Comparison of short term and long term SOC stock change in rice file rotated with energy crop

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Abstract:
This study focused on investigation of soil organic carbon change in short term and long term from abandoned rice field reclaimed by energy crop rotated with rice. The field experiment was designed in abandoned rice field from Aug 2009 to Jan 2013 at King Mongkut's University of Technology Thonburi, Ratchaburi campus, Thailand. The four crop rotation systems designed to fallow land- rice (RF), rice-rice (RR), corn-rice (RC), and sweet sorghum-rice (RS). The SOC stock at 0-15 cm of soil depth was estimated by equivalent soil mass method (ESM). The site mode of DNDC model (version 9.3) used to estimate the long term SOC stock change. In short term of field experiment, the SOC stocks changed from the initial soil through the land use change, tillage and crop rotation practices. The SOC stock from 1st to 2nd crop in RR was significant 33% increasing and from 2nd to 3rd crop in RF, RC and RS was significant increased 38%, 37% and 42%, respectively. Long term simulation, SOC stock in RR, RC and RS was higher 42%, 33% and 25% than fallow-rice crop system, respectively. The energy crop rotation in rice field able to maintain soil carbon storage in long term.

Keywords: *soil organic carbon; short term SOC; long term SOC; rice field; energy crop; crop rotation*

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1. Introduction

Rice cultivation area in Thailand is almost a half of all agricultural areas and over 90% is produced in lowland field with flooded soil (LDD, 2010). The lowland rice cultivation able to maintains or improves soil organic matter. The changing of soil organic carbon storage in rice system caused by land use and crop management practices including; crop rotation, tillage, irrigation, fertilization, and other activities (Witt et al., 2000; Zeng et al., 2007; Nishimura et al., 2008; Purakayastha et al., 2008; Kukal, 2009). In short term study, the sequestration of organic C and total N in rice-rice cropping under flooded condition was significant during two years while rice-maize reduced soil C and N sequestration (Witt et al., 2000). The study of long term (32 years) SOM sequestration in rice-wheat and maize-wheat system showed rice-wheat (260 kg C ha^{-1}) higher C sequestration than maize-wheat (70 kg C ha^{-1}). Then, the rotation of rice with upland crop (corn and sweet sorghum) in specific lowland rice area (i.e. abandoned rice field) talented to maintain soil C in short or long term period. This study focused on investigation of soil organic carbon change in short term and long term period by energy crop rotated with rice.

2. Material and methods

1.2 Site description

The field experiment was established in abandoned rice field at King Mongkut's University of Technology Thonburi, Ratchaburi campus in Ratchaburi Province, Thailand (13°35' N, 99°30' E). This experimental site was the abandoned rice field 10 years before the experiments began in 2010. The soil at this site is classified as Khao Yoi (Kyo) soil series with a sandy loam (SL) 53% sand, 45% silt and 2% clay, pH 5.8, bulk density 1.75 g cm^{-3}, and 0.69% total organic C content. An annual rainfall and mean air temperature in 2010 were 1,062.70 mm and 26.7°C, respectively.

2.2 Field experimental design

The short term study of SOC stock change started from Aug 2009 to Jan 2013. The experiment was prepared in randomized block design with total eight plots were established for four crop rotation systems with two replicated field plots (5 m × 15 m). The rotation systems were cultivated in abandoned rice field and designed to fallow land- rice (RF), rice-rice (RR), corn-rice (RC), and sweet sorghum-rice (RS) as showed in Table 1. The fallow land, irrigated rice, corn and sweet sorghum were cultivated in dry season, while rainfed rice in all treatments was cultivated in wet season. Tillage was carried out for two times per crop. Incorporation of cow-manure was applied with the rate of 7.2 ton ha^{-1} in 2010. The total N fertilizer application rate was 80-120 kg N ha^{-1} for the rice, 80-100 kg N ha^{-1} for corn and 100-123 kg N ha^{-1} for sweet sorghum.

Table 1 Structure of land use change and experimental crop rotation design

Year	2000 - 2009	2010	2011	2012	---------------> 2030
Treat.					
RF	Abandoned Rice field	Fallow - Rice	Fallow - Rice	Fallow - Rice	----> Fallow - Rice
RC		Corn - Rice	Corn - Rice	Corn - Rice	----> Corn - Rice
RR		Rice - Rice	Rice - Rice	Rice - Rice	----> Rice - Rice
RS		Sorghum - Rice	Sorghum - Rice	Sorghum - Rice	----> Sorghum - Rice

2.3 Soil sampling and analysis

The soil samples were collected three replicate from each field plot treatments at soil depth 0-15 cm and were analyzed for organic matter (OM) by wet oxidation method (Walkley and Black, 1934). The soil organic carbon stock of each crop was estimated by equivalent soil mass method (Lee et al., 2009).

2.4 Short term and long term simulation

The site mode of DNDC model (version 9.3) used to estimate the short term and long term SOC stock change. The major ecological factors to drive model for simulating the SOC from crop rotation included climate data, soil properties and crop management practices. The climate data from Thai Meteorological Department (Ratchaburi station) used for spin up time simulation in period of abandoned rice field (2000-2009) and crop cultivation period (2010-2012). The future simulation (2013-2030) was conducted the climate data from PRECIS Climate model ECAM4 SRES B2. Soil physical and chemical properties were collected from laboratory analyses. Crop management data were collected from field experiment.

3. Results and discussion

3.1 Short term SOC stock change from field experiment

Soil organic carbon (SOC) stock at soil depth of 0-15 cm from abandoned rice field (2009) to 6th crop (2012) are given shown in Fig 1. In short term, the SOC stocks decreased from the initial soil through the land use change by the field preparation but generally increased with crop rotation. The lowest SOC stock was observed in fallow period of RF plot (6.32 Mg C ha^{-1}) whereas highest SOC stock was occurred in corn and sweet sorghum crop rotation as 12.48 and 14.62 Mg C ha^{-1}, respectively. In rice season, the SOC stocks of 4th and 6th crop in RR, RC and RS were significant higher than RF. The SOC stock from 1st to 2nd crop in RR was significant 33% increasing, as in anaerobic condition of flooded rice soil was slow decomposition, which indicated to maintain soil carbon. Witt et al. (2000) showed that wetland soil was significant sequestration of C and total N during two years of cropping under flooded condition. Moreover, the SOC stock from 2nd to 3rd crop in RF, RC and RS was significant increased 38%, 37% and 42%, respectively. The seasonal SOC stock was high in dry season as affected by the rapidly decomposition of organic matter in aerobic soil (Sahrawat, 2004), caused to present high SOC stock in the 3rd and 5th crop.

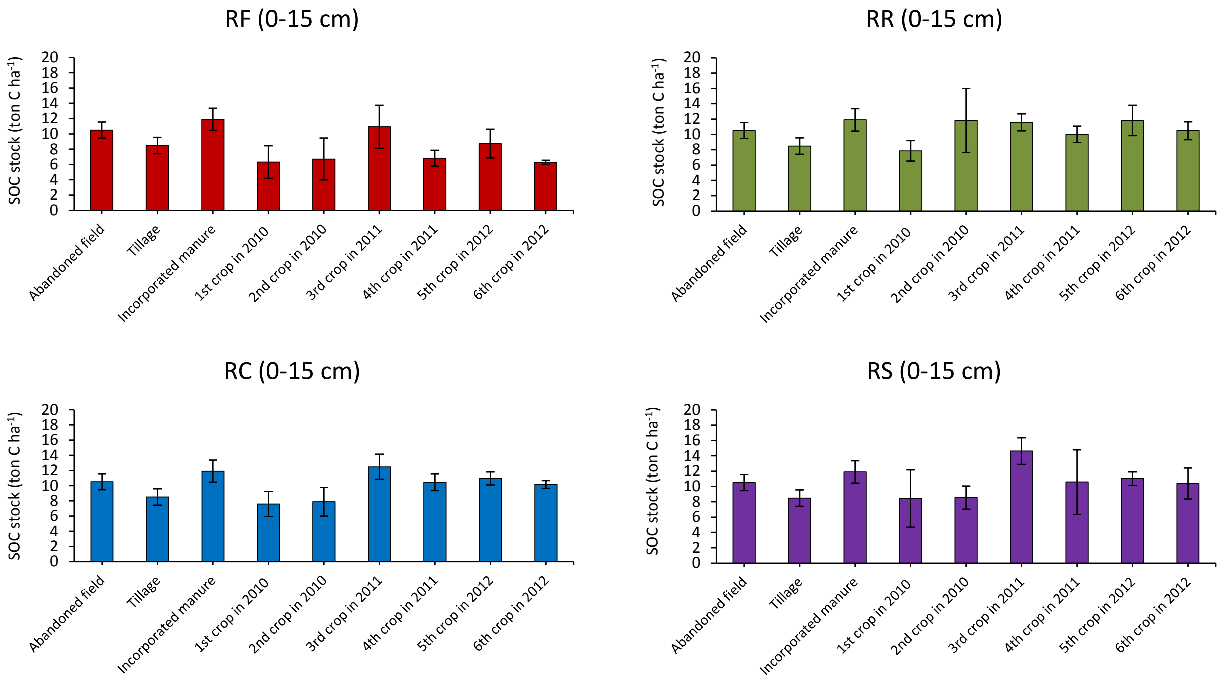

Fig. 1 Variation of SOC stock after field management and crop cultivation practices.

3.2 Long term simulation of annual SOC stock change

The annual SOC values at 0-20 cm of soil depth are ranging from 6.21 to 35.63 ton C ha^{-1} year^{-1} (Fig. 2). Long term spin up time simulation in period of abandoned rice field was not different decreasing from 2000 to 2009, but increasing after crop cultivation during 2010-2012. In long term of future prediction (2013-2030), SOC stocks in all crop rotation systems continuously increased during simulation year. The SOC stock in RR, RC and RS was higher 42%, 33% and 25% than baseline of fallow-rice crop system, respectively. Kukal et al. (2009) studied long term (32 years) of C sequestration in rice-wheat and maize-wheat system in Panjap (India), resulted the rotation of rice-wheat was 21-24 % of soil organic carbon (SOC) content higher than maize-wheat.

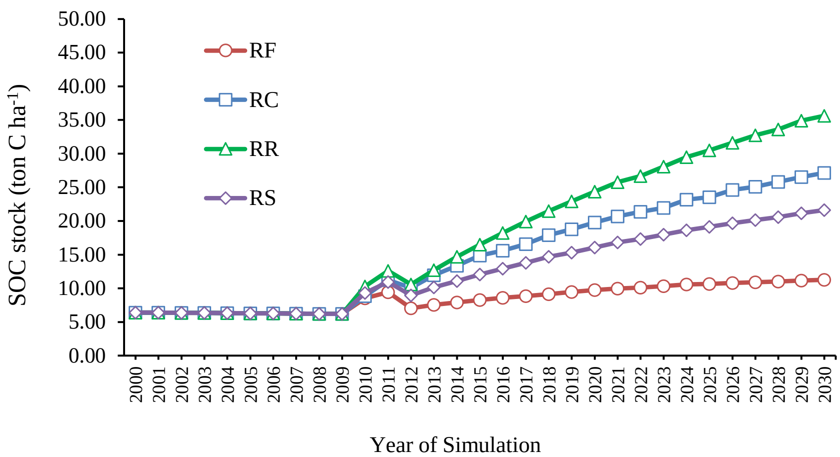

Fig. 2 Long term simulation of annual SOC stock from 2000 to 2030 by DNDC model.

4. Conclusion

Land use change from abandoned rice field to agricultural land through field preparation, manure and crop residue incorporation, and crop management practices were influenced to SOC stock change. Crop residues are the main source of organic carbon in the soil. The modeled results indicated that the SOC storage in rice-rice, corn-rice and sorghum-rice could able to maintain carbon into the soil than fallow land-rice during the simulated 20 years. There are in agreement with the long term projection of soil carbon stock change using DNDC model which confirmed that rotated of energy crop cultivation with rice can increase soil carbon in the long term.

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