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FIELD OBSERVATION OF THE TROPICAL PEAT SOIL RESPIRATION RATE UNDER VARIOUS GROUND WATER LEVELS

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SUMMARY

The peat soil respiration rate was measured under various ground water levels in southern Thailand. The respiration rate varied from 0.8 to 7.1 μmol CO_2 m^{-2} s^{-1} while the ground water level varied from 0.9 to -1.2m. The subsidence rates have been measured since 1983. These data show that the CO_2 emission rate due to peat soil respiration was from 13.7 to 18.9 Mg ha^{-1} y^{-1} in developed fields. In a conservation field, the rate was 7.5 Mg ha^{-1} y^{-1}. We formulated an equation that treats the ground water level as a variable for estimating CO_2 emission rate. Simulated CO_2 emission rate and peat subsidence correspond to the observed ones with considerable accuracy.

KEY WORDS: tropical peat soil, CO_2 emission, soil respiration, ground water level, subsidence of ground

INTRODUCTION

The total area of tropical peat soil in the world is approximately 380,000 km^2, and 280,000 km^2 are located in Southeast Asia (Rieley and Page, 2005). In the tropical peat swamp forests in this area, decayed vegetation matter, such as litter and fallen trees, are deposited in anaerobic flooded conditions. Therefore, organic decomposition is delayed, and as a result, the carbon in the air that is fixed by photosynthesis accumulates in the form of peat.

Because of a growing population and a shortage of food, these areas of tropical peat swamps have been converted into agricultural land since the 1970s. However, this development has not been successful, mainly because of the degradation processes in the peat swamps. To develop a peat swamp, an area is first drained. The depth of the peat layer varies considerably depending on its location but, in most cases, a marine clay layer exists underneath the peat layer. Marine clay contains pyrite. As a result, when the area is drained, sulfur contained in this pyrite is oxidized and the peat layer, which acts as a cultivated plough layer for crops, is changed to acid sulfate soil with high acidity. Most of these developed areas of peat soil have become unsuitable for agriculture and have been left as degraded land, such as secondary forests. Peat in degraded land decomposes quickly because of drainage, and field fires occur frequently during the dry season and are a major source of CO_2 emission. To prevent global warming, it is necessary to restore degraded peatlands to ecosystems that are able to store carbon and take urgent measures for ecosystem management of sustainable production. In this study, we conducted field observation to estimate the tropical peat soil respiration rate and the subsidence rate under various ground water levels.

OUTLINE OF INVESTIGATION SITES

To clarify the situation regarding CO_2 emission and the characteristics of carbon dynamics in peatland, investigations were conducted in the peatland of Narathiwat and Nakhon Si Thammarat provinces, located in the south of the Malay Peninsula, Thailand. The current status of the peatland of Narathiwat, Thailand, is shown in (Table 1). As the table shows, approximately 40 %, or 161 km^2, of the peatland has been developed. Part of the zone designated for development is used as agricultural land, such as oil palm and paddy fields. However, most development zones have not been used as agricultural land and have been left as degraded land, becoming secondary forests, dominated by *Melaleuca cajuputi*. The water environment of degraded land in these development zones is such that the ground water level varies from 10 to 30 cm during the rainy season and from -30 to -70 cm during the dry season, and the surface is exposed to extremely dry conditions. As a result, these zones are subject to frequent field fires.

Table 1. Peatland area in Narathiwat, Thailand.

	Development zone	Conservation zone	Preservation zone	Total
Bacho swamp	58.57	16.44	5.74	80.75
Kab Daeng swamp	32.95	-	-	32.95
To Daeng swamp	69.83	153.45	82.00	305.28
Total	161.35	169.89	87.74	418.98

(km^2)

RESEARCH METHODS

Measuring peat subsidence

The peat subsidence rate was measured at the Bacho swamp in Narathiwat province. A pole for measuring peat subsidence was installed at four locations of degraded land (Bacho1, Bacho2, Bacho3, and Bacho4) in the development zone and one location (Bacho5) in the conservation zone. Subsidence rates at the peat surface and the ground water level have been measured once a month since 1983. The pole for measuring peat subsidence is shown in (Fig. 1).

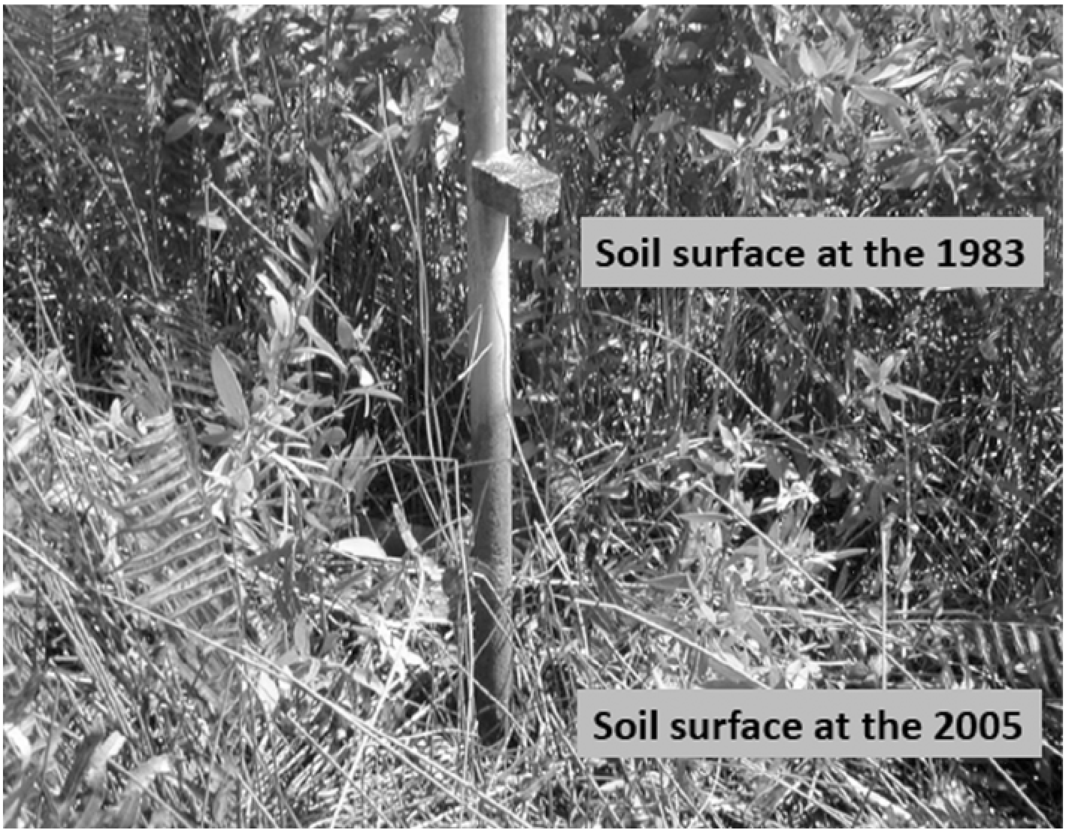

Figure 1. Measuring pole for measuring peat subsidence in Bacho, Narathiwat, Thailand (Bacho3).

Measuring soil respiration rate

CO_2 emission from the peat soil under flooded conditions was measured in the To Daeng natural peat swamp forest and in the drainage channels of the Bacho development zones. The soil respiration rate of the peat was measured in the peatland of the Nakhon Si Thammarat province. However, because Narathiwat province is currently under martial law because of political issues, field investigation activities could not be conducted, peat soil was taken from the Bacho swamp in Songkla province, and a soil box was filled with peat to measure its respiration rate. The peat soil box has the following dimensions: 93 cm height, 69 cm length, and 67 cm depth. To measure the soil respiration rate, continuous automatic measurement was conducted using LI-8100(LI-COR). However, because To Daeng swamp and Bacho were flooded throughout the year, LI-820(LI-COR) was used to measure the instantaneous values.

Carbon runoff from the peat swamp forest

In the peat swamp areas in To Daeng in the Narathiwat province, river water discharge data-taken from seven observation points was obtained from the Muno office of RID, Thailand. Samples of water from four outlet river locations and two inlet river locations were taken once a month between 2004 and 2006 to analyze the total organic carbon concentration and estimate the organic carbon runoff from the peat swamp forest.

RESULTS AND DISSCUSIONS

The measurement results for the soil respiration rate in the peatland of Nakhon Si Thammarat are shown in (Fig. 2). As the figure shows, a diurnal change in the soil respiration rate was apparent, which increased as the temperature increased. A correlation with soil temperature was apparent at a depth of 1 to 5 cm. The ground water level was -27 cm during the measurement period.

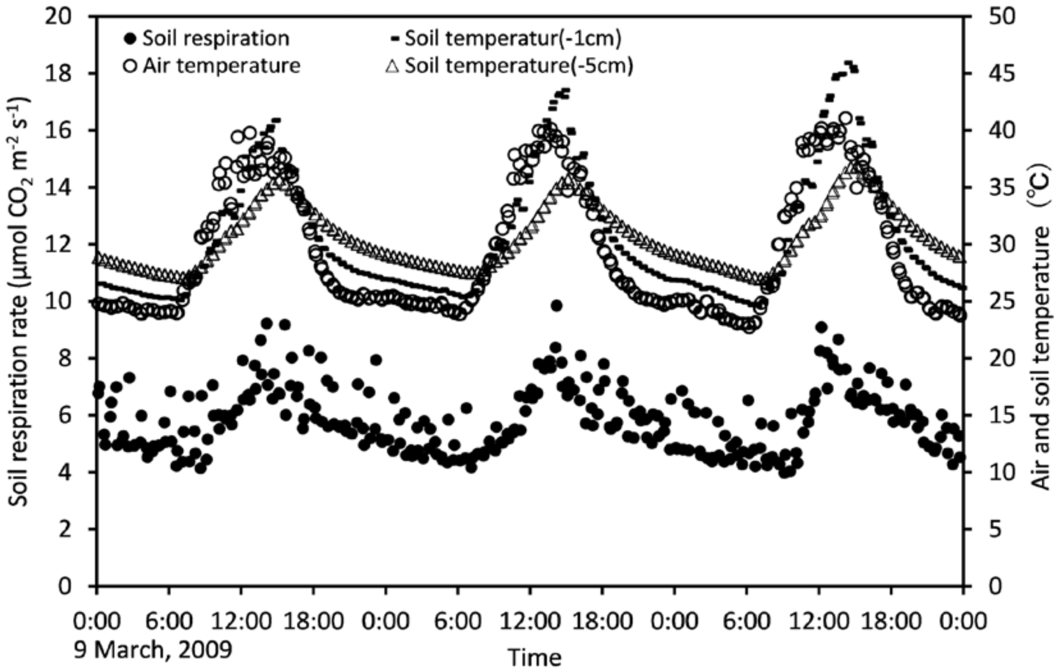

Figure 2. Diurnal change of soil respiration, air temperature and soil temperature.

The relationship between soil respiration rate or CO_2 emission rate and the ground water level is shown in Figure 3. A daily average was used for the soil respiration rate because a diurnal change in the respiration rate was apparent. However, an instantaneous value was used for the CO_2 emission rate in To Daeng and Bacho. Soil respiration rate varies significantly according to the ground water level, increasing as the ground water level decreases and changing from 0.8 to 7.1 CO_2 µmol m^{-2} s^{-1}, equivalent to from 3 to 27 MgC ha^{-1} y^{-1}. The CO_2 emission rate in To Daeng is high even under flooded conditions. This high value may be due to the effect of root respiration, because To Daeng is in a natural peat swamp forest where the average tree height is 23 m. The Nagano model was created using these results as shown in (Fig. 3) that is constant under flooding conditions regardless of water depth (i), linearly increases in proportion to the lowering of the ground water level (up to -30 cm) (ii), and is constant at the ground water level less than -30 cm (iii).

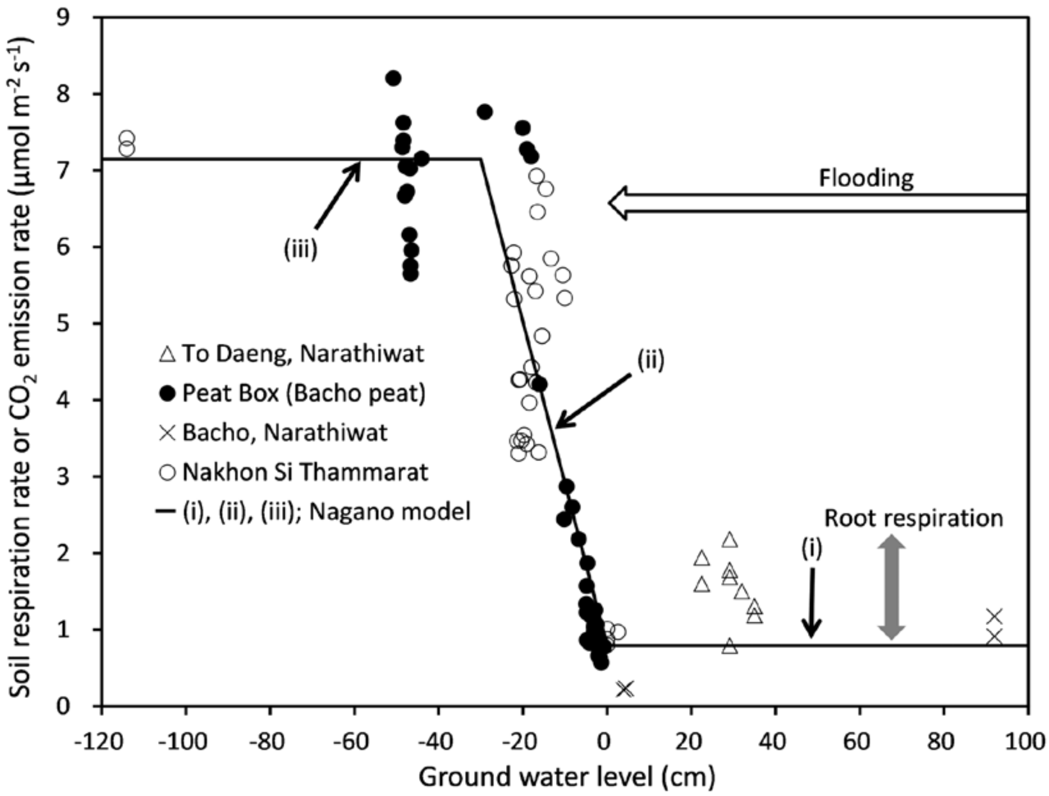

Figure 3. Relationship between soil respiration or CO_2 emission rate and groundwater level, and Nagano model.

The ground water level data from the Bacho peat subsidence measurement points were entered into the Nagano Model to estimate the carbon emission rate. Furthermore, the peat subsidence rate was estimated from the calculated carbon emission rate, carbon runoff, and carbon replenishment rate. It is reported that peat shrinks when the area of peat soil is drained for land reclamation (Couwenberg et al., 2009). Although the Bacho area where peat subsidence was measured was drained, it was flooded during the rainy season and the ground water level was not low throughout the year. Therefore, the impact of peat shrinkage due to drainage is not considered in this analysis. In the simulation that was conducted, physical properties of the soil used in the calculation were 0.18 g cm^{-3} bulk density, 0.8 organic content and 0.5 carbon content in the organic substance. Carbon runoff due to water discharge from the peatland were 1 Mg C ha^{-1} y^{-1}, and the peat replenishment rate due to litter fall in the degraded peatland (secondary forest) was 1.45 Mg C ha^{-1} y^{-1}(unpublished by T. Yamanosita).

The results for the conservation zone at Bacho5 are shown in (Fig. 4). Simulated peat subsidence over 25 years corresponds to the changes in observed peat subsidence with considerable accuracy. In addition, the results for the development zone at Bacho1 are shown in (Fig. 5). 90 cm of peat subsidence occurred in the past 20 years. The development zone has been frequently affected by field fires. Simulated peat subsidence corresponds to the changes in observed peat subsidence with correction of fire, as shown in the figure.

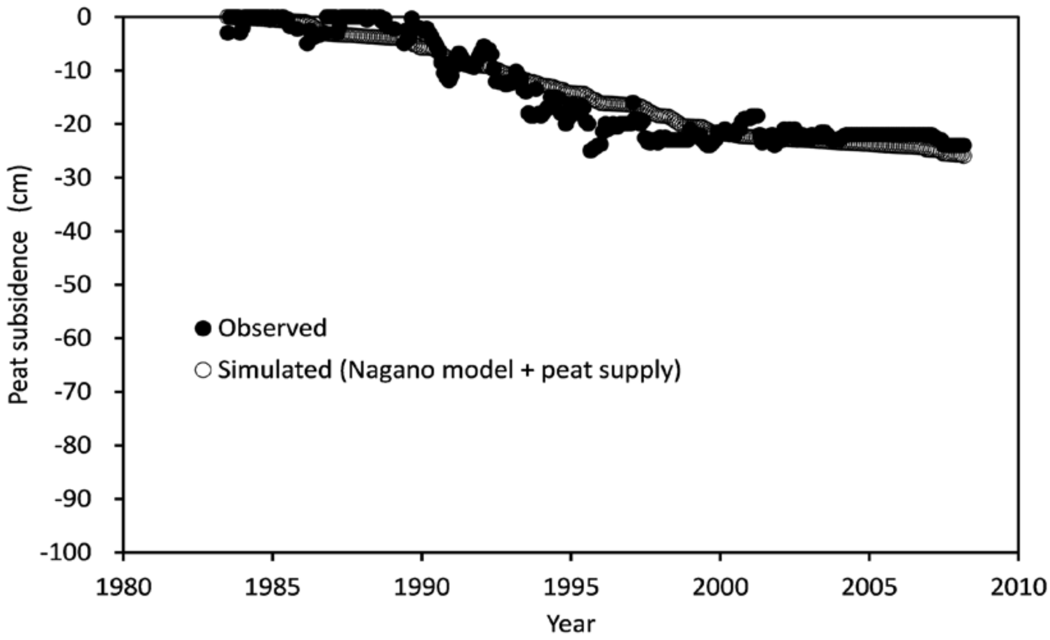

Figure 4. Changes of observed peat subsidence at conservation zone, Bacho5 and simulated peat subsidence by using Nagano model.

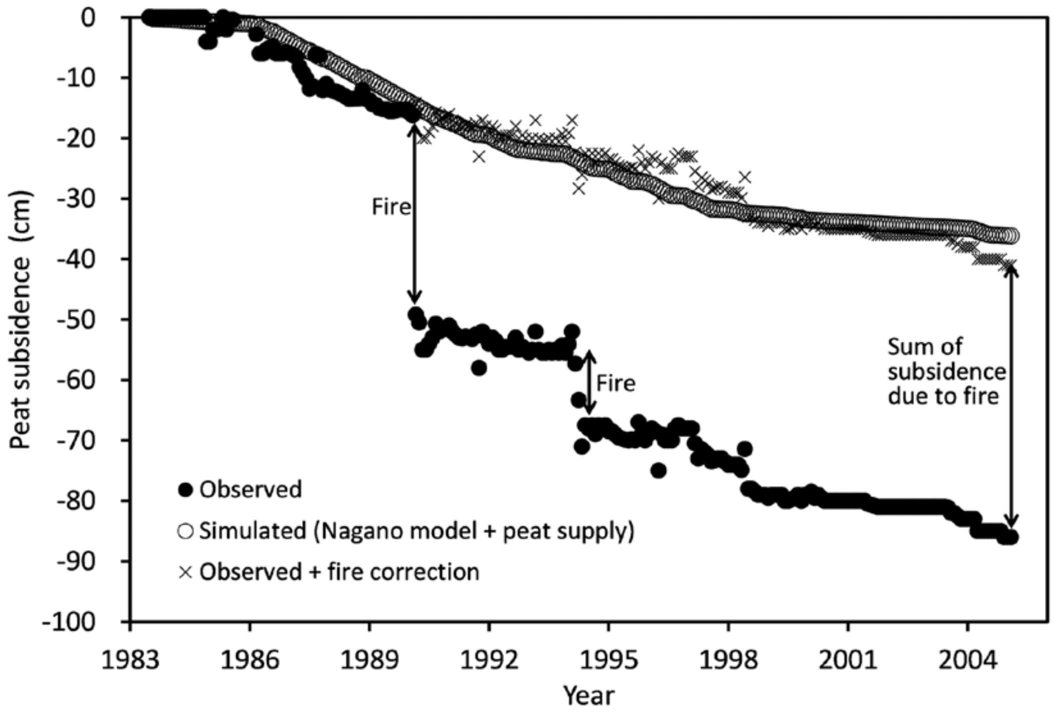

Figure 5. Changes of observed peat subsidence at development zone, Bacho1 and simulated peat subsidence by Nagano model.

(Table 2) shows the CO_2 emission in the observation period obtained from the Nagano model and the CO_2 emission estimated from observed subsidence. Simulated CO_2 emission rate by the Nagano model gave good agreement with soil respiration rate estimated from observed subsidence. Furthermore, the soil respiration rate varies significantly depending on the observation point. It is assumed that this is because of the water condition, which is significantly affected by the flooding periods. Bacho5 has the lowest soil respiration rate and is in the conservation zone, where flooding period is 68 %. Although some fires happened in this area, the fire did not reach peat soil. In the development zone, field fires break out frequently. This loss from field fires results in from 50 to 60 % of total CO_2 emission.

Table 2. CO_2 emission estimated from Nagano model and observed soil subsidence.

Observation point	Nagano model	CO2 emission estimated from subsidence			Flooding period (%)	Observation period
	CO_2 emission	(1) Soil respiration	(2) Field fire	(1)+(2) Total		
Bacho1	12.5	14.1	15.0	29.1	46.9	Jun. 1983 to Feb. 2005
Bacho2	15.0	13.7	8.9	22.6	35.9	Jun. 1983 to Aug. 2000
Bacho3	15.7	17.3	9.1	26.4	29.9	Jun. 1983 to Jan. 2006
Bacho4	18.7	18.9	19.3	38.2	19.9	Nov. 1989 to Oct. 2000
Bacho5	8.0	7.5	0.0	7.5	67.8	Jun. 1983 to Mar. 2008

(Mg ha^{-1} y^{-1})

CONCLUSIONS

1) Drained and degraded tropical peatland is a major source of carbon emission. In particular, the ratio of CO_2 emission caused by field fire is extremely high.
2) The peat soil respiration rate fluctuates significantly with water conditions, from 0.8 to 7.1 CO_2 μmol m^{-2} s^{-1}, equivalent to from 3 to 27 Mg C ha^{-1} y^{-1}.
3) CO_2 emission from peat soil and peat subsidence can be estimated with considerable accuracy based on the ground water level data by using the Nagano model.
4) It is vital to control the tropical peatland under flooding condition throughout the year so it can fully function as an ecosystem that stores soil carbon.

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