

Estimating Soil Organic Carbon Sequestration in Rice Paddies as Influenced by Climate Change under Scenario A2 and B2 of an i-EPIC model of Thailand

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Abstract

Carbon sequestration in soils constitutes an important option that can be used to reduce CO₂ emissions to the atmosphere and reduce environmental impacts. Soil organic carbon (SOC) is both a source of carbon release and a sink for carbon sequestration. Our objectives in this study were to validate the interactive Environmental Policy Impact Calculator (i-EPIC) model version 0509, as well as to estimate SOC sequestration under climate change scenarios A2 and B2 SRES emission scenarios in Thailand. The SOC estimated by i-EPIC was compared with data from the Office of Soil Resources Survey and Research, Land Development Department. The results indicated that performance testing of i-EPIC is able to estimate SOC. Validation of SOC proved to be satisfactory with a resulting root mean square error (RMSE %) value of 34.60. The SOC content showed a decreasing trend under B2 and A2 climate scenarios (average 0.87% and 0.85%, respectively) compared to the reference from 2007 (average 0.92%). Stepwise regression analysis also revealed that carbon from residue decomposition, biomass pool carbon, and the total change of the carbonpool were directly correlated with the SOC ($R^2 = 0.99, p < 0.01$). Furthermore, the change from rain supplied water to irrigation also resulted in an increase of carbon inputs but a decrease in the SOC sequestered during the 2007-2017 period. Regression analyses indicated that soil carbon sequestration responds linearly to carbon input. Significant changes in carbon input as well as decreases in SOC levels were observed as temperature and precipitation increased. Based on the testing and analysis, we concluded that i-EPIC is capable of reliably simulating effects of climate change on SOC sequestration. Based on the results, this knowledge and information can increase effectiveness in the promotion of integrated rice management for rice production in Thailand.

Keywords: soil organic carbon; climate change; i-EPIC model; rice paddy; Thailand

1. Introduction

The global average surface temperature has increased by about 0.3 to 0.6°C since the late 19th century. The cause can be split into two groups; anthropogenic and natural. Carbon dioxide (CO₂) is the primary greenhouse gas emitted through human activity in the atmosphere, accounting for about 64% of the total greenhouse gases (IPCC, 2007; Saree *et al.*, 2012). Soil organic matter is the key to soil health; it plays a major part in holding the nutrients, water and trace elements which contribute to plant growth. As a source and sink of nutrients, it also plays a vital role in soil fertility (Post *et al.*, 1990; FAO, 2001). Accelerated oxidation of soil organic matter not only results in a reduction of SOC and an increase of atmospheric CO₂ concentration, but it also affects soil function and biodiversity (Victoria

et al., 2012). Therefore, optimal SOC storage requires the correct balance between carbon addition from the non-harvested portions of crops and organic matter amendments, and SOC loss. This occurs primarily through organic matter decomposition and the release of respired CO₂ to the atmosphere. Increasing the carbon content in agricultural soil may result in improvement of soil and water quality, decrease of nutrient loss and soil erosion, increase of water conservation, and crop production (Chan, 2008; Hoorman, 2009); management techniques which are successful in providing a carbon sink in soils (Schlesinger, 1999; ESA, 2000). Thus, soil organic matter is not only an important source of carbon for soil processes but also a sink for carbon sequestration.

The Environmental Policy Integrated Climate (EPIC) model was chosen for this study because it is one of most predominant crop models currently

available and has been widely evaluated under various environmental conditions (Williams *et al.*, 1989; Rosemberg *et al.*, 1992; Brown and Rosemberg, 1999). Rice yields were also used to analyses the impact of climate change on the relationship between several crop yields and SOC sequestration (Priya and Shibasaki, 2001; Tan and Shibasaki, 2003; Thomson *et al.*, 2006; Wang and Li, 2010; Balković *et al.*, 2011). In this study, the research objectives were to validate the interactive Environmental Policy Impact Calculator (i-EPIC) model version 0509 and estimate SOC sequestration under the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) A2 and B2 of Thailand.

2. Materials and Methods

In this paper, the EPIC0509 version and i-EPIC (interactive EPIC) interface were applied. The Environmental Policy Impact Calculator (i-EPIC) can assess the effect of soil erosion on productivity, and predict the effects of management decisions on soil, water, nutrient and pesticide movements and their combined impact on soil loss, water quality and crop yields for areas with homogeneous soils and management (Williams, 2006). Pumijumnong and Arunrat (2012) found that the performance of the i-EPIC model is reliable and has potential for estimating rice yields in Thailand. One main reason for choosing EPIC0509 for the estimation of carbon sequestration is the improved carbon turnover routine.

2.1. EPIC model description

The EPIC model is a widely used and tested model for simulating agro-ecosystem processes (Izaurrealde *et al.*, 2001; 2006). EPIC requires topographical (e.g., slope gradient and length) characteristics, field or watershed dimensions, soil properties (e.g., bulk density, organic carbon, sand and silt content, pH) and crop management (e.g., cultivars, fertilisation, irrigation, tillage, and harvesting) as input variables. Monthly values of precipitation, minimum/maximum air temperature, solar radiation, wind speed, and relative humidity drive the EPIC (Gassman *et al.*, 2003; 2005; Zhang *et al.*, 2010). The model simulates bio-physical processes encompassing an agricultural system, such as photosynthesis evapotranspiration, runoff, water erosion, and wind erosion (Brown *et al.*, 2000; Izaurrealde *et al.*, 2006). EPIC is well suited for the simulation of scenarios such as land use, land management, and climate change, in which soil moisture supply and soil matrix properties vary concurrently (Cooter *et al.*, 2012), as shown in Fig. 1. The i-EPIC interface

has built-in graphics capabilities that are used with Microsoft Access. By using the Microsoft Access database file format, data can be manipulated using i-EPIC's file import (Pumijumnong and Arunrat, 2012). The current EPIC community code can be downloaded from <http://epicapex.brc.tamus.edu>.

2.2. Data preparation

The estimation of SOC changes was performed by using the following procedures: (i) preparing EPIC input database files for all simulation units, (ii) running the simulations, (iii) extracting the output files and transferring to the database, and (iv) analysing the results.

The geographic information system (GIS) datasets of the spatial distribution used included: (1) land use, (2) digital elevation model (DEM), (3) slope data, (4) soil series, (5) soil nutrients status, (6) weather data 81 station, and (7) simulation units, each of which was polygonal, measuring 0.1 x 0.1 degrees in size, and covering 11.11 x 11.12 km in area with similar environmental conditions. A total of 1219 grid cells were used for the model.

GIS data preparation was performed according to the slightly modified procedure described by Pumijumnong and Arunrat (2012). We used Kriging interpolation methods that were available in the ArcGIS 10 Spatial Analyst tool. To predict the cell values at locations that lacked sampled points, values were weighed from a specific number of known points, and then the unknown weights were determined based on the distance between the interpolated and known points.

2.3. EPIC inputs

2.3.1. Soil data

From the survey of soil nutrient status in Thailand during 2004-2008, 6,422 soil nutrient testing results (pH, organic matter content, available phosphorus, and available potassium contents) were collected in the laboratory of the Office of Science for Land Development, Land Development Department.

2.3.2. Climatic data

A reference climatic scenario (REF) for the year 2007 was prepared with the EPIC model using data from the Thai Meteorological Department. In addition, we used the IPCC SRES A2 and the B2 scenario from Southeast Asia START Regional Centre (SEA START) for years 2007 to 2017. The EPIC model requires monthly climate variables consisting of maximum and minimum air temperature, precipitation, rain days and solar radiation.

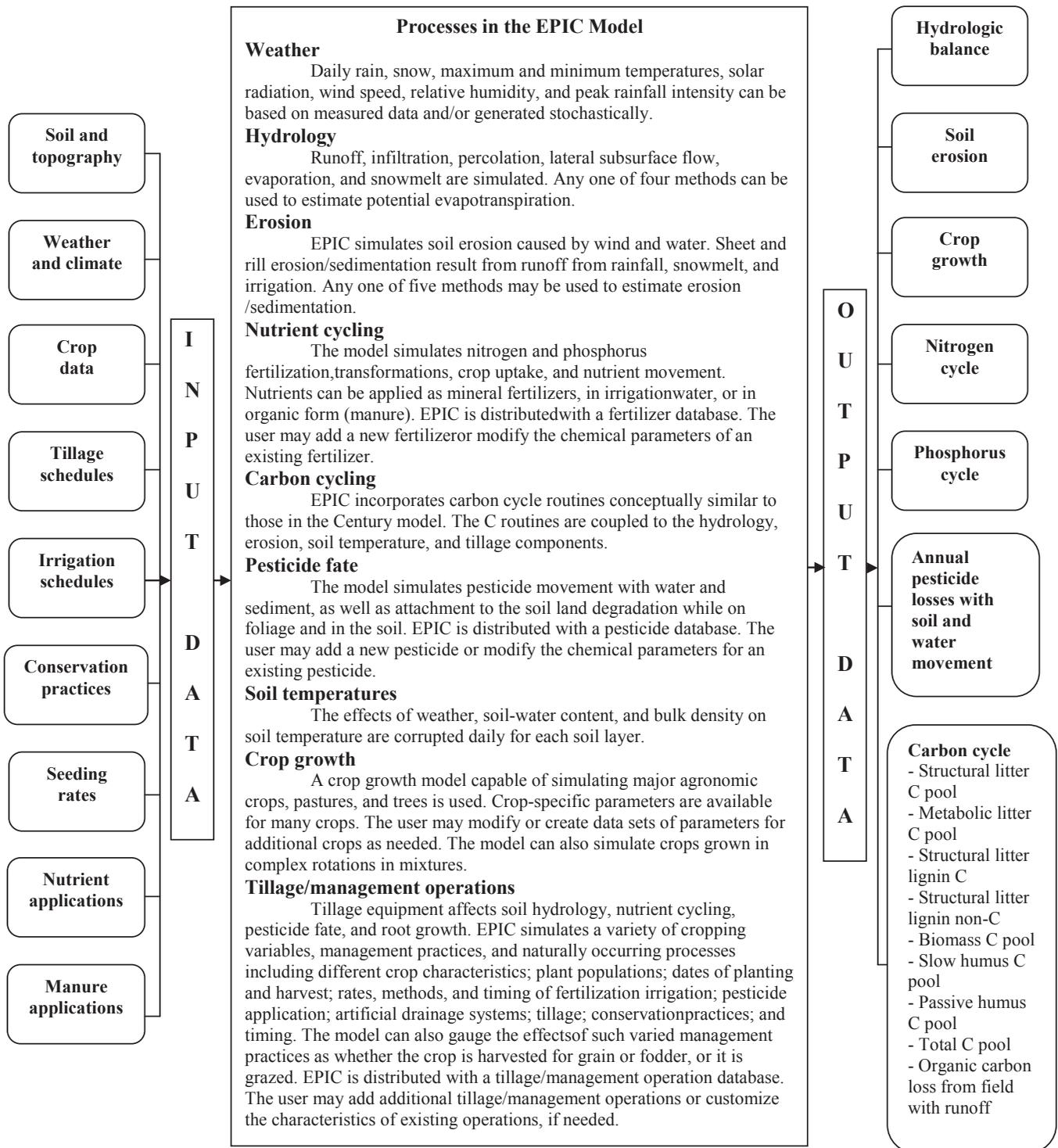


Figure 1. General schematic of the key processing steps required of the i-EPIC model (Source: modified from USDA, 2006)

2.3.3. Crop management data

On the basis of crop parameters and other related parameters, the EPIC model can be adopted to calculate the uptake of soil water and nutrients by crops, estimate the impacts of temperature, water, nutrients, air and salt stresses on crop biomass accumulation and crop yield, and examine the process of crop growth in daily steps (Wang and Li, 2010). In this study, relevant crop parameters and rotation operations (Tables 1 and 2) were modified on the basis of measured and published data from the Rice Department of Thailand. In the EPIC model, potential evaporation was calculated by the Penman-Monteith method.

2.4. Model validation and statistical analysis

2.4.1. Model validation

The validation process focused on the rice yield and SOC using the observed values of yield that were collected from the Agricultural Statistics of Thailand for the years 1996 to 2011, which were generated by the Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives (MOAC). The observed values of SOC were collected from the Land Development Department of Thailand for the 2004 to 2008 period.

2.4.2. Statistical analysis

A statistical analysis was calculated to represent different aspects of model performance. A root mean square error (RMSE) is another measure of the overall magnitude of the relative model error. RMSE is often used to measure the difference between values predicted by a model and the values actually observed from the study area. Its range is from 0 to infinity, and a value of 0 implies perfect agreement. The ability of the model to simulate the variation of yield and SOC was examined by comparing standard deviations (StDev) of the model simulated yield and SOC with that of observed values. The statistical analysis was implemented using the statistical package for the social sciences (SPSS; IBM, USA).

$$RMSE = \sqrt{\sum_{i=1}^n (y_i - x_i)^2} \times \frac{100}{\bar{x}}$$

In this equation, x_i and y_i refer to the observed and predicted values, respectively, \bar{x} refers to the mean of observed values, and n signifies the sample number ($n = 1219$).

Table 1. Important crop parameters for the EPIC model based on measured and published data (Pumijumng and Arunrat, 2012).

Input variable	Explanation	Rice
WA	Biomass-Energy Ratio	25
HI	Harvest index	0.5
TOPC	Optimal temperature for plant growth	33
TBSC	Minimum temperature for plant growth	15
DMLA	Maximum potential leaf area index	6
DLAI	Fraction of growing season when leaf area declines	0.8
DLAP1	First point on optimal leaf area development curve	30.01
DLAP2	Second point on optimal leaf area development curve	70.95
RLAD	Leaf area index decline rate parameter	0.5
RBMD	Biomass-energy ratio decline rate parameter	0.5
ALT	Aluminum tolerance index	3
GSI	Maximum Stomatal Conductance	0.008
CAF	Critical aeration factor	1
SDW	Seeding rate	50
HMX	Maximum crop height in m	0.8
RDMX	Maximum root depth in m	0.9
WAC2	CO ₂ Concentration /Resulting WA value (Split Variable)	660.31

Table 2. Rotation operation of rice in Thailand (Pumijumnong and Arunrat, 2012).

Rotation operation	Major rice ¹		Second rice ²	
	Date	Month	Date	Month
Tillage	1	June (06)	1	January (01)
Planting	15	June (06)	15	January (01)
Fertilizer	1	September (09)	1	February (02)
Harvest	31	December (12)	30	April (04)
Kill	31	December (12)	30	April (04)

Note: ¹Major rice represents the rice grown during the rainy season between June and December. ²Second rice represents the rice grown during the dry season between January and April of the following year.

3. Results

3.1. Validation of EPIC

The model evaluation that compared major rice production revealed a predicted and observed yield average of 2.92 and 3.14 ton ha⁻¹, respectively, whereas the model evaluation that compared the second rice production revealed a predicted and observed yield average of 3.77 and 3.88 ton ha⁻¹, respectively. Based on the statistical analysis, the RMSE of major and second rice productions were 27.12 and 24.68%, respectively. The SOC content comparison showed that the predicted value average was 0.66%, whereas the observed value average was 0.68%, which gives an RMSE (%) of 34.60%. An important positive slope in the regression line was also observed together with a positive intercept by the linear regression relationship between observed and predicted rice yields (both major and second rice) and SOC content (Figs. 2 and 3).

The results of the assessment of greenhouse gas emission scenarios (IPCC SRES) A2 and B2 used 2007 as the reference (REF) year data (as shown in Table 3). Comparisons of SOC, soil temperature, carbon loss with residue decomposition and biomass pool carbon between major and second rice in Thailand are shown in Table 4.

3.1. Soil organic carbon (SOC)

The total pool of initial carbon (TPIC) of soil illustrates that the average TPIC of both the major and second rice production during the growing season was 0.81% and 0.77%, respectively, whereas the soil SOC

level averaged 0.77% and 0.73% during the major rice growing season and the second rice growing season, respectively. Both the TPIC and SOC were higher during the major rice growing season than during the second rice growing season. The SOC level under the A2 scenario was lower compared to the SOC level under the B2 scenario. This was due to the fact that the temperature under the A2 scenario, as well as the precipitation, rose much higher than during the B2 scenario (as shown in Table 3), resulting in an elevated amount of carbon release and a decreased carbon reservoir. In addition, when analysing each region of Thailand, the eastern region showed the highest TPIC levels, followed by the central, southern, northern, northeastern, and western regions, respectively. In addition, the pool change carbon (PCC) under the B2 scenario was slightly higher than that of the A2 scenario, and the region with the highest carbon level alternation was southern, followed by the northern, western, central, eastern, and northeastern regions, respectively (Fig. 4).

The level of SOC sequestration can be categorised into the following five levels: (1) very high (> 2.0%), (2) high (1.0-2.0%), (3) medium (0.5-1.0%), (4) low (0.25-0.5%), and (5) very low (< 0.25%) (Fig. 5).

In general, the SOC level in the rice paddy in the central region of Thailand was found to be at a medium level. Provinces with high SOC levels included NakhonPathom, PathumThani, Nontaburi, PhraNakhon Si Ayutthaya, NakhonNayok, Suphanburi, AngThong, Singburi, and Saraburi, respectively. Provinces with a medium level of SOC were Phitsoulouk, LopBuri, Phetchabun, ChaiNat, Phichit, Sukhothai, NakhonSawan, and Bangkok. Areas with low SOC levels included UthaiThani, and SamutPrakan.

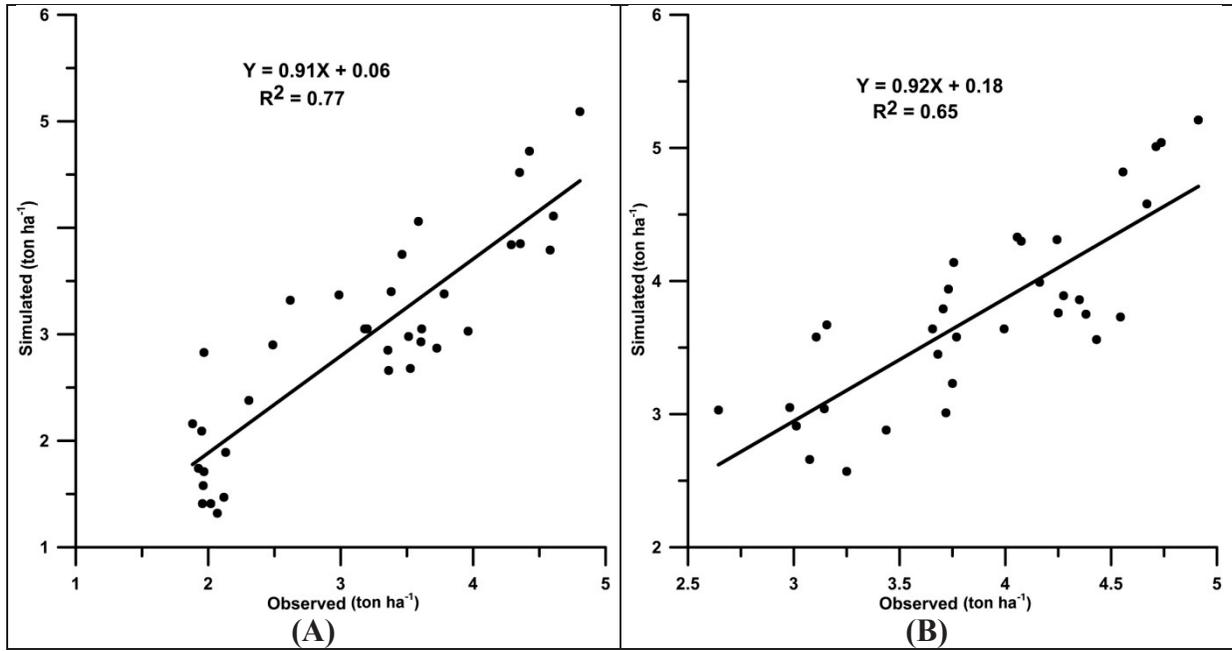


Figure 2. Comparison of rice yields between EPIC-simulated and observed for (A) major rice yield, (B) second rice yield.

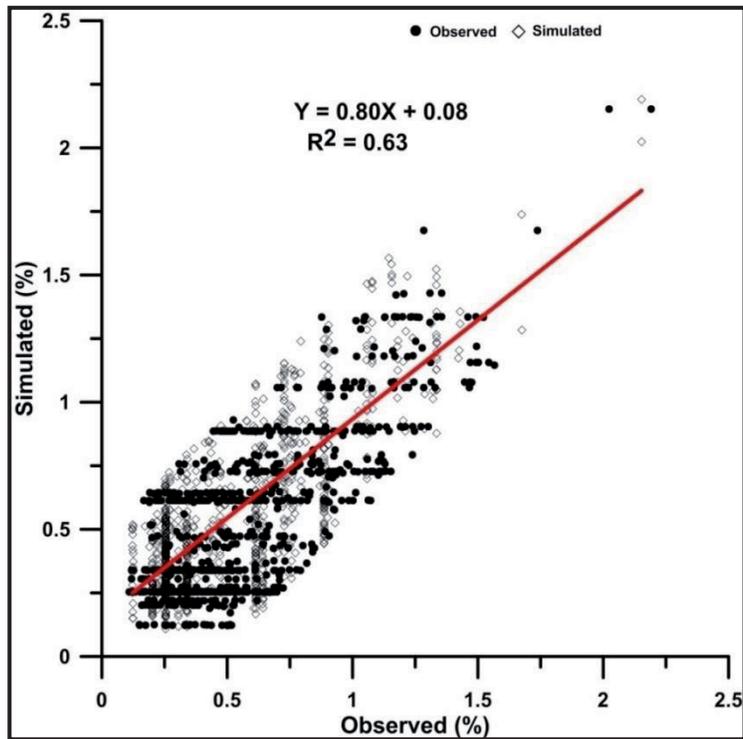


Figure 3. Comparison of soil organic carbon (SOC) between EPIC-simulated and observed

Table 3. Summarised climate changes in Thailand.

	2007 (REF scenario)	A2 scenario	B2 scenario
1) Temperature (°C)			
Air Temperature Average Max	32.74	33.13	33.20
Air Temperature Average Min	22.99	24.18	22.52
2) Precipitation Average (mm)			
	141.24	129.39	125.60
3) Rain days Average (day)			
	10.93	18.73	18.49
4) Solar Radiation (MJ/m ²)			
	114.81	198.78	200.17

Table 4. Simulation results of major and second rice are divided according to regions of Thailand.

Region	Major rice				Second rice			
	Soil organic carbon (%)	Soil temperature (°C)	Carbon loss with residue decomposition (%)	Biomass pool carbon (%)	Soil organic carbon (%)	Soil temperature (°C)	Carbon loss with residue decomposition (%)	Biomass pool carbon (%)
2007 (REF scenario)								
Central	0.848	26.68	0.035	0.0195	0.797	26.64	0.036	0.0172
Eastern	1.246	26.97	0.031	0.0367	1.057	26.87	0.040	0.0265
Northern	0.725	26.32	0.039	0.0137	0.728	26.30	0.039	0.0140
Northeastern	0.554	26.78	0.029	0.0098	0.558	26.78	0.030	0.0097
Southern	0.775	26.68	0.050	0.0110	0.779	26.66	0.050	0.0111
Western	0.477	26.37	0.030	0.0067	0.479	26.36	0.030	0.0068
A2 scenario								
Central	0.852	28.80	0.033	0.0198	0.800	28.76	0.034	0.0177
Eastern	1.247	29.26	0.031	0.0368	1.060	29.21	0.039	0.0270
Northern	0.731	26.70	0.036	0.0141	0.733	26.68	0.035	0.0145
Northeastern	0.556	27.91	0.027	0.0102	0.560	27.89	0.028	0.0103
Southern	0.779	29.32	0.048	0.0110	0.780	29.29	0.052	0.0113
Western	0.482	29.53	0.029	0.0072	0.487	29.48	0.030	0.0073
B2 scenario								
Central	0.853	27.78	0.032	0.0199	0.800	27.74	0.033	0.0177
Eastern	1.248	28.55	0.030	0.0371	1.060	28.50	0.039	0.0268
Northern	0.732	26.21	0.035	0.0141	0.732	26.21	0.035	0.0145
Northeastern	0.558	26.99	0.026	0.0102	0.559	26.97	0.027	0.0103
Southern	0.777	30.17	0.048	0.0109	0.779	30.13	0.051	0.0111
Western	0.482	29.55	0.029	0.0071	0.486	29.48	0.029	0.0073

The eastern region of Thailand, as well as provinces of Chachoengsao and Prachinburi, had medium SOC levels. Provinces with low SOC levels included Chonburi and Sakaeo. Northern Thailand, including Lamphun, Chiang Rai, Chiang Mai, Uttaradit, Phayao, Lampang, and Phraealso, had medium levels of SOC. In contrast, northeastern Thailand had low levels of SOC. Provinces with medium SOC levels were Nongkhai, Chaiyaphum, Loei, SakhonNakhon, KhonKaen, Nongbualamphu, UdonThani, Kalasin, and Surin, whereas areas with low SOC levels included

NakhonRatchasima, Buriram, NakhonPhanom, Srisaket, MahaSarakham, UbonRatchathani, Amnat Charoen, Roi Et, Mukdahan, and Yasothon, respectively.

Southern Thailand had medium levels of SOC. The NakhonSiThammarat province had high SOC levels, whereas Pattani, Songkhla, and Phatthalung had medium SOC levels. Finally, western Thailand had medium SOC levels. Provinces with high SOC levels included Phetchaburi, whereas areas with medium SOC levels included Ratchaburi and Kanchanaburi.

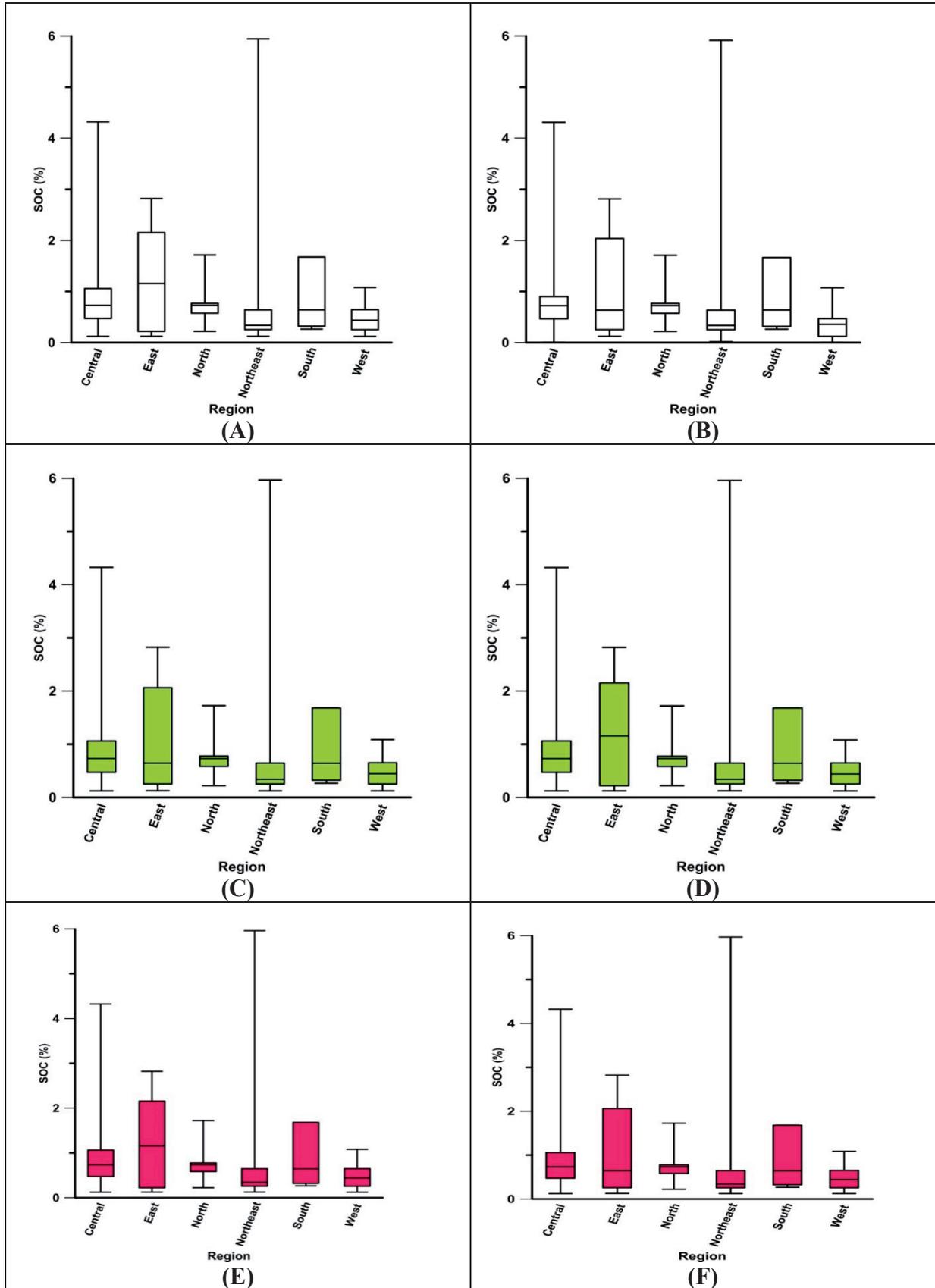
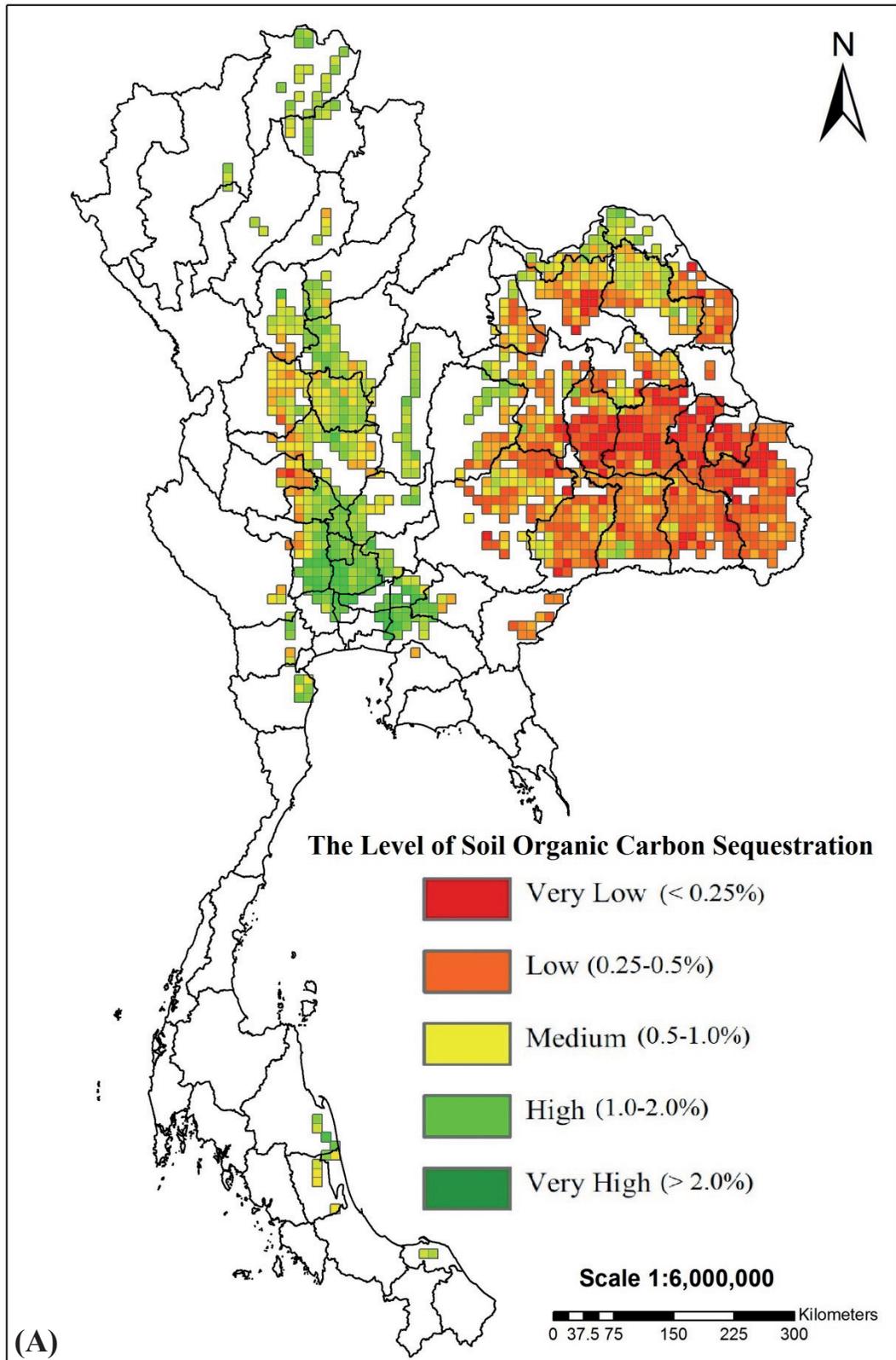
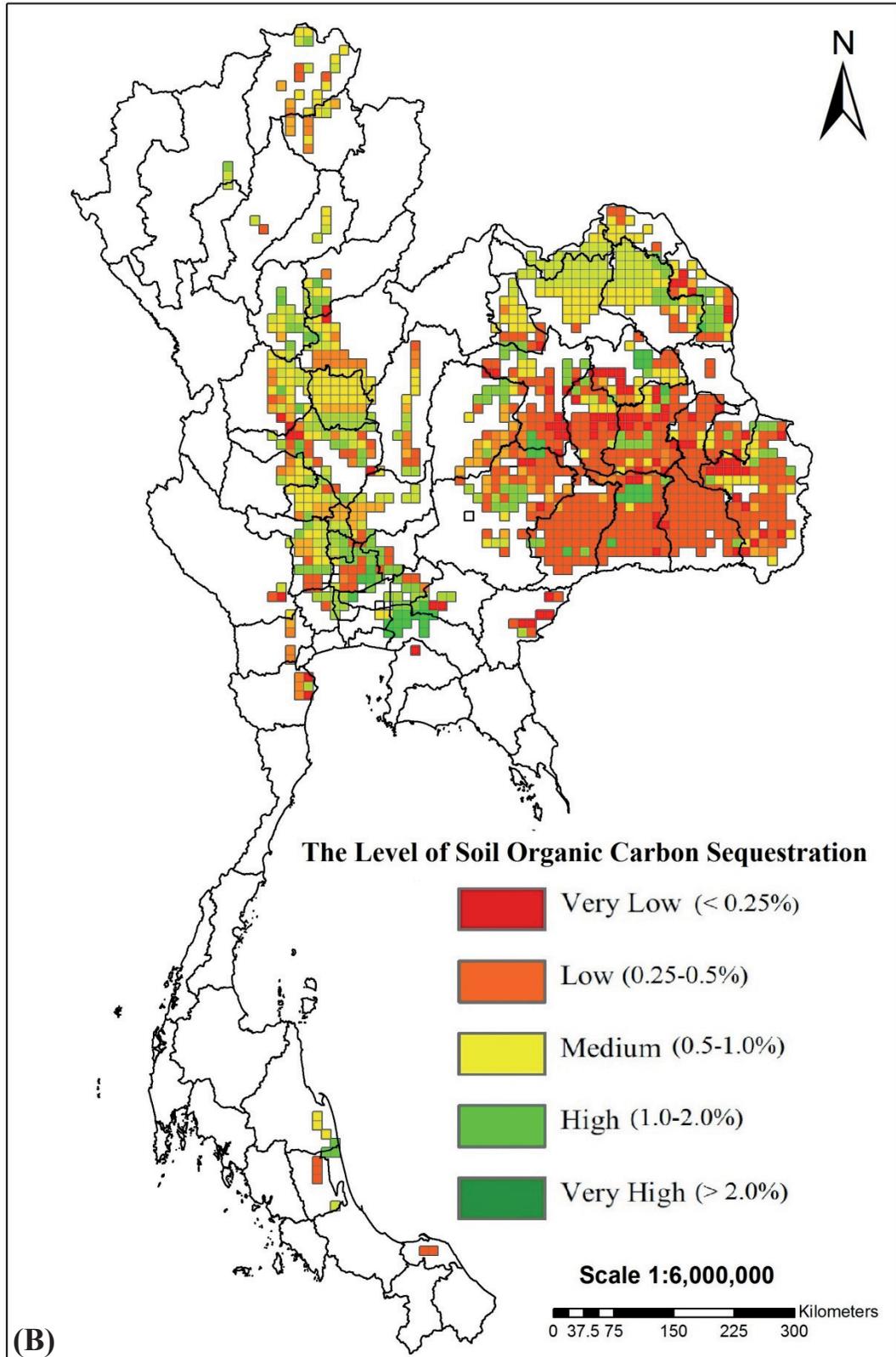


Figure 4. Comparisons of the change in soil organic carbon (SOC) according to the regions of Thailand: (A) and (B) reference scenario (REF) 2007 for major and second rice seasons; (C) and (D) A2 scenario for major and second rice seasons; (E) and (F) B2 scenario for major and second rice seasons, respectively.





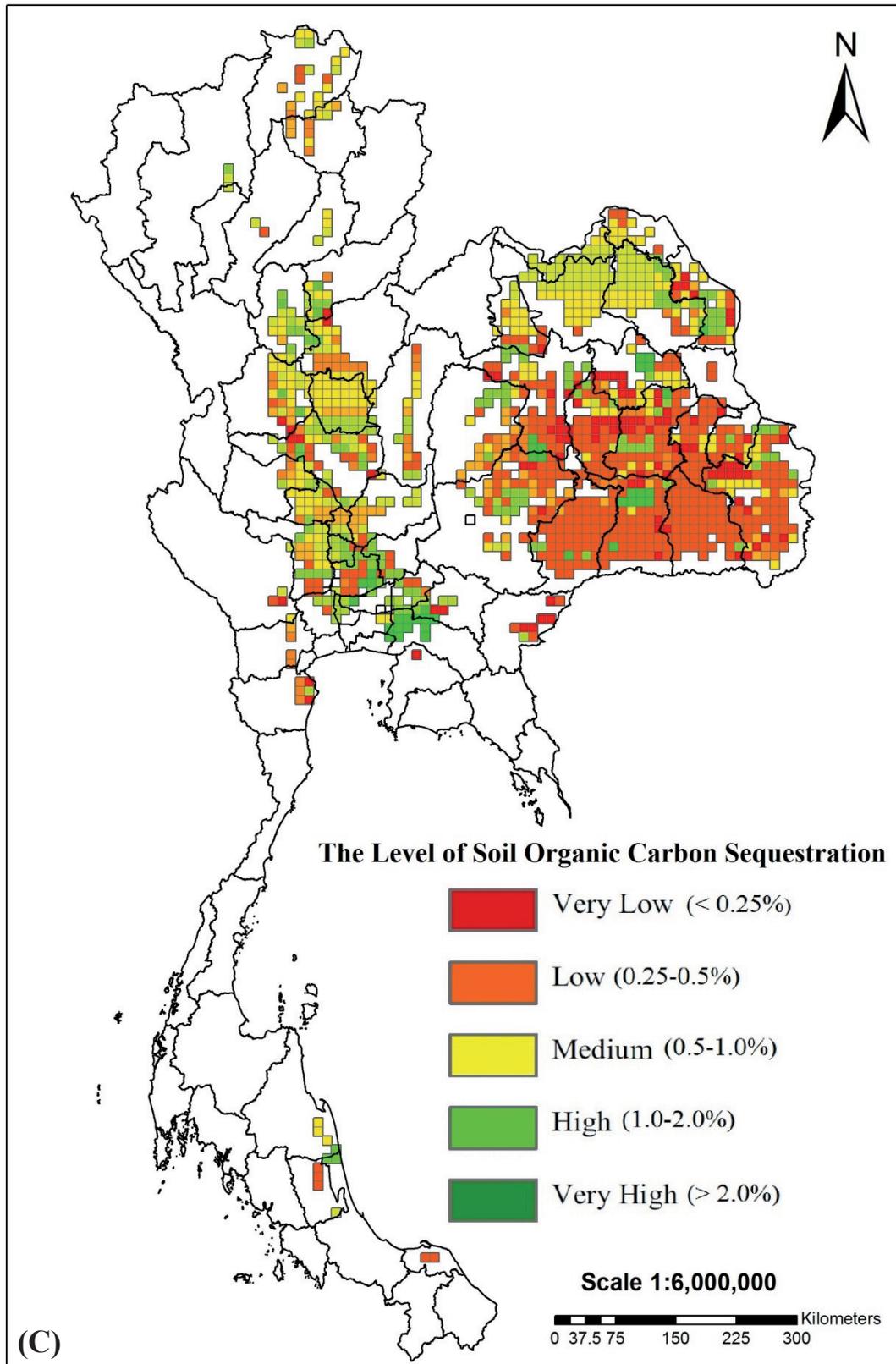


Figure 5. Spatial distribution of soil organic carbon (SOC) sequestration under climate change scenarios for (A) Reference Scenario (REF) 2007, (B) A2 Scenario and (C) B2 Scenario.

3.2. Soil temperature

Simulation results of soil temperature revealed that during the season of major rice production, the soil temperature rose slightly higher than that of the second rice by approximately 0.02-0.1°C. The maximum temperature in the A2 scenario was also lower than the maximum temperature of the B2 scenario, but the lowest temperature of the A2 scenario was higher than the lowest temperature of the B2 scenario. Nevertheless, the soil temperature of both A2 and B2 scenarios increased from the REF by approximately 3-4°C (as shown in Table 4). An analysis of each region of Thailand showed that the southern region of the country had the highest soil temperature during the season of major rice production under the A2 scenario, followed by the western, eastern, central, northeastern, and northern regions. On the other hand, the region with the highest soil temperature during the second rice production season under the same scenario was the western region of Thailand followed by the southern, eastern, central, northeastern, and northern region. However, under the B2 scenario, the region that had the maximum soil temperature of both the major and second rice production seasons was the southern region of Thailand, followed by the western, eastern, central, northeastern, and northern regions.

3.3. Carbon loss with residue decomposition

The level of carbon loss with residue decomposition during the major rice production season was lower than that of the growing season of the second rice production, and the level of carbon loss with residue decomposition under the A2 scenario was higher than that under the B2 scenario (as shown in Table 4). However, the level of carbon loss with residue decomposition under both scenarios decreased when compared to the REF. The study also found that the maximum level occurred in the southern part of the country, whereas the lowest level occurred in the northeastern region.

3.4. Biomass pool carbon

In terms of carbon levels of the biomass pool, the major rice growing season exhibited a higher level than the second rice growing season (as shown in Table 4). In addition, the levels under the A2 scenario were higher than the levels under the B2 scenario. Nevertheless, the carbon levels of the biomass pool under both scenarios were higher than the REF, with the eastern and western regions of the country exhibiting the highest and lowest levels, respectively.

In order to analyse the relationship between carbon loss with residue decomposition, biomass pool carbon, change in total pool carbon and SOC content, a correlation analysis and stepwise regression analysis were used. The levels of SOC were positively correlated with carbon loss with residue decomposition ($R^2 = 0.71$, $p < 0.01$), biomass pool carbon ($R^2 = 0.90$, $p < 0.01$), and change in total pool carbon ($R^2 = 0.65$, $p < 0.01$) (Fig. 6).

4. Discussion

The projected property of soil as a carbon sink exhibits an unstable tendency due to rapid loss of SOC under different climate changing conditions, including arise in temperature. In general, soil respiration may be defined as the amount of CO₂ evolved from the respiration of soil organisms, roots and mycorrhizae. These activities are sustained by organic matter input to the soil from above ground and roots by oxidation of root exudates, plant detritus, and soil organic matter (Raich and Schlesinger, 1992). Soil carbon respiration rate is increased 2-fold for a 10 °C warming if microbial activity is not limited (Davidson and Janssens, 2006). In the future, evaluation of the carbon balance in soil between input and losses will be even more difficult, as a result of climate variability. Raich and Schlesinger (1992) and Frank *et al.* (2006) reported that temperature, precipitation and moisture are important factors influencing soil respiration. It can be postulated that the progressing decomposition holds an exponential function relationship with temperature (Lloyd and Taylor, 1994). Soil water content and soil temperature are major factors regulating SOC decomposition. On the other hand, a faster SOC turnover associated with higher temperatures could result in the loss of significant amounts of carbon stored in agricultural soils (Conant *et al.*, 2008). Based on the study of Almagro *et al.* (2009), soil respiration depends on both soil temperature and the level of precipitation. Smith *et al.* (2005) conducted research on SOC changes under different models of climate change in the agricultural areas of Europe and assessed the changes in carbon levels in soil. According to their findings, the direct impact of climate change on SOC dynamics affects the balance between the rising temperature and decreasing soil moisture. In addition, soil management processes can also lead to changes in soil moisture as well as soil properties, such as texture, clay content, mineralogy, and acidity (FAO, 2001). The interactive effects of warming, soil moisture and CO₂ increase on SOC turnover were further revealed among agricultural classes. The supply of water in the irrigated areas predicted a slightly lower carbon gain than the areas under rain-fed conditions. Therefore,

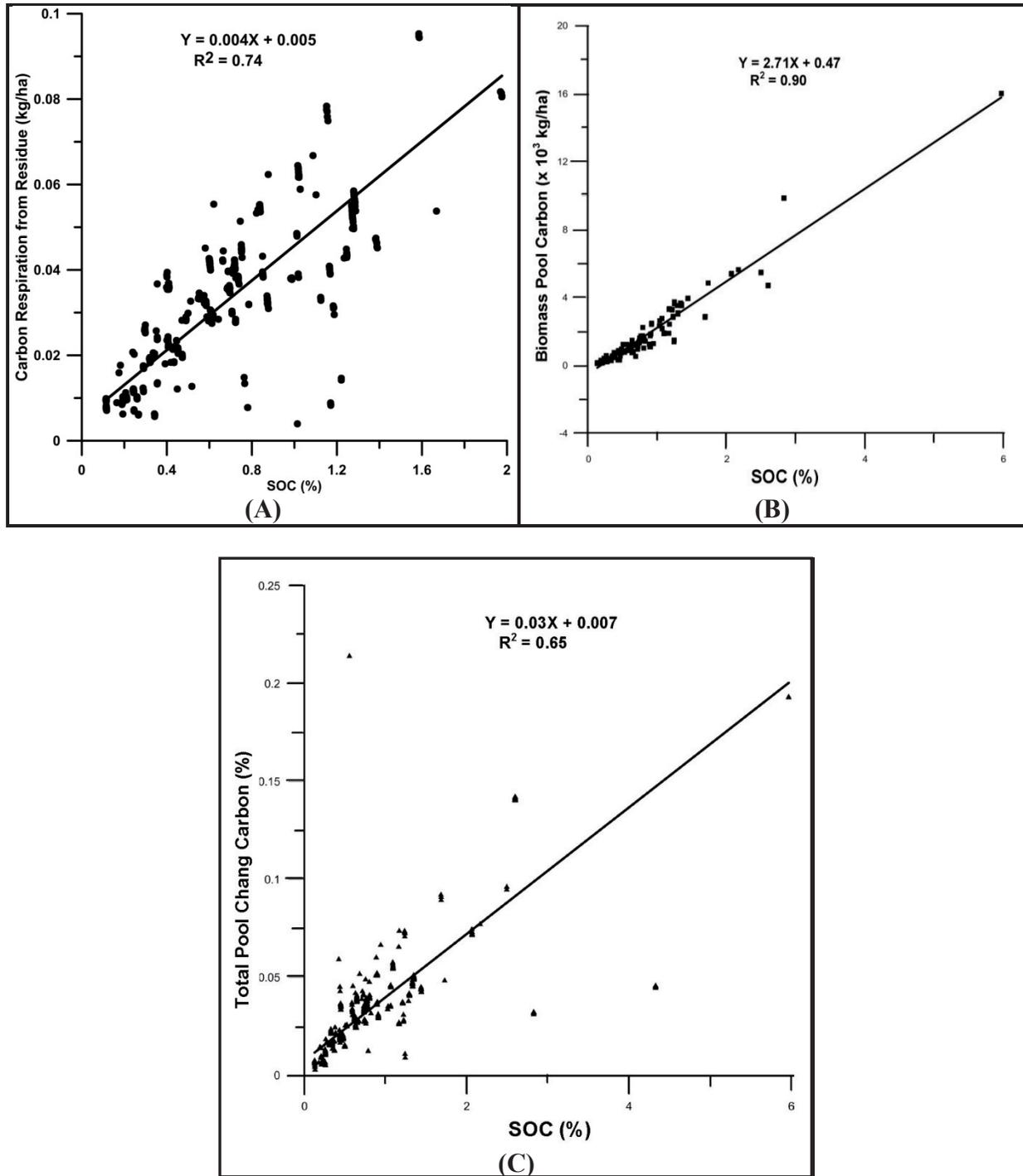


Figure 6. Comparison of regression analysis between (A) carbon loss with residue decomposition and SOC, (B) biomass pool carbon and SOC and (C) change in total pool carbon and SOC.

an additional water supply together with an increase in temperature could stimulate soil microorganisms. Gillabel *et al.* (2007) discovered that SOC turnover rates increase under irrigated conditions compared to rain-fed conditions, since the rise in soil moisture limits the stimulation of soil microbial activities. This is in agreement with the study of Kladviko (2001), which found that crop yield and organic matter content are affected by soil fertilisation and irrigation. Organic

matter and the biological activity that it generates, have a major influence on the physical and chemical properties of soils. This results in the rapid formation of microbial compounds and body structures, which are important for the structure of the soil in order to reduce erosion and release carbon dioxide into the Earth's atmosphere. All of these steps are positively affected by the particles being held together due to the sudden emergence of the compounds and structures.

One way to reduce soil carbon release is to stop burning straw in the rice paddies (Reeves, 1997; Bird *et al.*, 2001; Follett *et al.*, 2005). The burning of this organic matter obstructs the increasing levels of carbon accumulation in soil because the organic matter is lost during the burning process. Most importantly, the burning process reduces the already accumulated organic matter in the soil (Biederbeck *et al.*, 1980; Fynn *et al.*, 2003). The major component of soil organic matter is carbon, and therefore the reduction of organic matter in the soil would also mean a reduction of carbon. In addition, land stripping processes for the purpose of exposing soil to sunlight, heat, and air, also intensifies the loss of carbon in soil. Although the burning of straw may not directly cause a higher release of greenhouse gases, it leads to a higher release of carbon from that accumulated in the soil. Thus, any rice field where straw is frequently burned will most likely have a low level of organic matter in the soil.

5. Conclusion

Based on our model analysis, under the conditions of A2 and B2 scenarios during 2007 to 2017, the average of SOC sequestration in Thailand tends to decrease. The SOC levels under both A2 and B2 scenarios revealed a descending tendency compared to REF. Based on these scenarios, it can be inferred that increasing temperature correlates with climate changes as well as rapid SOC loss. Carbon inputs were also simultaneously increased, while a decrease in straw resulted in a loss of SOC over time when compared to rain-fed systems and irrigated systems. The SOC dynamics were also changed as a result of the different effects from precipitation and temperature changes. This is dependent upon the style of management used and could lead to the optimisation of SOC sequestration, which conversely reduces CO₂ levels. Consequently, increasing SOC levels can be achieved by increasing carbon input to soils through reducing straw burning in rice paddies. The model also revealed that climate changes can affect SOC accumulation significantly. Although it may be difficult to directly validate SOC changes, SOC alternation will likely result in changes of rice production.

Our knowledge of SOC dynamics under climate change and SOC monitoring was applied within the i-EPIC model with GIS techniques, which enhanced associated spatial and temporal dimensions. This approach is based largely on a range of information gained from various departments of Thailand, reflected in the national strategy to address climate change. It also reflects a growing understanding of the paddy field environment.

Acknowledgements

This research was supported by the National Research University under the cluster “Innovation, Social, Education and Environment to Human Wellbeing”, sub cluster Climate change and Human well-being, 2011-2013, and was funded by The Ministry of Education. The authors would like to thank the reviewers for their helpful comments to improve the manuscript.

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Received 11 September 2013

Accepted 29 November 2013

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