well. Thus, the model became one of the conditions for predicting rice yield.

Rice yield forecast was developed by Jitrawet and Keomuangmoon (2017) using DSS-SRY4cast and CSM-CERES-Rice models for estimation.

It needed many input factors to be in the process such as soil characteristic, topography, weather, society,

economic, and maintenance. Because of its needs the data was insufficient to process the model and it required such a long time to provide the result (Keating et al., 2003). Many models were applied with remote sensing methods for an early prediction.

However, these approaches required several input factors (Som-ard et al., 2018). Many researches, based on remote sensing methods, used spectral value and NDVI index of MODIS and NOAA images with the correlation coefficients and a regression analysis to predict rice yield (Son et al., 2014 and Huang et al., 2013). Shen et al., (2009) integrated multi-temporal and multi-polarization ENVISAT ASAR data with the SCE-UA optimization algorithm to estimate yield. SPOT data were high resolution image which were generated for rice prediction of crop's models (Noureldin et al., 2013). In many cases, on the resolutions (spectral, spatial, radiometric, and temporal) were so limited that satellite images had to allow timely collection for information on the growth and development stages of the rice crop (Mosleh et al., 2015). The important issue was efficiency of physical properties in the place that were nutrient to grow rice crop and these combined spatial factors in GIS model and paddy rice field to extract satellite images. The approaches were conducted to predict rice yield (Kihoro et al., 2013 and Singha et al., 2016). Rice production with the number of consumption were very necessary to analyze security situation, based on accessibility of food.

This study was to identify paddy rice field area in season in 2009 and 2017 and evaluate rice security using spatial analysis. Landsat 5 and Sentinel-2 images were classified by OBIA with hierarchy classification approaches. Rice phenology, applying NDVI index, was defined to extract the rice field objects. The suitability areas practiced according to influence factors which include soil, meteorology, topography, slope, distance from the road, and distance from the water. Thematic maps and suitable area were conducted to estimate yield. The demand of consumption and production were required to evaluate the security. Rice field maps, suitability areas, and rice security per each district were presented, and these could assist to plan and manage agricultural plantation and food stocks as well.

This research selected a study area in Maha Sarakham province located in Northeast of Thailand, the boundary from south to north to between 15° 24'

2. Materials and Methods

2.1 Study Area



13° to 16° 38' 35" N and west to east between 102° 50' 47" to 103° 30' 27" E. The weather, meteorology, topography, soil properties, and slope in this province are the highest suitability to plant agriculture such as rice, sugarcane, and cassava, particularly rice plantation in season that has been a popular agriculture since from the past to recent (Som-ard et al., 2018, Kunlanit, 2017 and Kheoruenromne et al., 1998). Most of the people plant rice over 89.19 percent of agricultural areas and mainly consume rice food (Office of Maha Sarakham Province, 2012). Moreover, in the southern part of the province is located in Thung Kula Ronghai which is very famous for the highest potential of rice plantation (Lin et al., 2013) (Figure 1).

2.2 Data

According to Office of Agricultural Economics (2017), that in 2009 rice production was very staple

and stable to consumption and export. While in 2017, the production was rapidly decrease due to government policies, low rice price's situation, reduced labor, and agricultural management. This study used Landsat 5 and Sentinel-2 satellite images that observed the study area on 9th November, 2009 and 31st October, 2017. During the date of data collection, rice phenology in season was in dough stage. This stage was very appropriate to extract rice field using spectral reflection of satellite images (Singha et al, 2016, Soontranon et al, 2014 and Office of Agricultural Economics, 2017). The soil characteristics (soil texture, soil pH, soil drainage, soil depth), meteorology (average temperature, average rainfall, and average moisture from 2009-2017), slope, distance from the road, and distance from the water were collected to analyze suitable area for rice growth (Table 1).

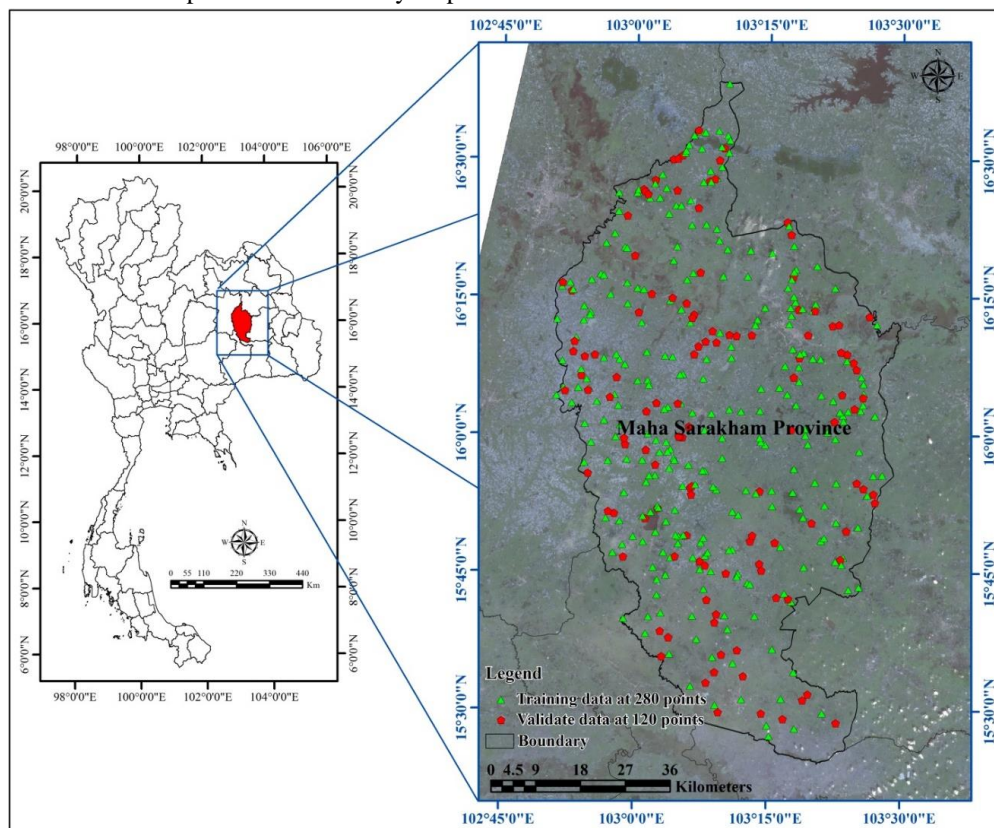
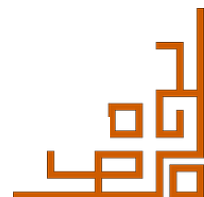


Figure 1: Study area (Left shown location in Thailand map and Right shown study area on a RGB Landsat 8 image observed in October 2017)

Table 1: The detail of data used



Data	Type of data	Explanation	Data sources
1. Satellite data - Landsat 5 image - Sentinel-2 image	Raster	Landsat 5 and Sentinel-2 images are spatial resolution as 30x30m and 10x10m (R, G, B, and NIR), used to extract paddy rice field.	- 2009, U.S. Geological Survey (USGS); https://earthexplorer.usgs.gov/ - 2017, European Space Agency (ESA); https://scihub.copernicus.eu/dhus/#/home/
2. Slope	Raster	Spatial resolution 30x30m; used to analyze suitable area for rice growth.	- 2011, NASA/JPL-Caltech/National Geospatial Intelligence Agency; http://www2.jpl.nasa.gov/srtm/ .
3. Soil characteristics - Soil texture, soil pH, soil drainage, and soil depth	Vector	Generated suitable area.	- 2009, Land Development Department.
4. Meteorology - Temperature, rainfall, and moisture	Vector	The average of data from 2009-2017, used to conduct suitable area.	- 2009-2017, Thai Meteorological Department.
5. Road	Vector	Used to analyze suitable area.	- 2013, Ministry of Transport.
6. Water	Vector	Analyze suitable area.	- 2015, Land Development Department.
7. Study area	Vector	Boundary of study areas	- 2015, Ministry of Interior.
8. Population data	Document	Population from 2009-2017, used to evaluate rice security.	- 2017, National Statistical Office.
9. Harvested rice yield	Document	Assessed rice yield from estimation technique.	- Ground survey in 3-10 November 2017.

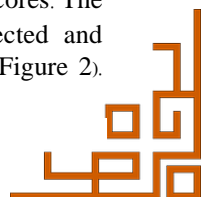
The demand of people's consumption in the study area was received and collected according to their age. validation and training data for OBIA classification were obtained from ground truth data. (Pimple et al., 2017 and Immitzer et al., 2015). The training and validation samples were applied stratified random sampling method and performed in QGIS to design the number of sampling points (Hay, 1979 and Fitzpatrick-Lins, 1981). This study defined 400 total of sampling data and two classes which included 254 for non-rice and 146 for rice. For ground data, included 280 points for training data and 120 points for validation. Those were sufficient to cover the study area. The harvested yield was collected from sampling plots of 120 points including 30 points per each class of suitable area for rice growth, it was also used to estimate yield in large area.

2.3 Data Pre-Processing

Sentinel-2 image was practiced to pre-processing by atmospheric correction in the Sen2Cor tool in SNAP software. The result presented real reflected objects on ground of pixel values as the improvement of the quality image. The geometric correction was not used because of a high containment (Padró et al., 2017 and Louis et al., 2016). The Landsat 5 image corrected

digital number (DN) radiance to top of atmosphere (TOA) by using algorithm, followed by Chander and Markham (2003). Moreover, FLAASH model was conducted to correct surface reflectance by physics-base which was measured by atmosphere characteristics such as topography, surface albedo, water vapor, cloud depth, moisture, atmosphere temperature and sun light (Noureldin et al., 2013). All approaches provided very good output data to identify rice field as well.

GIS data include the soil characteristic (soil texture, soil pH, soil drainage, soil depth), meteorology (average temperature, rainfall, and moisture from 2009-2017), slope, distance from the water, and distance from the road that was collected and prepared to analyze suitable areas for rice growth. These data were defined the map to georeferenced coordination at WGS 1984 zone 48N. The data created raster grids as 30x30m. A factor had different rate of influences to grow rice and all factors in this study created the rates by defining scores in attributes (Table 2). Table 2 presented range and score of all factors to analyze efficiency on rice growth and the factors were designed per each level as scores. The criteria levels of each factor were collected and generated as shown in the criteria maps (Figure 2).



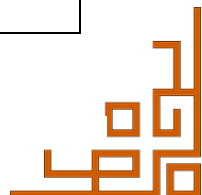
Normally, before analyzing suitable area, the researcher has to assign the weight to all factors. This research used the Analytic Hierarchy Process (AHP). It is a multi-criteria decision to make an approach, represented by Saaty (1977, 1994), and to create the weights. Several researches have used the approach to be carried as the weight; due to, the effective mathematical properties of the method (Triantaphyllou and Mann, 1995). This study, the AHP processes includes as followed; 1) ten experts: five agricultural educators, four physical geographers, and a geographer; they were interviewed and collected information 2) interview data and a pairwise comparison matrix were applied 3) weights, defined by normalized pairwise comparison matrix which were taken by dividing the column components of matrix by sum of each column. The row components

in taken matrix were summed. The total value was divided by the number of components in the row. The weights were in scale range 0-1, and sum equal to 1 (Malczewski, 1999 and Akıncı et al., 2013). 4) conducting criteria in AHP approach; a certain level of inconsistency might happen. Consequently, the consistency of pairwise comparisons had to be checked. To clarify more, the consistency ratio created by Saaty (1980) was also used.

The consistency ratio was calculated from the pairwise comparison matrix. This ratio is below or equal to 0.10, it was sufficient degree to continue for analyzing suitable rice growth (Akıncı et al., 2013). Population data (2009 and 2017) were collected from National Statistical Office (2017) and the data used to measure the consumption per year.

Table 2: Ranging and scores of the criteria maps

Factor	Range	Score	Sources
Soil texture	Loam (L), clay loam (CL), clay (C)	4	FAO, 1993, Zolekar and Bhagat, 2015, Akıncı et al., 2013
	Silt loam clay (SLC), silt clay (SC)	3	
	Silt loam (SL), loam silt (LS)	2	
	Silt (S)	1	
Soil depth	High	3	FAO, 1993, Zolekar and Bhagat, 2015, Akıncı et al., 2013
	Medium	2	
	Low to light-brown stone	1	
Soil drainage	Poorly drained	3	FAO, 1993, Zolekar and Bhagat, 2015, Akıncı et al., 2013
	Poor to moderately drained	2	
	Moderate to well drained	1	
Soil pH	7-6	3	FAO, 1993, Zolekar and Bhagat, 2015, Akıncı et al., 2013
	5-6, 7-8	2	
	4.5-5, 8-8.5	1	
Slope (%)	< 8	4	FAO, 1993, Kihoro et al., 2013, Akıncı et al., 2013
	8-15	3	
	16-30	2	
	> 30	1	
Average rainfall (mm)	1453.37-1663.12	2	FAO, 1993, Kihoro et al., 2013, Zolekar and Bhagat, 2015
	1243.60-1453.36	1	
Average moisture (%)	81.35-92.84	2	FAO, 1993, Kihoro et al., 2013, Zolekar and Bhagat, 2015
	69.84-81.34	1	
Average temperature (°C)	30.05-32.33	2	FAO, 1993, Kihoro et al., 2013, Zolekar and Bhagat, 2015
	28.76-30.04	1	
Distance from the water (m)	< 1,500	4	FAO, 1993, Kihoro et al., 2013
	1,500-3,000	3	
	3,001-4,500	2	
	> 4,500	1	
Distance from the road (m)	< 300	4	Kihoro et al., 2013, Ground survey
	300-600	3	
	601-900	2	
	> 900	1	



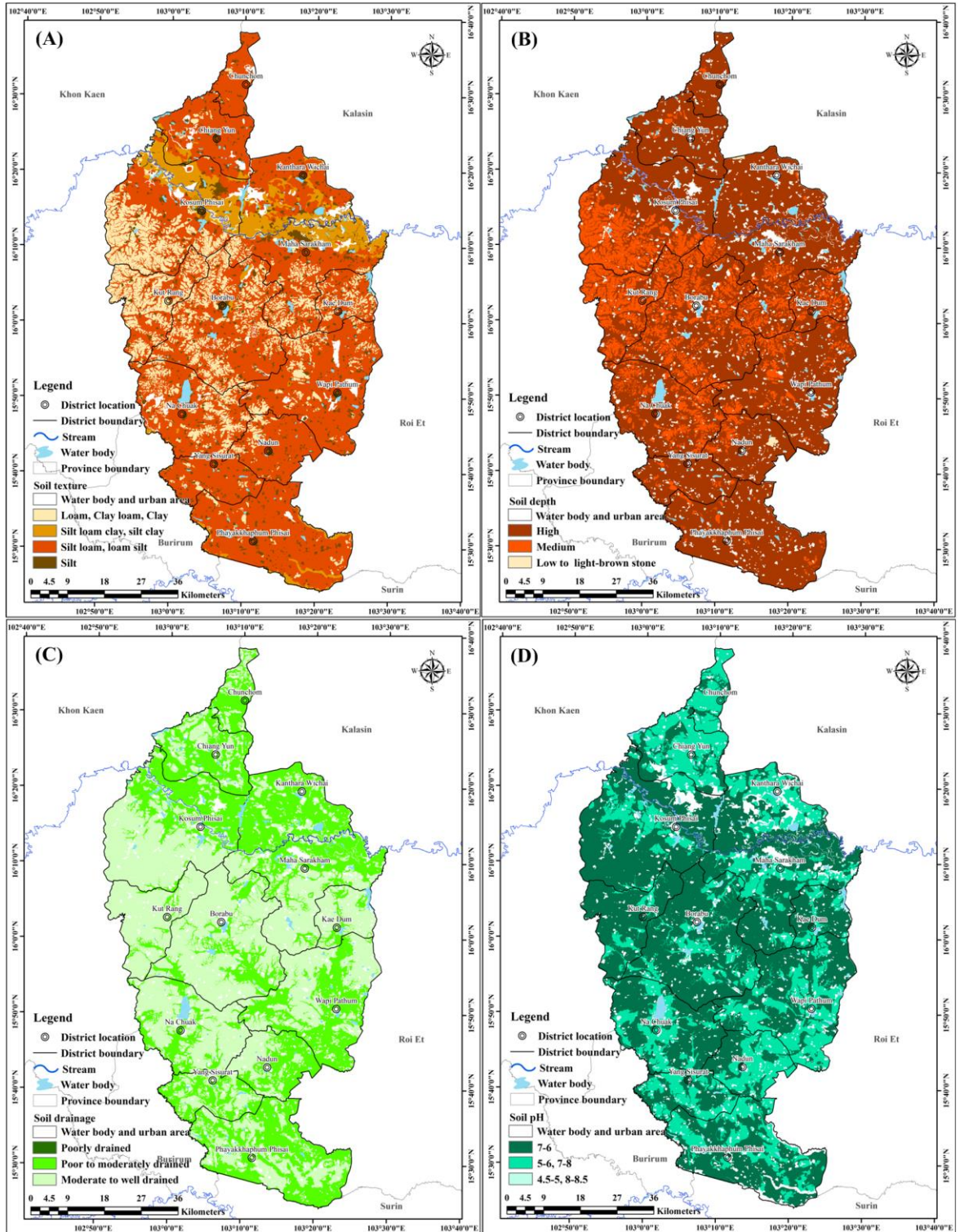
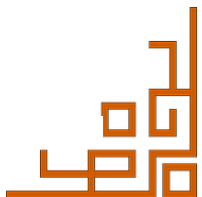


Figure 2: Criteria maps (continue next page)



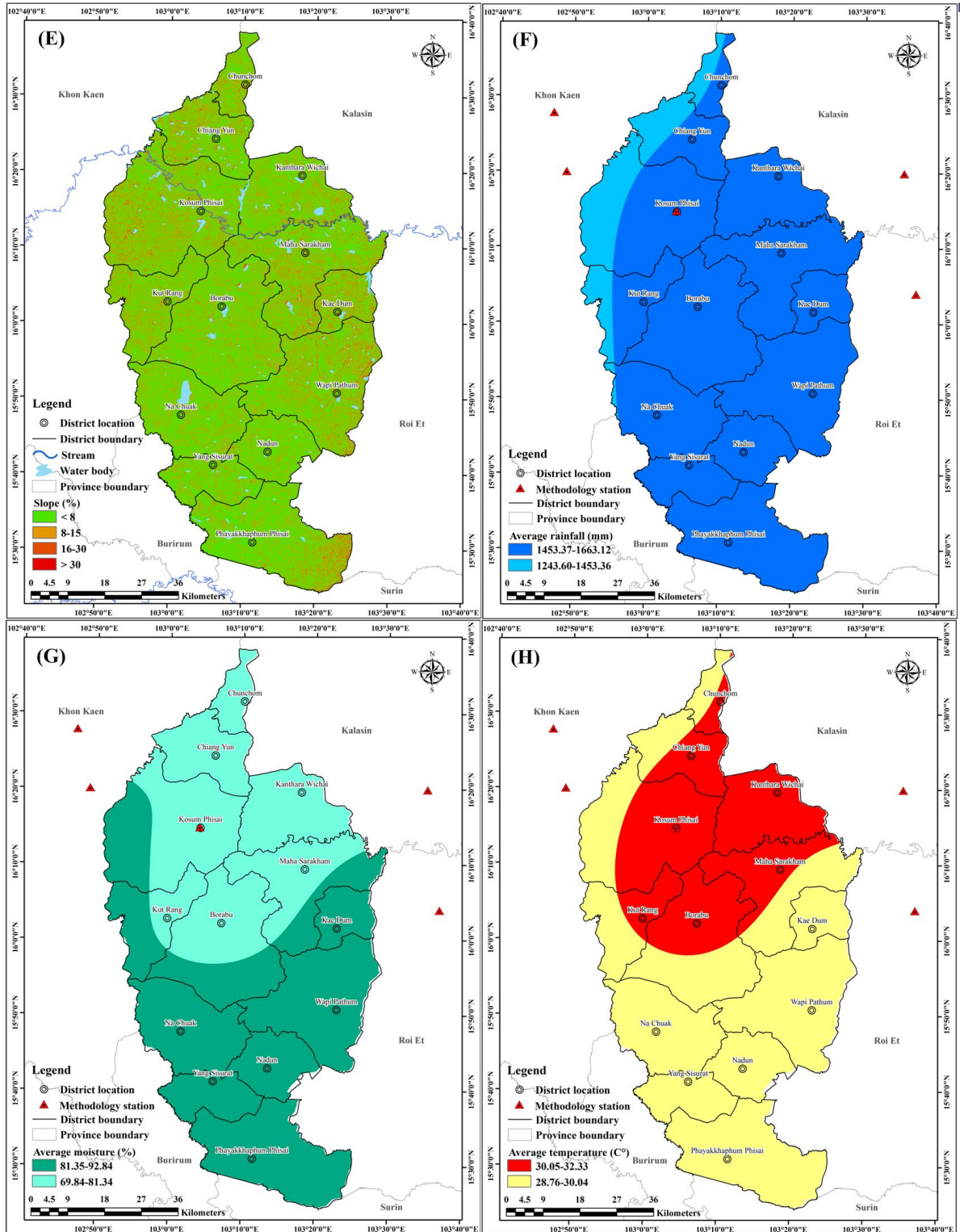
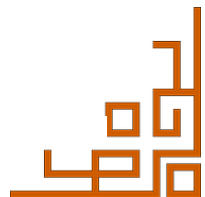
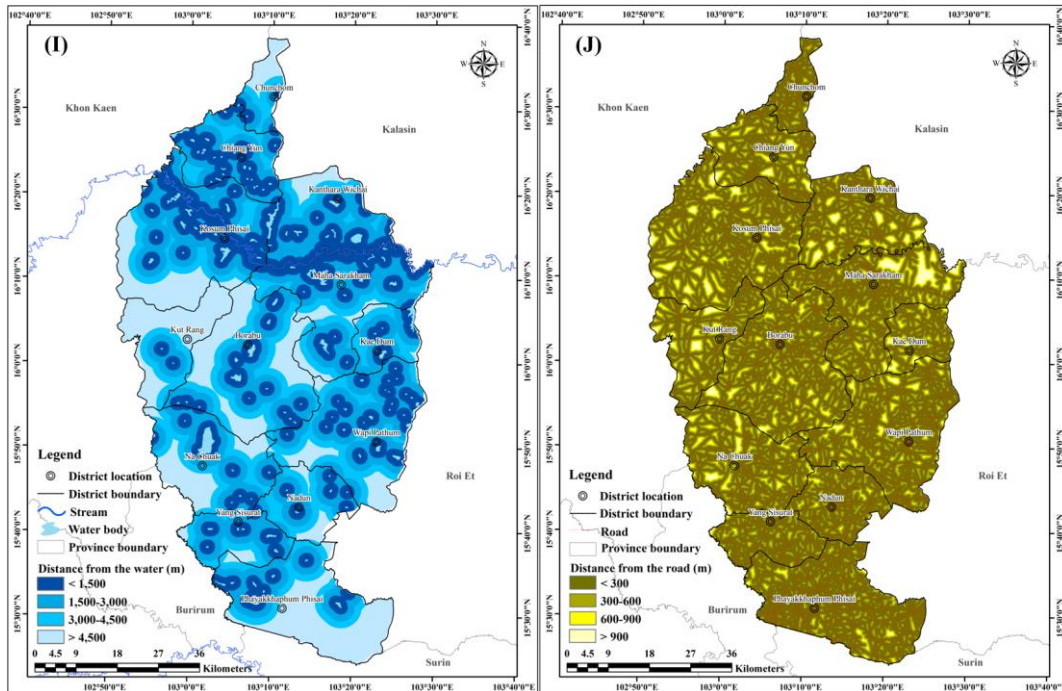


Figure 2: Criteria maps (continue next page)





(A) Soil texture, (B) Soil depth, (C) Soil drainage, (D) Soil pH, (E) Slope (%), (F) Average rainfall (mm), (G) Average moisture (%), (H) Average temperature ($^{\circ}$ C), (I) Distance from the water (m), (J) Distance from the road (m)

Figure 2: Criteria maps

The study was separated by ages of population based on sufficiency in nutrient of growth which was proposed by FAO, (2002) and Committee on the Synthesis of Food Knowledge and Nutrition for Consumers, (2015). The ages of population were between the ranges from 0-4, 5-12, 13-25, 26-60, to over 60 years respectively.

2.4 Paddy Rice Field Identification

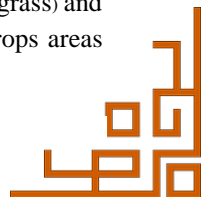
2.4.1 Image segmentation

Image segmentation was applied to divide different objects into image by using spectral, spatial, and textural information. This method generated the pixels into same homogeneity based on statistical approach and the information as image properties. This study used Multiresolution segmentation approach to perform Landsat 5 and Sentinel-2 images after correcting pre-processing. The method defined the best rule parameters (Scale, Shape, and Compactness) in consideration to divide similar regions (Singha, 2016 and Som-ard et al., 2018). The image data created regions based on image properties (spectral, spatial, textural information) of R, G, B and NIR bands, and there were defined best-rules, including 10, 0.28 and 0.32 of Landsat 5. While,

Sentinel-2 was best-rule of 12, 0.22 and 0.37. To evaluate suitable rules of segmentation, ground truth data was required to validate and interpret assessment. The results segmented objects to match with the real rice field sizes (Figure 3).

2.4.2 OBIA classification

OBIA is an approach of object-based classified into homogenous areas by image properties. This method is the most potential with high resolution image to provide stable accuracy (Blaschke, 2010). The OBIA method in this study, top to down concept with hierarchical classification was processed to identify rice field by using mean NDVI value based on rice phenological variable. NDVI index was calculated and generated in each object, and mean value per each object was classified for rice field. The classes (rice and non-rice) were considered based on membership function for merging decision in same homogenous (Singha, 2016 and Som-ard et al., 2018). This research was assigned mean NDVI value of Landsat 5 which had 0.26-0.42 of rice canopy area. Less than 0.26 (soil, water, bare land and grass) and more than 0.42 were no rice area (other crops areas and forest).



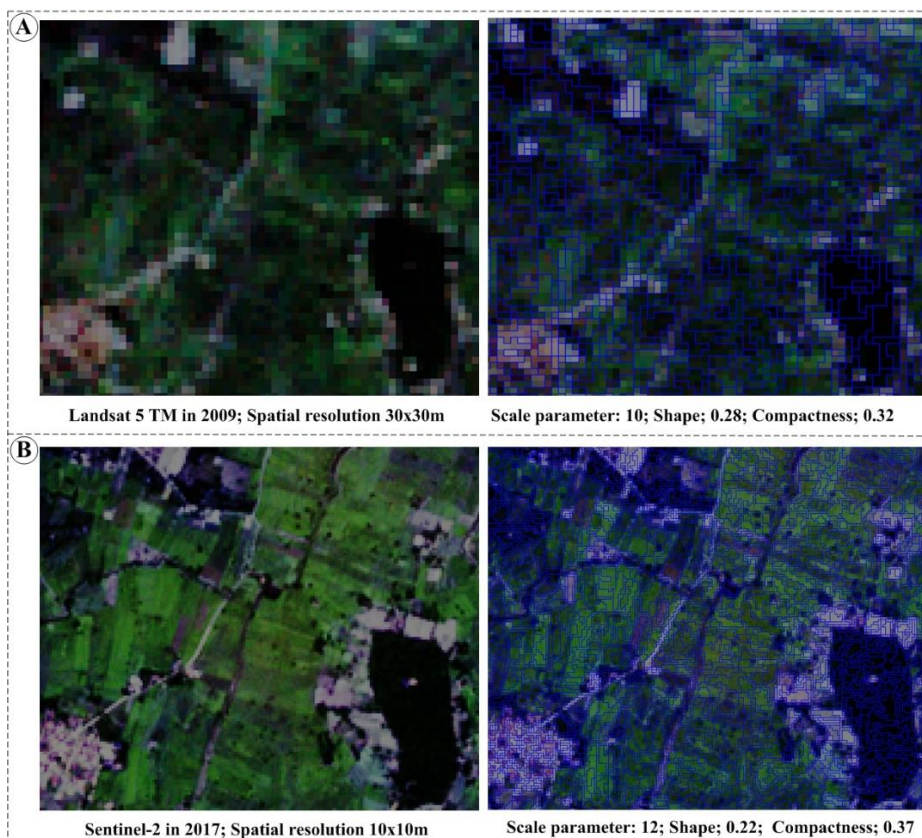


Figure 3: Image segmentation of both data, (A) segmented object of Landsat 5; (B) Sentinel-2 data

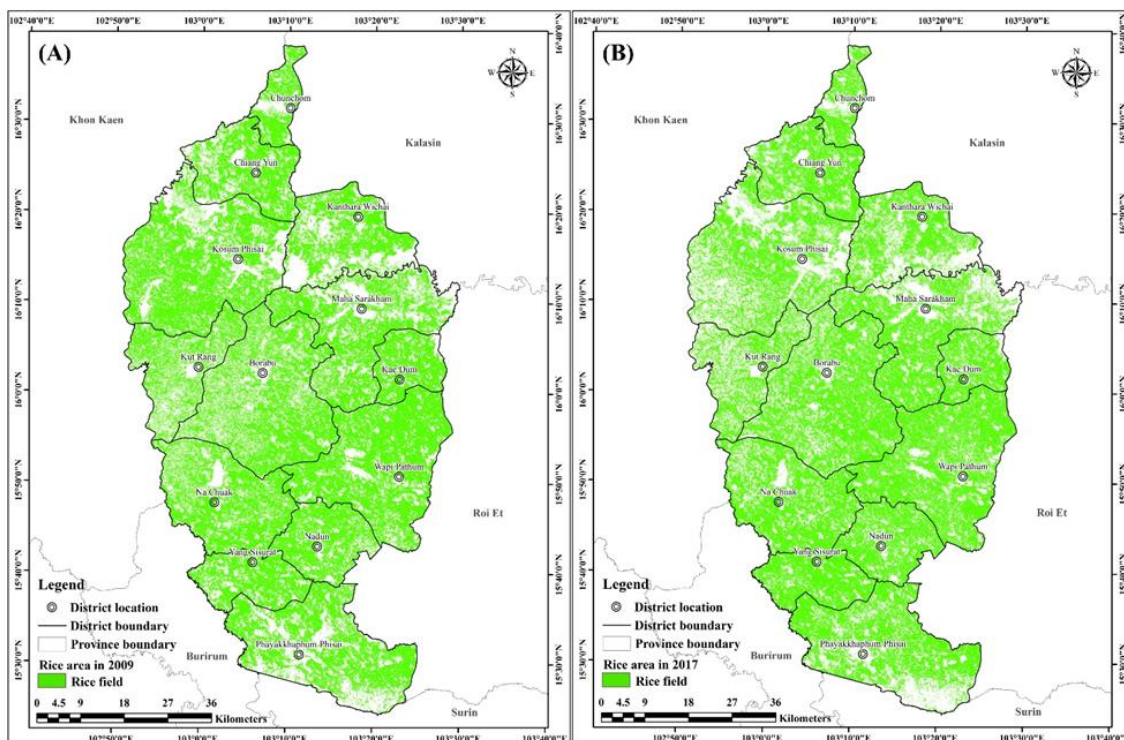
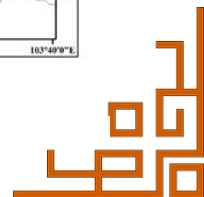


Figure 4: Rice map in 2009 (A) and 2017 (B)



While, Sentinel-2 was defined mean value as 0.39-0.59 of rice areas. Less than 0.39 and more than 0.59 were no rice area.

2.4.3 Accuracy assessment

To validate the accuracy of thematic map, confusion matrix and kappa coefficient values were conducted (Congalton and Green, 2008). The maps were compared assesses with ground truth data from collected field survey in 3rd-10th November 2017. Regions from segmentation were taken to set the sampling units, and this method helped to validate accuracy of classification and potential segmentation. The image objects selected 100 samplings to assess the suitable segmentation using ground data. (Fitzpatrick-Lins, 1981, Vieira, et al., 2012 and Singha et al., 2016). This study validates data from field survey which were 120 points (76 of non-rice field; 44 of rice field classes). They were randomly collected to be accurately assess by confusion matrix (Katherine, 1981). These sampling locations were sufficient data and covered study area to validate the accuracy. Moreover, rice area was conducted to analyze agricultural statistic information. The results of accuracy and rice area statistic were detected to check acceptance of rice map results.

2.5 Evaluation of Rice Security

2.5.1 The suitable area for rice growth

The suitable area analysis is basically statistic model to overlay several factors with weight from the multi-criteria decision. The factors and data from field survey were generated to represent result. This research was conducted to cover all factors which defined scores and was multiplied by weights of AHP as Equation 1 (Kihoro et al., 2013).

$$MQ = \sum_{i=1}^n W_i * C_i$$

Equation 1

Where; MQ=overall sum index, Wi=weight, CiS=core per each factor, n=number of factors. The result identified different suitability using value of overall sum index model. In this study, the level of suitable area for rice growth was generated without four classes, based on mean and standard deviation (S.D.) (Lee and David, 2001). The result showed levels of rice growth that were used to estimate rice yield.

2.5.2 Rice yield estimation

The rice yield estimation has many techniques such as DSS-SRY4cast model, regression analysis, spectral monitoring, and SCE-UA approach for SAR (Son et al., 2014, Huang et al., 2013 and Mosleh et al., 2015) and these are some limitations of yield perdition. This study, rice yield estimation, had many constraints due to poor spectral value, different physical properties in large area, and accessibility of the water sources (Kheoruenromne et al., 1998 and Lin et al., 2013). With this, the research performed yield estimation from suitable area for rice growth, rice field map and actual yield per sampling plot (40x40m). Basic statistics, including percent error, mean, mean deviation and standard deviation, were calculated to measure with harvested yield. The prediction was conducted as Equation 2.

$$Y_e = S_a \times R_f \times Y_a$$

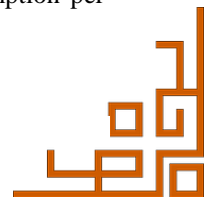
Equation 2

Where; Ye=yield estimation, Sa=suitable area, Rf=rice field area, Ya=harvested yield per plot sampling. Moreover, rice map and suitable area are very important to identify the levels of rice growth. This study was generated by overlay approach and the map which included four classes for spatial information to farmers choosing cropping pattern (Kihoro et al., 2013).

2.5.3 Evaluated rice security

Food security is the sufficient nutrient of consumption in long term (Sen, 1981). For food security analysis, FAO (2002) defined four dimensions, including availability, access, utilization and stability. These are very important tools. Also, several evens have been used to predict food sufficiency through population growth as well (Ingram, 2011 and Garcia and Rosenberg, 2010). The population in each age needs to obtain nutrient in capabilities for growth (FAO, 2002 and Committee on the Synthesis of Food Knowledge and Nutrition for Consumers, 2015). This study focused on access rice production because rice is main food for nutrient of the most people in Maha Sarakham province (Office of Maha Sarakham Province, 2012). This method focused on physical, economic and social access. These were required the production from yield estimation with population to analyze rice security (Equation 3). The study presented percent of rice food security and demand of consumption per each district in 2009 and 2017.

$$R_s = R_y - C_p$$



Equation 3

Where; Rs=rice security, Ry=rice yield by estimation, Cp=consumption per year. In this research, the rice security was measured using spatial analysis, including estimated rice yield (Ry) and total consumption per year (Cp). Cp is the all consumption of local people in Maha Sarakham that needs nutrient in capacities. It calculated from number of population in each age. The result shown rice production in stock (tones) as security that the local people can access and consume in a year. The percent of rice's stock was created to compare quantity of rice security in 2009 and 2017.

3. Results and Discussions

3.1 Identified Rice Field Using OBIA Approach

The phenological variables of rice were also used to extract the field pattern. The dough stage was most suitable time to classify rice field in season (Singha et al., 2016). Landsat 5 and Sentinel-2 images in study area during October to November were also used (Soontranon et al., 2014 and Office of Agricultural Economics, 2017). OBIA and hierarchy approaches were performed to segment and classify the regions of rice field using NDVI value, based on rice phenology. The phenological variables as mean NDVI value per object were required. If it is less than 0 that means water surface and soil moisture. The mean NDVI value is closed to 0 which is soil, bare land, and grass. If it is medium from 0 and 1 that is rice extent, based on phenology as efficiency of green intensity per pixel. The mean value of cassava and sugarcane objects are the same as rice phenology, but surrounds cassava and sugarcane objects are more different in green intensity. In addition, divided rice field without cassava and sugarcane objects were merged or edited using visual interpretation method. These were obviously separated objects. The highest

mean value with large boundary was forest and tree areas because these were high green intensity. This study used ground data as a referent set to validate with rice maps. Moreover, accuracy of identified paddy rice field map was calculated as well (Table 3).

The results of OBIA classification for rice plantation were presented in Table 3. The overall accuracy was 90 and 96% of thematic maps in 2009 and 2017. A rice map using Sentinel-2 was slightly high, it was more overall accuracy than Landsat 5 because of different spatial resolutions of Landsat 5 and Sentinel-2 (30x30m with 10x10m of spatial resolution). The pixel size of Sentinel-2 was good enough to segment the real plantation at about 16-36 pixels of areas. The OBIA approach was absolutely potential classification with high resolution image (Blaschke, 2010). This approach was very good to segment and identify the rice field using NDVI, spectral, and texture information. Landsat 5 image with OBIA method showed quite sufficiency for identifying rice field areas but the classification took long time to find the best result (Singha et al., 2016). The ground data, including rice crop pattern, plantation size and land use were used to refer for identifying rice crop areas (Figure 4). The rice extent, identified in 2009, showed the total areas as 3,566.36 Sq.km and 3,516.85 Sq.km in 2017. The result of rice areas in Maha Sarakham province was higher in number of rice area in 2009 than 2017 as Figure 4. To compare plantation, rice areas in 2009 were more than 2017 because the government supported farmers to change rice cultivation in unsuitable areas to plant other crops (Office of Agricultural Economics, 2017).

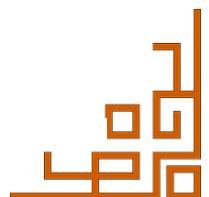
3.2 Rice Security Mapping

3.2.1 Suitability analysis for rice growth

The efficiency factors of rice growth were calculated to find the weight by using ten experts and AHP approach.

Table 3: Statistical measures for rice identification in 2009 and 2017

Data used	Classes	Overall accuracy (%)	Producer accuracy (%)	User accuracy (%)	Kappa
Landsat 5 TM image in 2009	Rice	90	100	78.85	0.81
	No rice		85.89	100	
Sentinel-2 image in 2017	Rice	96	100	89.58	0.92
	No rice		93.50	100	



The result showed the important weights, including soil drainage (0.38), average rainfall (0.37), soil pH (0.33), distance from the water (0.26), average moisture (0.25), soil texture (0.16), slope (0.09), soil depth (0.07), average temperature (0.07), and distance from the road (0.04). Soil drainage was higher valuable than the other factors because it can take the water from rain off to underground for nutrient of rice.

The suitability map for rice growth was conducted by applying overlay analysis method to calculate the factors and criteria weight. This study included four classes to divide suitable area of rice growing plantation (Figure 5). Suitability map contained the total area of 55,134.57 sq.km and the number of area (Sq.km) was available for rice in each suitable class as follows: highly suitable (S1), 13,888.90 sq.km, moderately suitable (S2) 31,264.26 sq.km, marginally suitable (S3) 9,100.69 sq.km and not suitable (S4) 880.71 sq.km. They illustrated 25.19, 56.71, 16.51 and 1.60% of land area respectively. S1 presented rice growing areas in current and the S1 areas were located in the factors of land by; soil drainage of poorly drained, average rainfall about 1450-1570 mm, soil pH of 7-6, distance from the water as < 1,500 m, average moisture about 82-92%, soil texture of L CL C, slope in < 8%, soil depth as high, average temperature about 30-32°C and distance from the road as < 300 m. S1 areas were closed long Chi river, and those areas were poorly drained of soil. These located sub around Chi river, and the soil characteristics were necessary of nutrient for rice growth (Bureau of Soil Survey and Land Use Planning, 2007). S4 part was found at moderate to well drained of soil and soil texture with pH were silt and 4.5-5 or 8-8.5. The waste of Maha Sarakham was likely S4 that rice crop was very deficiency. Also, referred to soil survey of Land Development Department (2007), it shown and mentioned the higher suitable areas located in soil drainage of poorly drained, texture of L CL C, depth as high, and slope in less than 10%. This reason seems like a suitable map of this study in Figure 5.

3.2.2 Rice yield estimation

The harvested rice production was collected using 120 sampling plots (40 x 40 m) from ground survey. Each class of rice growing (Figure 5) was performed 30 plots for collecting production. To be more confident, the harvested yield and levels of suitability were calculated by correlation (R) and shown as 0.87. The correlation was very good to estimate yield in Maha Sarakham province. Actual rice production was collected from Office of Agricultural Economics (2017) which had 582,209 and 754,092 tones, while yield estimation was 554,564.26 and 736,320.73 tones in 2009 and 2017. The statistical analysis was measured for rice yield estimation (Table 4).

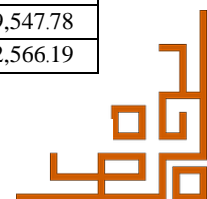
3.2.3 Evaluated rice security

The consumption per age and yield production were applied to evaluate the sufficiency of rice food per year. The capacity of people consumed rice food had to be determined. The rule to evaluate food security of FAO (2002) was defined to analyze rice security in this study. The percent of rice stock's production per year was predicted to demand for consumption in Maha Sarakham province (Table 5). The rice growth area in 2009 was high (25.27%), moderate (56.71%), marginal (16.44%) and not growth area (1.58%). In 2017, the rice growth area had 26.50%, 60.26%, 12.46% and 0.78% respectively.

Levels of rice growth in 2009 and 2017 were highest in moderate class, and the rice map in 2017 (Figure 6A) shown high rice growth at closed to long Chi river and highly clustering in Wapi Pathum and Yang Sisurat district. The ground information and spatial data were collected and analyzed the levels of rice growth as well (Kihoro et al., 2013). The percent of rice security in 2009 as shown in the Table 5 was highly stable in Kosum Phisai, Borabu, Wapi Pathum, Na Chuak, Kut Rang, Phayakkhaphum Phisai and Muang Mahasarakham district, which were 18.04, 14.41, 10.29, 9.98, 9.71, 8.57 and 7.44%, respectively.

Table 4. Statistical analysis for rice yield estimation (unit: tones)

Years	Yield (ton) estimation	Harvested(ton) yield	Percent error	Mean	Mean deviation	Percent of Mean deviation	Standard deviation
2009	554,564.26	582,209.00	4.75	568,386.60	6,911.19	1.22	19,547.78
2017	736,320.73	754,092.00	2.36	745,206.40	4,442.82	0.60	12,566.19



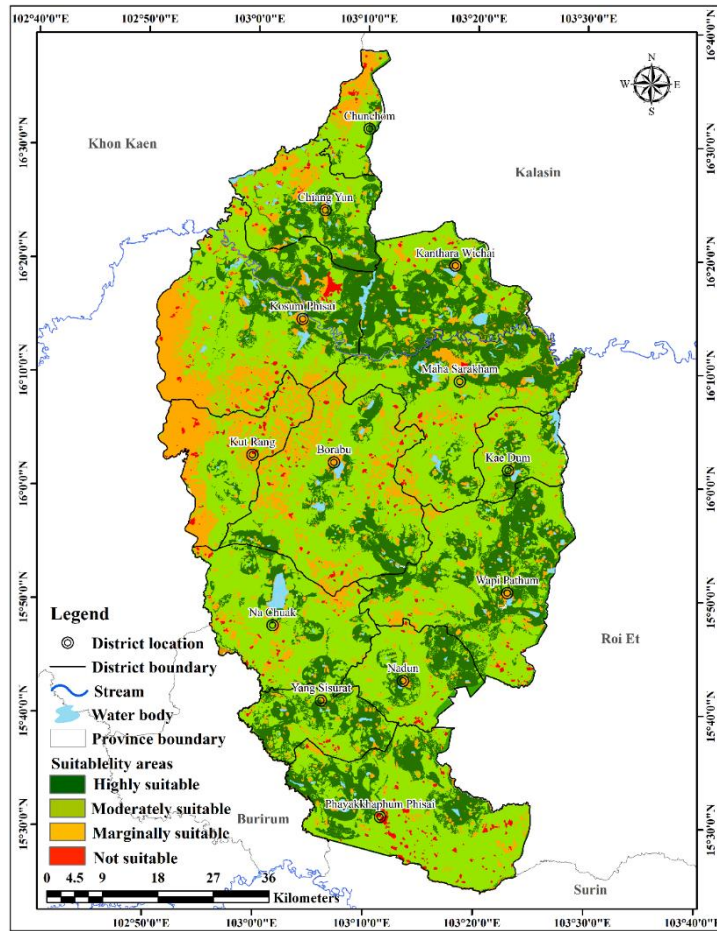


Figure 5: Suitability map of rice growing

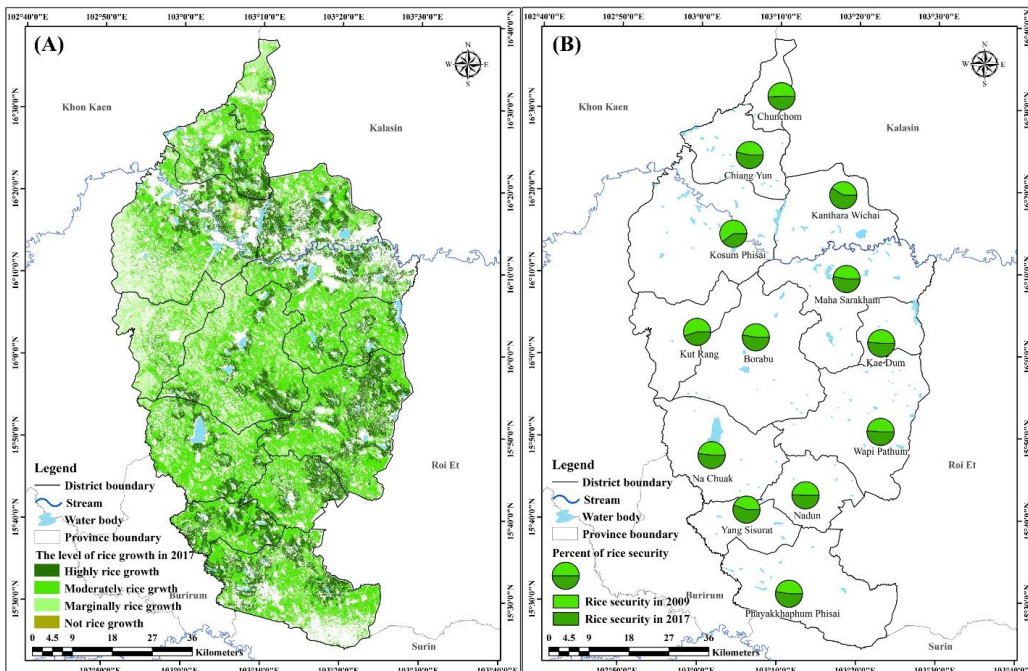


Figure 6: Present rice growing (A) and percent of rice security in 2009 and 2017 (B)

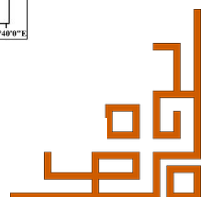


Table 5: Percent of rice security in 2009 and 2017

District	2009				2017			
	Rice consumption per year (tonnes)	Rice production (tonnes)	Production in stocks per year (tonnes)	Percent of security (%)	Capital rice consumption per year (tonnes)	Rice production (tonnes)	Production in stocks per year (tonnes)	Percent of security (%)
Muang Mahasarakham	19,539.48	48,162.48	28,622.58	7.44	20,561.44	67,956.28	47,394.84	8.34
Kae Dum	5,643.41	19,081.17	13,437.75	3.49	4,989.13	25,797.09	20,807.97	3.66
Kosum Phisai	22,277.87	91,678.87	69,401.01	18.04	22,580.78	90,707.30	68,126.52	11.99
Kanthara Wichai	15,125.72	26,337.68	11,211.96	2.92	10,963.23	34,936.54	23,973.30	4.22
Chiang Yun	11,475.39	28,985.48	17,510.09	4.55	11,516.87	41,310.58	29,793.72	5.24
Borabu	20,491.52	75,911.66	55,420.14	14.41	20,776.61	112,943.92	92,167.31	16.22
Na Chuak	11,610.72	50,012.25	38,401.53	9.98	11,699.15	72,497.05	60,797.90	10.70
Phayakkhaphum Phisai	15,995.39	48,947.06	32,951.67	8.57	16,351.34	7,0053.62	53,702.28	9.45
Wapi Pathum	21,714.87	61,308.25	39,593.38	10.29	21,998.02	83,639.64	61,641.63	10.85
Nadun	6,514.95	24,115.89	17,600.94	4.58	6,682.18	33,489.85	26,807.67	4.72
Yang Sisurat	7,195.42	18,850.97	11,655.54	3.03	7,211.70	28,825.56	21,613.86	3.80
Kut Rang	7,384.41	44,716.11	37,331.70	9.71	7,593.43	52,912.95	45,319.52	7.97
Chunchom	4,989.53	16,456.81	11,467.28	2.98	5,030.58	21,250.36	16,219.78	2.85
Total in province	169,958.67	554,564.26	384,605.59	100	167,954.44	736,320.73	568,366.29	100

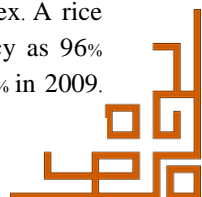
While, rice security in 2017 was highly stable in Borabu, Wapi Pathum, Na Chuak, Phayakkhaphum Phisai, Muang Mahasarakham, and Kut Rang districts, which represented 16.22, 10.85, 10.70, 9.45, 8.34, 7.97 and 5.24%, respectively. Soil and water resource were high quality for rice growth in these districts. That was located in highly and moderately suitable areas for rice growth in current. To be compared in both years, rice security in Muang Mahasarakham, Chiang Yun, Borabu and Na Chuak was highly increased because of suitability of rice cultivation.

The farmers had developed and expanded the rice plantation to increase production, while the number of people in these district decreased. These released access, availability, utilization, and stability of food situation in 2017 for local consumers. However, Kosum Phisai, Kut Rang and Chunchom districts were fewer because most areas were located in marginally suitable for rice growing. Kosum Phisai was high reduced percent of security than others because sugarcane mill located in the district. The farmers changed rice areas to sugarcane fields due to decrease transportation cost. For current, the farmers slightly changed rice field to the other crop cultivations. That the government also encouraged farmer to plant the suitable crops and rice plantation. While, agricultural labors reduced in 2017. The situation of food security, especially rice production in Maha Sarakham had an effect on local consumptions and production export to other countries. This study evaluated rice food security using rice extent, yield from estimation and

consumption. They were very important variables to measure sufficiency of rice consumption (Milovanovic and Smutka, 2017 and Singhapreecha, 2015). The disasters, including flood and drought, occurred and led to the damage of agricultural area as a result of climate change. These caused to decrease quality of rice food (Office of Agricultural Economics, 2017; Laosuwan et al., 2015). In future that rice consumption level will plunge about 10 percent, also trends of demographic structural will be changed in 2020. Agricultural labor has been decreasing 1% per year of all people in Thailand (Singhapreecha, 2015). This also contributed to the reduction of rice production and cultivation. This enlarged risk of rice food security. Related agencies should have plan for agricultural cultivation to accord decision marketing for crops economic growth and this study can be used to prevent rice food situation.

4. Conclusion

This study presented new approach to integrate the spatial analysis to evaluate rice security in Maha Sarakham province. For rice mapping in 2009 and 2017, Landsat 5 and Sentinel-2 were performed to classify rice field plantation by using OBIA and hierarchy classification. The spatial, spectral, and phenology feature were parameters to identify rice crop field. Spatial resolution was considered using for segmentation, based on size of the field referring to ground data. The dough stage was very good result to identify rice's phenology from NDVI index. A rice map in 2017 was high in overall accuracy as 96% more than thematic map which was at 90% in 2009.



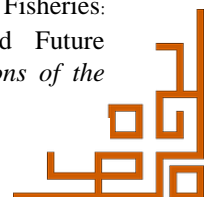
Sentinel-2 data with OBIA approach was absolutely extracted feature, and spatial information was adequate to segment rice field. The rice field maps were very significant information for decision market, plan, and management. The dimensions of food security were defined to evaluate rice situation using rice extent, suitability map and consumption per district. The influence factors were followed, according to FAO (1993). The suitability map for rice growth was agreed with using ground data that showed high correlation with harvested yield. For rice yield estimation, physical and soil properties were different in most large areas of Maha Sahakham. Rice extent, suitable areas and ground data were necessary. The levels of rice growth maps were highest area in moderate class and they related ground information in current. Farmers can apply spatial information as growth levels to select rice and others pattern in local level. The results of rice yield estimation were rather close to harvested yield from Office of Agricultural Economics (2017). Rice yield estimation using spatial data was an essential method to big areas, and this technique can be a lot useful in long term; although, the technique needed a long time to process the data. Rice security approach was also evaluated because food in the world is not stable. It becomes new issue in nowadays. In closed, the researches can used rice map and physical factors as the spatial data to estimate food security situation in the other areas.

Acknowledgement

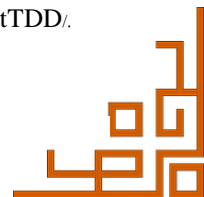
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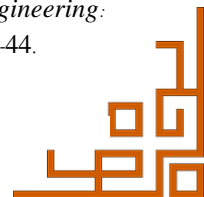
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