SIMULATION OF METHANE EMISSION FROM RICE FIELD IMPLEMENTED WITH ALTERNATE WETTING AND DRYING (AWD) BY DNDC MODEL

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A THESIS REPORT SUBMITTED AS A PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEER IN ENVIRONMENTAL TECHNOLOGY AND MANAGEMENT

THE JOINT GRADUATE SCHOOL OF ENERGY AND ENVIRONMENT AT KING MONGKUT'S UNIVERSITY OF TECHNOLOGY THONBURI

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ABSTRACT

Methane (CH_4) emissions from rice fields constitutes the highest proportion of the agricultural total greenhouse gas emissions in Thailand. Recently, alternative wetting and drying (AWD) technique has been introduced as one of the promising mitigation techniques. The objective of this study is to evaluate the potential of denitrification-decomposition (DNDC) model to simulate CH_4 emission and reduction by AWD. The results indicate that DNDC was able to simulate well the emissions and reduction of CH_4 under both conditions. However, the ability to simulate CH_4 emission varies on the site characteristics. The result of CH_4 emissions from observation six study sites under continuous flooded and AWD conditions were 112.83 and 92.48 kgC/ha/day, respectively. Thus, applying AWD was resulted in CH_4 emission reduction from observation around 57%. The results of simulation CH_4 emission using the DNDC model with the obtained data from six study sites were 100.68 and 81.89 kgC/ha/day, respectively. This is within ±90% of the observed emission. It was concluded that DNDC can reasonably simulate CH_4 emissions and reduction when the field is treated with AWD technique. However, because the simulation outputs are highly sensitive to input parameter, accurate input parameters is required to ensure its applicability. In addition, validation is required for further application of DNDC to estimate mitigation potential under AWD.

Keywords: Methane emission; Rice filed; Denitrification-decomposition (DNDC) model; alternative wetting and drying (AWD)

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CHAPTER 1

INTRODUCTION

1.1 Rationale/Problem statement

Global warming caused by greenhouse gas emissions into the atmosphere is an important problem. Warming the atmosphere can lead to climate changes such as changes in the amount and distribution patterns of rainfall, increased frequency of droughts and floods, and rise in sea level. To enhance cooperation among world community, countries have agreed to reduce greenhouse gas emissions from sources and to increase removal by sinks. This agreement is the basis of United Nations Framework Convention on Climate Change (UNFCCC), implemented since 1990. The objective of the convention is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interferences with the climate system. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Currently, the total greenhouse gas emission of the United Nations Framework Convention on Climate Change (UNFCCC) from parties not included in Annex I (1994) is 11,735,437 Gg CO_2 e, including CO_2: 63.07%, CH_4: 25.78% and N_2O: 11.45%. The source of greenhouse gas can devide into 5 sectors including energy, industrial process, agriculture, waste and land use-land use change forest and each sector emitted 63%, 6%, 25%, 4% and 2% respectively (UNFCCC, 2005, Figure1.1, 1.2).

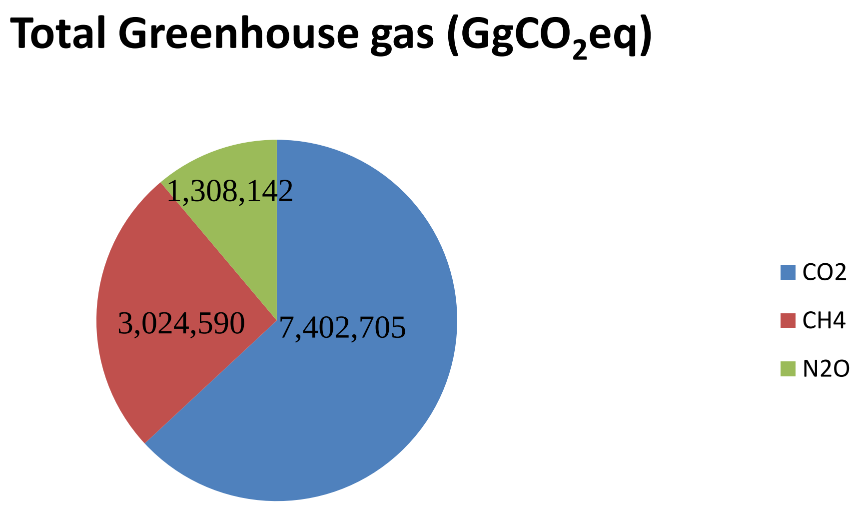


Figure 1.1 Total greenhouse gas emissions for the year 1994 (UNFCCC, 2005).

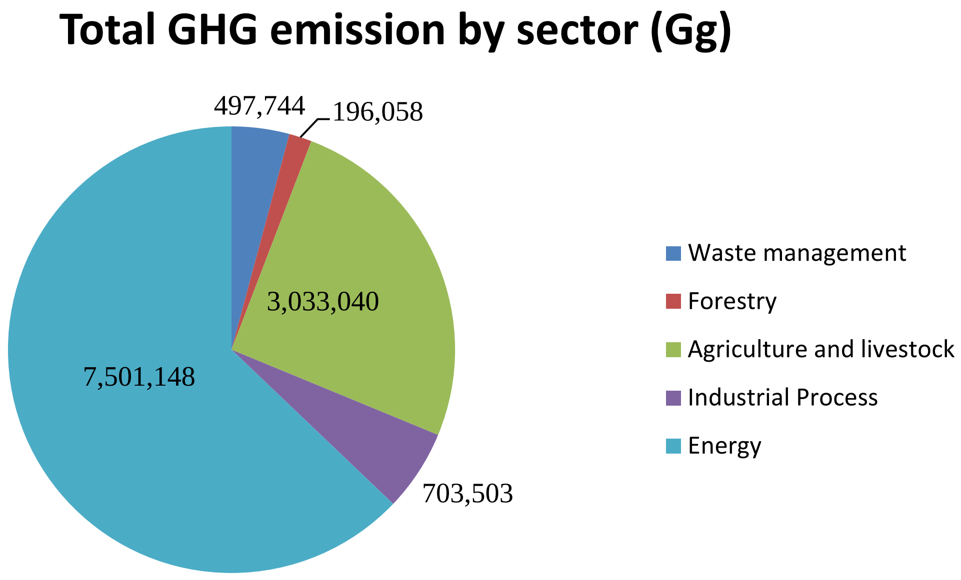


Figure 1.2 Total greenhouse gas emissions from sectors in 1994 (UNFCCC, 2005).

Thailand greenhouse gas emissions was 229.08 million tons CO_2e in 2000. The main emission comes from energy, agriculture and livestock, industrial process waste and forestry, respectively (Figure. 1.3).

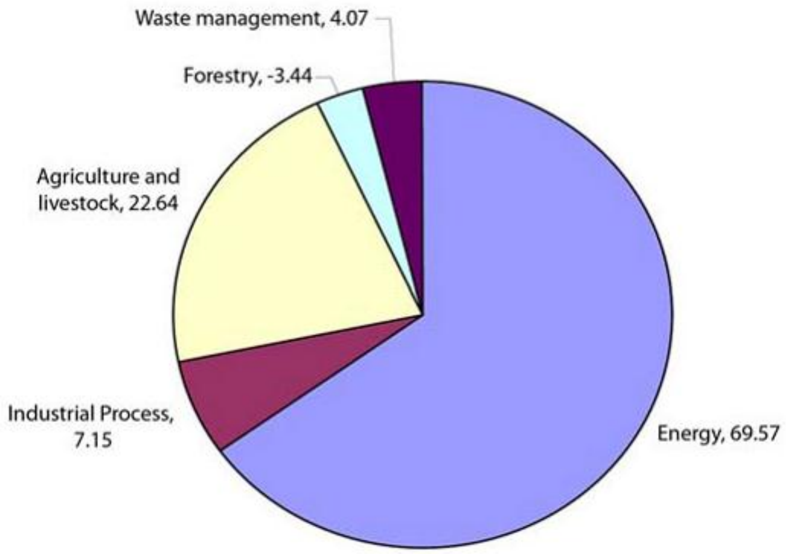


Figure 1.3 Thailand GHG emissions by source in CO_2e for year 2000 (%) (ONEP, 2000)

Emissions from the agricultural sector was second highest after the energy sector. Within the sector, rice field is the most important source of greenhouse gas emission (CH_4). Therefore, greenhouse gas mitigation in rice field may be one of the options that would contribute to the national emission reduction target.

Recently, one of the promising options for mitigating CH_4 emission reduction in rice fields is AWD technique. The main aspect of this technique is keeping water at the level that usually inhibits methanogenesis and at the same time is sufficient for plant growth (usually 15 cm below surface of the soil). Besides reducing CH_4 emission, it also helps save water use. This technology has not been tested under Thai conditions. However, since 2013, the potential of AWD to mitigate CH_4 emission in Thailand has been tested by Rice Department. With these data it is now possible to carry out the investigation through modeling work to enhance our understanding of mitigation potential and the effects of AWD on other aspects of rice field biogeochemistry.

In this study, DNDC model was used to simulate the amount of CH_4 (CH_4 emissions from rice cultivation). This model is one of those being studied in details at JGSEE and it can adapt for planning for cultivation (water management in rice field, fertilization, tillage, etc.). Therefore, this project investigated the application of AWD and DNDC model for mitigation and estimate greenhouse gas emission from rice field in Thailand.

1.2 Literature Review

1.2.1 The potential of water management in mitigation methane emissions

The existence of flooded water is the important factor causing the production and emissions of the greenhouse gas CH_4. Therefore, water management is the important factor for mitigation CH_4 emission. In the past, there have been various studies demonstrating that water managements are indeed effective in reducing CH_4 emission.

Li *et al*. (2002) studied the CH_4 emission mitigation by water management in China's rice paddies during 1980–2000 under midseason paddy drainage and continuous flooding conditions. It was found that CH_4 was significantly emitted from continuous flooding field more than a midseason drainage field. During 1980-2000, CH_4 emission was mitigated over 5 $TgCH_4\ yr^{-1}$, by this midseason drainage practice.

Zai (2001) studied new irrigation regimes for sustainable water productivity. They found that the main irrigation can be divided into three kinds that have very high efficiency in reducing methane emission. These include the shallow water depth with wetting and drying (SWD), the alternate wetting and drying (AWD) and the semi-dry cultivation. When compare among these three irrigation schemes, the alternate wetting and drying (AWD) has higher irrigation efficiency and rice yields than shallow water depth with wetting and drying (SWD) (Table 1.1, 1.2).

Table 1.1 Irrigation water use (M, m^3/ha) under different irrigation systems (Zai, 2001).

Year	Term	Early rice			Late rice			Whole year		
		TRI	SWD	AWD	TRI	SWD	AWD	TRI	SWD	AWD
1997	M (m^3/ha)	2390	2190	1785	8100	7890	7385	10490	10080	9710
	Percentage	100	91.6	74.1	100	97.4	91.2	100	96.1	92.6
1998	M (m^3/ha)	2750	2439	2415	6743	5867	6341	9493	8306	8756
	Percentage	100	88.7	87.8	100	87.0	94.0	100	87.5	92.2
Average	M (m^3/ha)	2570	2312	2100	7422	6879	6863	9992	9193	9233
	Percentage	100	90.0	81.7	100	92.7	92.5	100	92.0	92.4

** TRI = traditional irrigation regime

SWD = the shallow water depth with wetting and drying

AWD = the alternate wetting and drying

Table 1.2 Rice yields (kg/ha) of different irrigation systems (Zai, 2001).

Year	Yield (kg/ha)		
	TRI	SWD	AWD
1997	4335	4424	4380
1998	5766	5772	5919
1999	5504	7970	7995
Average	5201	6055	6098
Percentage of average	29.97	34.891	35.139

** TRI = traditional irrigation regime

SWD = the shallow water depth with wetting and drying

AWD = the alternate wetting and drying

Towprayoon and Smakgahn (2003) observed the mid season drainage and multiple drainage effects in Samutsakorn rice fields Thailand. They found that the water drainage could reduce CH_4 emission, but rice yields was also decreased a little from traditional rice field. Besides, the water drainage has the stimulating effect of N_2O emission.

Li *et al*. (2005) studied water management of rice field in China by integrating between GIS with DNDC model under water management condition in two scenarios: continuous flooding and midseason drainage.They found that water management could reduce CH_4 emission around 40% or 50% TgCH_4/ yr of total global methane from rice field. In contrast, changing water management from continuous flooding to midseason drainage could increase N_2O from Chinese rice paddies by 0.15 Tg N/yr (around 50% increase).

Chumvong (2008) studied the mitigation potential of CH_4 emissions under three water management conditions; shallow water depth (SWD) (water depth around 10 to 15 cm), alternate wetting and drying (AWD) (water depth around 5 to-15 cm) and traditional irrigation (water depth around 20 to 30 cm) in the Maeklong river basin, Thailand. The best mitigation option for CH_4 emissions was AWD, followed by SWD and traditional irrigation,respectively. In drainage water to public canals, nitrate and phosphate concentration decrease with traditional irrigation. Furthermore, it can be saving water around 40 % - 63 % and maintain yield. Therefore, water management in rice field has potential for mitigation CH_4 emission and improving quality of water.

Nalley (2014) studied the economics of AWD and greenhouse gas emissions (CH_4) in a rice field. They found that AWD can be saving water around 20-70% and mitigate CH_4 emissions around over 50% (when compared with continuous flooding). However, they found that the rice yield had also decreased around 10%.

1.2.2 Simulating the methane emissions by the Denitrification – Decomposition (DNDC) model

Recently, researchers have developed various models for estimating greenhouse gas emissions from rice fields. The DNDC model is well known in Asia such as China, India, Japan, etc.

Towprayoon and Smakgahn (2003) studied and simulated the CH_4 emission in paddy field using process-based model and empirical model in Smutsakorn, Thailand under the drainage condition. They found that the accuracy of the DNDC model and empirical model were about 50 to 153% and -30 to 30%, respectively. Therefore, they suggested that both models should be improved for higher efficiency.

Cai *et al*. (2003) studied the trace gas emissions (CH_4, N_2O and NO) from cropping systems in Japan, China and Thailand using the DNDC model. They found that the seasonal patterns of CH_4 and N_2O emission simulated by the DNDC model and that from the observation are different. They suggested to improve the model simulation by using local soil properties and management. However, the DNDC model satisfies the simulations of variation of greenhouse gas emission from cropping system.

Babu *et al*. (2005) studied CH_4 emissions in India by simulating and using the DNDC model and by observation using manual chamber flux measurements. They reported that the sensitive parameters to CH_4 emission are soil texture, pH, organic C content and the quantity of aboveground biomass. They concluded that the DNDC model has potential for estimating greenhouse gas emission and application for investigating the impacts of climate change.

Fumoto *et al*. (2008) revised a process-based biogeochemistry model (DNDC) to simulate CH_4 emissions from rice paddy fields under various residual management and fertilizer regimes in Japan and China. They reported that the revised DNDC indicate the effects of soil electron donors and acceptors and it can be quantitatively estimated CH_4 emissions from rice fields under a range of conditions.

Qi *et al.* (2009) studied C sequestration strategies affecting N_2O and CH_4 emissions by using the DNDC model under climate, soil and crop condition from the six agricultural sites across China. They found that firstly, the increases in sequestration rate increase may affect to N_2O and CH_4 emission. Secondly, they found that fertilization has effect to N_2O production. They concluded that the DNDC model could help investigation and developmental management at large regional scales.

1.3 Objectives

To simulate the emissions and mitigation of methane by denitrification – decomposition (DNDC) model under AWD conditions.

1.4 Scope of Research Work

This work simulates the emissions and the mitigation potential with AWD techniques for rice field CH_4. Input data for simulation of the emission and mitigation of CH_4 from AWD field were obtained from 6 locations of the Rice Department Research Stations during December 2013 until April 2014, covering one crop cycle (dry season). Other auxiliary data were also available from the same source.

CHAPTER 2

THEORIES

2.1 Greenhouse gases, the greenhouse effect and climate change

The energy from sun, solar radiation, reaches to Earth's surface and reflects back to space in infrared radiation form, but greenhouse gases in the Earth's atmosphere can trap infrared radiation (heat energy). The effects of this heat energy trapping is the atmospheric temperature will be increased. This primarily phenomenon is termed “greenhouse effect”. The excess presence of greenhouse gases in the atmosphere when compared to its natural levels will lead to “excessive heat” trapped in the atmosphere and this is known generally as “global warming”. There are concerned that the global warming will bring about various aspects of climate change that adversely affect to the Earth and human well-being. These are, for example, natural disaster (flooding, drought, earthquake) changes in pattern of rain, temperature, moisture, seasonal patterns. The main sources of greenhouse gas emissions is human activity, especially during fossil fuel combustion. The important greenhouse gases are CO_2, CH_4, N_2O and CFC. Each gas has the different global warming potential as shown in Table 2.1.

Table 2.1 Global warming potentials of major greenhouse gases (IPCC, 2014).

Species	Lifetime (years)	Global warming potential
Carbon dioxide (CO_2)	200-400	1
Methane (CH_4)	9-15	28
Nitrous oxide (N_2O)	120	265
chlorofluorocarbon (CFC)	100	10,200

2.2 Rice field as the most important source of methane emission in Thailand

In terms of global warming potential CH_4 is the second after CO_2. Out of the total emissions, it is the second emitted gas in Thailand with the emission amount in 2000 of 1,977 Gg. Of the total emissions, more than 70% came from agriculture (Table 2.2,2.3), with rice cultivation accounting for a major proportion (ONEP, 2000).

Table 2.2 The methane emissions in Thailand divide by sources (ONEP, 2000).

Source	Methane (CH_4) (Gg.)
Energy	413.9
Industrial process	6.4
Agriculture	1,977
Land-use change and forestry	10.4
Waste	393.8

Table 2.3 The methane emissions from agriculture in Thailand (ONEP, 2000).

Agriculture	Methane (CH_4) (Gg)
Enteric fermentation	393.3
Manure management	122
Rice cultivation	1,425.7
Field burning of agricultural residues	35.9

2.3 Process of methane production in rice fields

CH_4 is produced under anaerobic decomposition of organic matter by methanogenic bacteria (Fumoto *et al.*, 2008). The anaerobic conditions generated in wetland rice fields prevents oxygen diffusion from the atmosphere into the soil. In soil, many microorganisms use electron acceptor in the oxidation - reduction process, so that oxygen is also depleted very rapidly. Therefore the redox potential (Eh) which indicate the oxidation-reduction conditions in the soil gradually drops. The redox potential that initiates the production of CH_4 is usually below -150 mV (1996 IPCC Guidelines, 1996) (shown in Table 2.4 and Figure 2.1).

Table 2.4 The oxidation-reduction process and Eh value (Chidthaisong, 2000).

Oxidation-reduction process	Eh value (pH 7,25 C°) (mV)
O_2+ $4H^+$+ $4e^-$ => $2H_2O$	816
NO_3^-+2H++$2e^-$ => N_2O-+H_2O	412
MnO_2+$4H^+$+$2e^-$ => Mn_2++$2H_20$	396
$Fe(OH)^3$+$3H^+$+e^- => Fe^{2+}+$3H_2O$	-182
SO_4^{2-} +$10H^+$+$8e^-$ => H_2S+$4H_2O$	-215
CO_2+$8H^+$+$8e^-$ => CH_4+$2H_2O$	-244

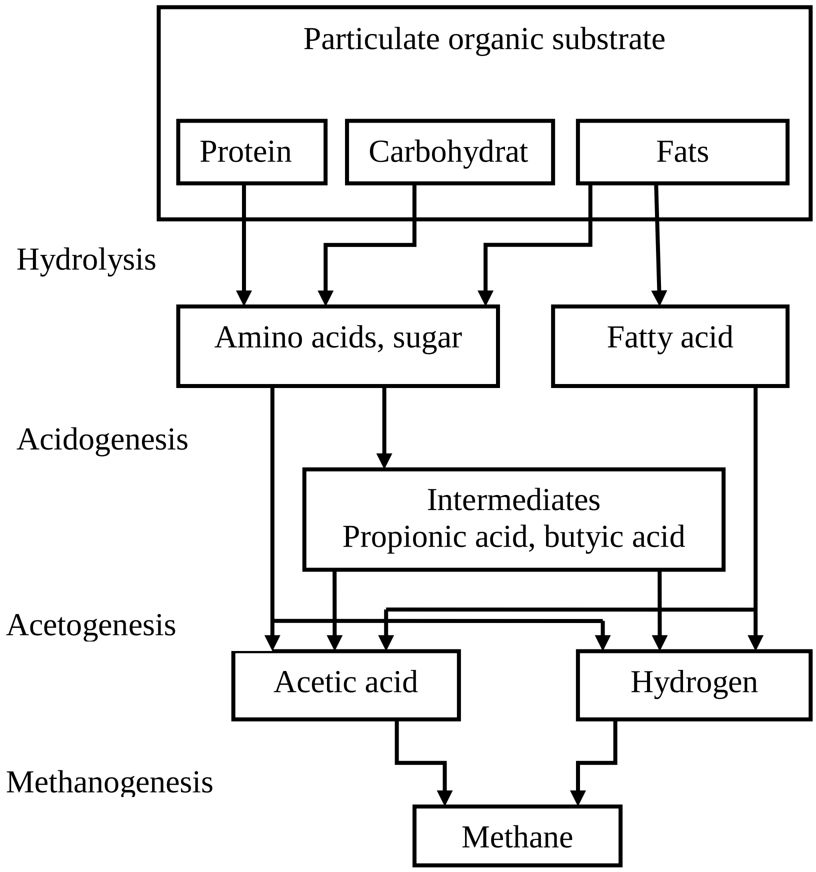


Figure 2.1 Methane production in rice fields by decomposition process (Le Mer *et al.*, 2001).

The first stage is called Hydrolysis process. During this stage, bacteria convert the particulate organic matter (polymer) into liquefied monomers such as protein, carbohydrate transform to amino acid monosaccharides respectively.

In the second stage, Acidogenesis, bacteria utilize the products from the first stage and convert to short chain volatile acids, ketones and alcohols. The acidogenesis stage products are for example propionic acid (CH_3CH_2COOH), and butyric acid ($CH_3CH_2CH_2COOH$).

In the third stage, Acetogenesis bacteria convert the remaining products from the acidogenesis stage into the hydrogen, carbon dioxide and acetic acid (CH_3COOH). The acetic acid (CH_3COOH) is an important substrate for producing CH_4 because 70% of CH_4 produced is converted from the acetic acid (CH_3COOH) (as shown Equation 1).

The fourth and last stage, Methanogenesis process, methanogenic bacteria convert the hydrogen, carbon dioxide and acetic acid (CH_3COOH) into CH_4 and CO_2. It is common to find that in natural habitats about 70% of CH_4 produced comes from acetic acid conversion (Eq. 1), and the rest comes from CO_2 reduction (Eq. 2).

$$CH_3COOH \rightarrow CO_2 + CH_4 \qquad \text{(Eq. 1)}$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \qquad \text{(Eq. 2)}$$

2.4 The transfer of methane from the soil to the atmosphere

CH_4 from soil can be transfered by three processes to the atmosphere: vascular transport process, ebullition process and diffusion process. Each process has different pathways and factors to controlling the transfer CH_4 (Figure 2.2).

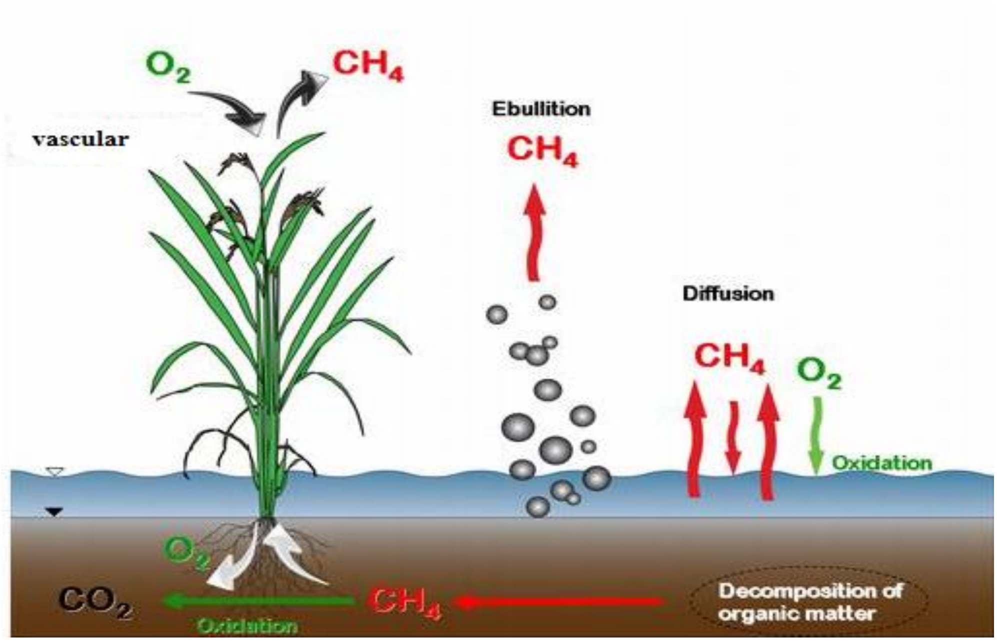


Figure 2.2 The process of CH_4 transfer from soil to the atmosphere (Brevik, 2012).

Vascular transport is a particularly important process in the transportation of CH_4 through rice plants, from the soil into the atmosphere. Rice plants transfer CH_4 from the rhizosphere to the atmosphere through aerenchyma. Aerenchyma has a function like a conductive tube. Aerenchyma of rice plants transfers O_2, CO_2, CH_4 and other gases in rice plants. CH_4 is emitted into the root cortex through aerenchyma and released into the atmosphere through the leaves. Basically, the CH_4 transportation capacity of rice plants depends on height of rice plants, aerenchyma size and leaves type. These differ among rice cultivars. Therefore, the selection of rice plant cultivars which are less efficient in transporting CH_4 could be an option for reducing CH_4 emissions. The other process, “ebullition”, is the release of CH_4 through bubbling into the atmosphere. These bubbles are the results of CH_4 build up over time in the soil, which occurs during the transportation of CH_4 directly to the atmosphere. The amount of emitted CH_4 through the ebullition process depends on many factors, such as, depth of floodwater, speed and direction of wind, atmospheric pressure, solar radiation and water temperature.

Generally, the total CH_4 emissions from ebullition is not more than five percent of the amount of CH_4 emitted by rice fields. However, during the beginning period of rice plantation when aerenchyma size and leaves are small, the CH_4 emission from ebullition is important because CH_4 cannot be transferred by the vascular transport process. Finally, there is the diffusion process, which is the movement of CH_4 through soil and water into the atmosphere (Figure. 2.2). However, the diffusion of gases in water is not as easily as in air. Therefore, the diffusion of CH_4 from rice fields depends on the CH_4 concentration in the floodwater, as well as the speed and direction of wind.

2.5 Factors affecting methane emission from rice fields

2.5.1 Soil properties

Soil chemical and physical properties can influence the emissions of CH_4 from rice fields in various ways. The redox potential (Eh) that indicates the oxidation – reduction conditions suitable for CH_4 production by methanogen bacteria is approximately -150 to -160 mV, and this is in part related to soil property. Higher Eh has usually higher oxidative conditions that are not suitable for CH_4 production and thus only small amounts of CH_4 emissions could be expected. Others, such as pH and soil texture have also reported to affect the production and emissions of CH_4 in rice fields, by affecting to Eh and the amount of electron acceptors (Chomvong, 2008) (Figure. 2.3).

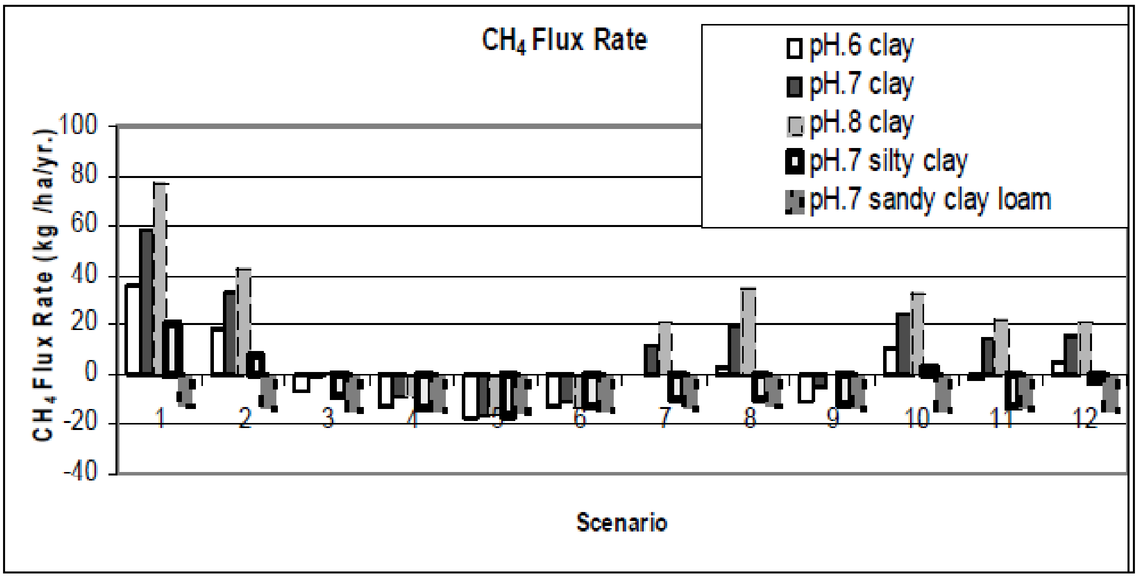


Figure 2.3 The comparison between methane emission from various scenarios and pH and texture of soil (Chumvong, 2008).

2.5.2 Temperature

Temperature is the important factor that affects to production, consumption and transfer of CH_4, especially for the activity of microorganisms. The optimal temperature for methonogens is around 30 °C. At high temperature, particularly more than 30 °C, CH_4 production, mineralization and availability of carbon substrate is reduced. CH_4 transport and emission also depends on temperature. The Daily CH_4 emission varies with the difference of daily temperature (Jain *et al*., 2004).

2.5.3 Fertilizer

Fertilizer is one of the factors that affects to pH of the soil, amount of microorganisms, and the activity of methanogens. CH_4 production is decreased from the competition for electron acceptors with nitrate and sulfate reducers. Thus, some fertilization type such as nitrogen, sulfate which are applied to soil will reduce CH_4 production and emission.

2.5.4. Rice varieties

Rice has different varieties types such as lowland rice, floating rice, upland rice, red rice, khao'yipun and etc. (BRRD, 2009). Variety characteristics such as growth duration, height, shape of the leaf and aerenchyma size vary among varieties. Since these characteristics are related to the gas transport of rice plant, CH_4 emissions have been reported to be different among rice varieties (Punkeaw, 2003).

2.5.5 Water Management

Water is important for rice growing (Table 2.5). For water management, the irrigation method of traditional rice cultivation is continuous flooding which consumes a lot of water and is the main cause that stimulates CH_4 production. Oxygen cannot diffusion or difficult to diffuse from atmosphere to soil with the existence of flooding water. CH_4 emission, thus, usually increase with the period of flooding in rice field and rice growing. Therefore, if the duration of flooding can be reduced, the emissions of CH_4 are also reduced (Yoyrurob, 2000).

Table 2.5 Water demand of rice growing period (Wanichpongpan, 1993).

Rice growing period	Water & Demand of rice plant	Comment
Start Planting	Very much	More submerged water
Tillering	Not too much	Only moisture of rice field, soil rust not submerge
Maturing	Very much	Irrigation or submerged water
Flowering	Litter	Only moisture of rice field, soil must not be submerged
Young flowering	Not too much	Only moisture of rice field, soil must not be submerged
Old flowering/Harvesting	Less	Stop flowing/drainage

Various researchers have started to search for new technology for water saving irrigation (WSI) and mitigation of CH_4 emissions by irrigation in rice field. WSI includes various techniques such as, midseason-drainage, combining shallow water depth with wetting and drying (SWD), alternate wetting and drying (AWD) and semi-dry cultivation (SDC), and etc.

2.5.5.1 Midseason-drainage

Midseason-drainage is a water draining activity during maturity stages. During period oxygen from atmosphere can be transferred into the soil. Therefore, it could reduce CH_4 emission around 10-80 %, while maintaining a reasonable rice yield, but there are cause an increase in N_2O rice field (Li, 2005).

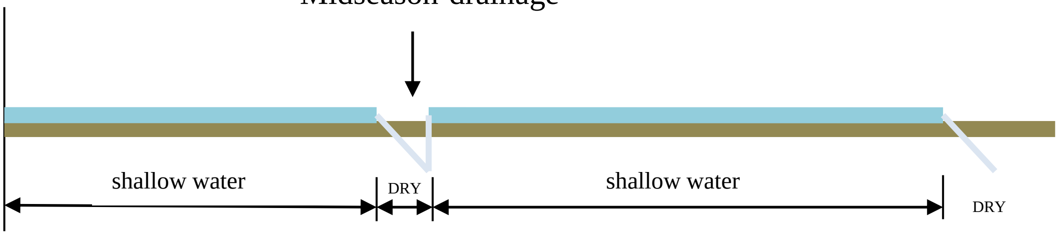
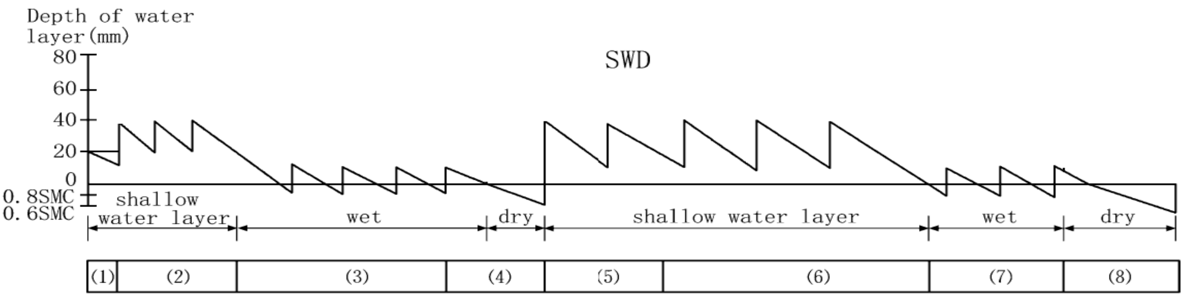


Figure 2.4 Graphical description of midseason- drainage (Zai, 2001).

2.5.5.2 Combining shallow water depth with wetting and drying (SWD)

SWD is a water depth control strategy in rice field. Firstly, during transplanting, seedling, booting and heading & flowering stage the water depth is controlled to be around 10-60 mm. with saturated moisture content (SMC) around 60 – 80 %. Secondly, during the early & mid stages of tillering, milk ripening stage, shallow water depth 10-30 mm is maintained with SMC around 80 %. During the rest of growing season the field is kept dry (Zai, 2001). SWD can reduce CH_4 emission around 20.2 % (chomvong, 2008).



(1) Transplanting, (2) Seedling, (3) Early & mid stages of tillering
(4) Late stage of tillering, (5) booting, (6) Heading & Flowering,
(7) Milk ripening, (8) Yellow repening

Figure 2.5 Graphical description of combining shallow water depth with wetting and drying (Zai, 2001).

2.5.5.3 Semi-dry cultivation

Semi-dry cultivation is no water depth in rice fields that maintained water only during vegetation growth.

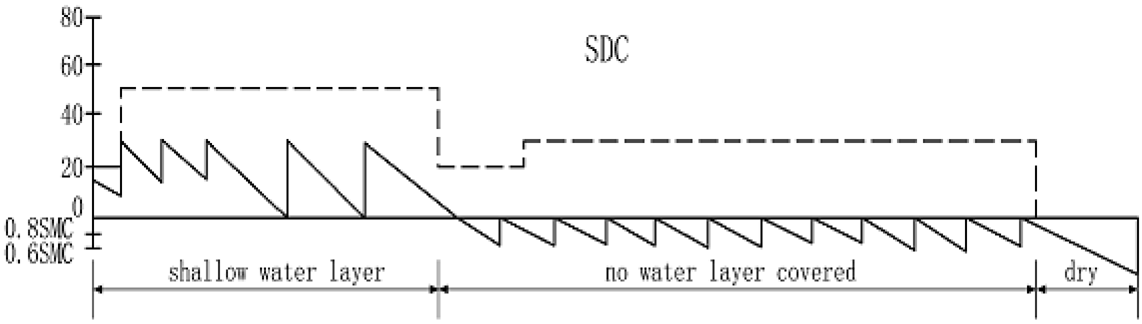


Figure 2.6 Graphical description of semi-dry cultivation (Zai, 2001).

2.5.5.4 Alternate wetting and drying (AWD)

From the beginning of the rice planting, the water level is allowed to gradually decrease until the water level dropps around 15 cm below the surface the field will be re-flooded to the water depth of around 5 cm at period of flowering from 1 week before to 1 week after the maximum flowering because prevent water stress that affect to rice grain yield. After flowering, grain filling and mature rice plant, the water level can be dropped again around 15 cm below the surface of the soil (IRRI, 2004) (Figure 2.8,2.9).

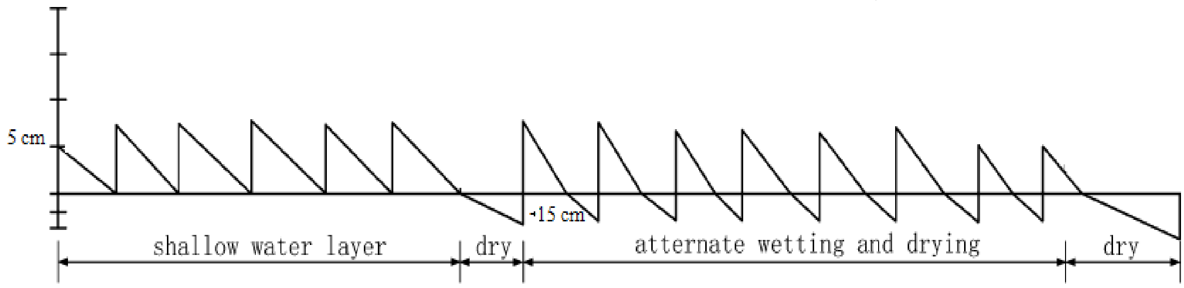
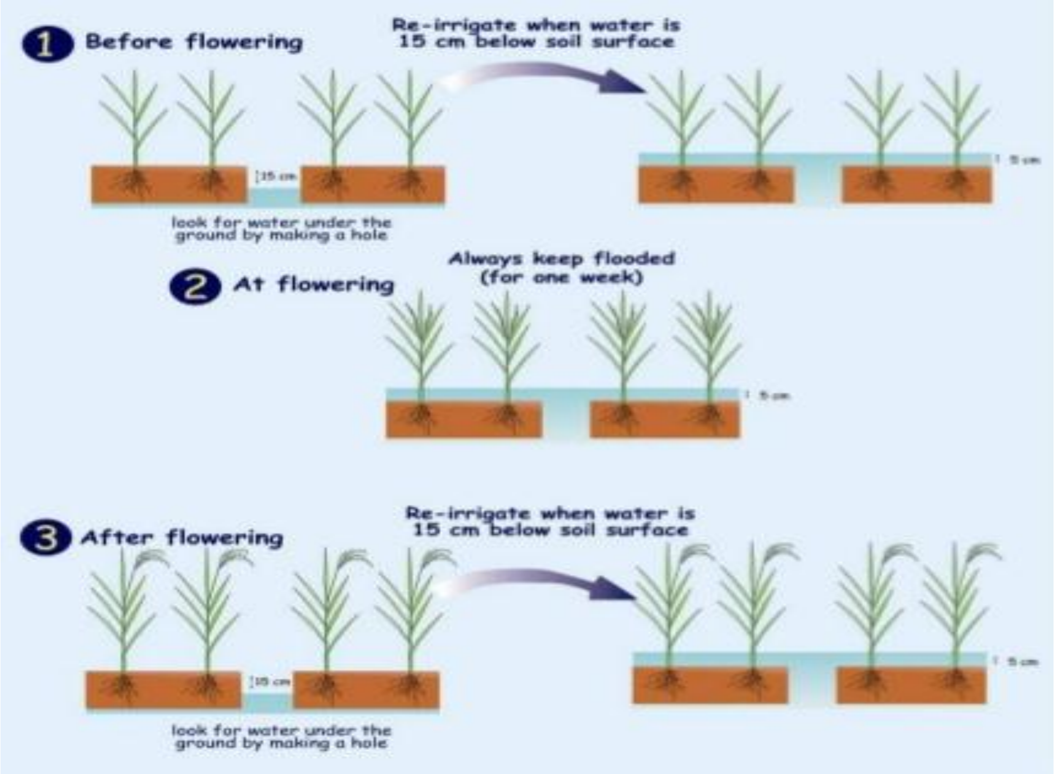
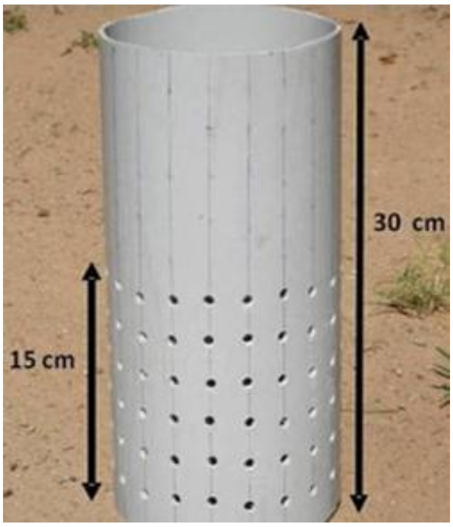


Figure 2.7 Graphical description of alternate wetting and drying (Zai, 2001).

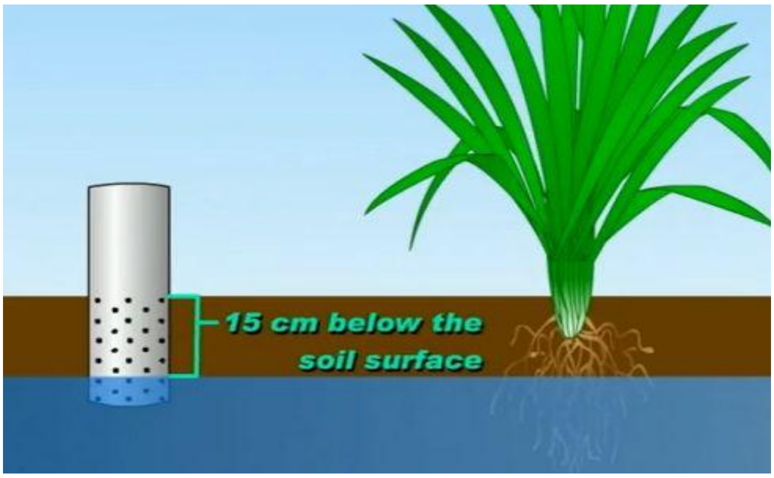


(A)

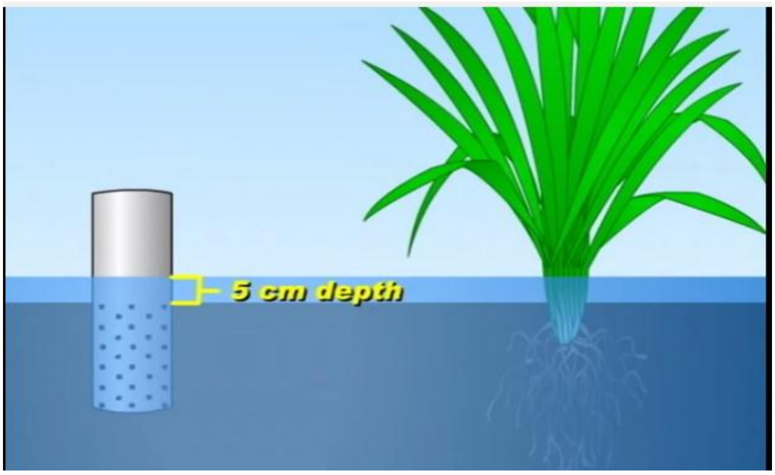


(B) (C)

Figure 2.8 (A) Control AWD system. (B) The water tube made is from PVC and about 40 holes are dilled on all sides. (C) Check equivalention of water level inside and outside water tube.



(A)



(B)

Figure 2.9 (A) The water level dropped around 15 cm below the surface of the soil and (B) Re-flood into rice field around 5 cm.

AWD can mitigate greenhouse gases from rice fields, because there is alternate anaerobic and aerobic that reduces CH_4 production. AWD also help save water and prevent chemical contamination drains to public water source and may reduce the need of diesel for water pumps. In many cases, AWD helps added yields because during the period of drying root of rice plant has been growing more than during the continuous flooding. However, sometime AWD technology reduces yield because moisture stress condition. AWD technology also improves soil stability that is easy for mechanical harvesting.

2.6 Simulating methane emission in rice field by the Denitrification - Decomposition (DNDC) model

The Denitrification-Decomposition (DNDC) model, is a computer model for predict crop yield, carbon sequestration and trace gas emission in agoecosystem, developed by Li Changsheng (Li *et al.*, 1992). The sub – structure of DNDC model have 2 components. First, it was about ecological aspect, including soil climate, crop growth and decomposition. The second component includes the nitrification, denitrification and fermentation processes. The results from simulation of two components are soil temperature, moisture, pH, redox-potential (Eh), substrate concentration profiles, emissions of CO_2, CH_4, ammonia (NH_3), nitric oxide (NO), nitrous oxide (N_2O) and dinitrogen (N_2) from the plant-soil systems.

Ecological process includes environmental factors such as moisture, temperature, and O_2 concentration in the soil by using soil properties, climate and rainfall data for simulation. Also, crop growth is simulated by the accumulative temperature, N uptake, and water stress at a daily time step under principle of photosynthesis, respiration, C allocation. The crop growth parameters for simulation are maximum yield, biomass portioning, C/N ratio, season accumulative temperature, water demand, and N fixation capacity. Furthermore, the decomposition simulation is based on the input parameters including the pool size, the specific decomposition rate, soil clay content, N availability, soil temperature, and soil moisture. Soil organic matter decomposition produces dissolve organic carbon (DOC) and microbes can immediately consume DOC. Organic nitrogen decomposition was transformed to ammonia phases (NH_4^+) lead to nitrification and denitrification process ,respectively (Fumoto *et al.*, 2008) (Figure 2.10).

2.6.1 Input parameters

The DNDC model can be divided into two modes including site mode and region mode. Input parameters for site mode are climate, soil properties and farm management information which the farm management has a sub-parameter that consists of crop type and rotation, tillage, fertilization, manure amendment, irrigation, flooding, plastic film use and grazing and grass cutting.

2.6.2 Output parameters

The main outputs are soil carbon and nitrogen profiles for 0 -50 cm, daily air temperature, precipitation, snow pack, evaporation, transpiration, crop biomass, N uptake, water stress and daily fluxes of NH_3, CH_4, N_2O, NO, and N_2 (Figure 2.11).

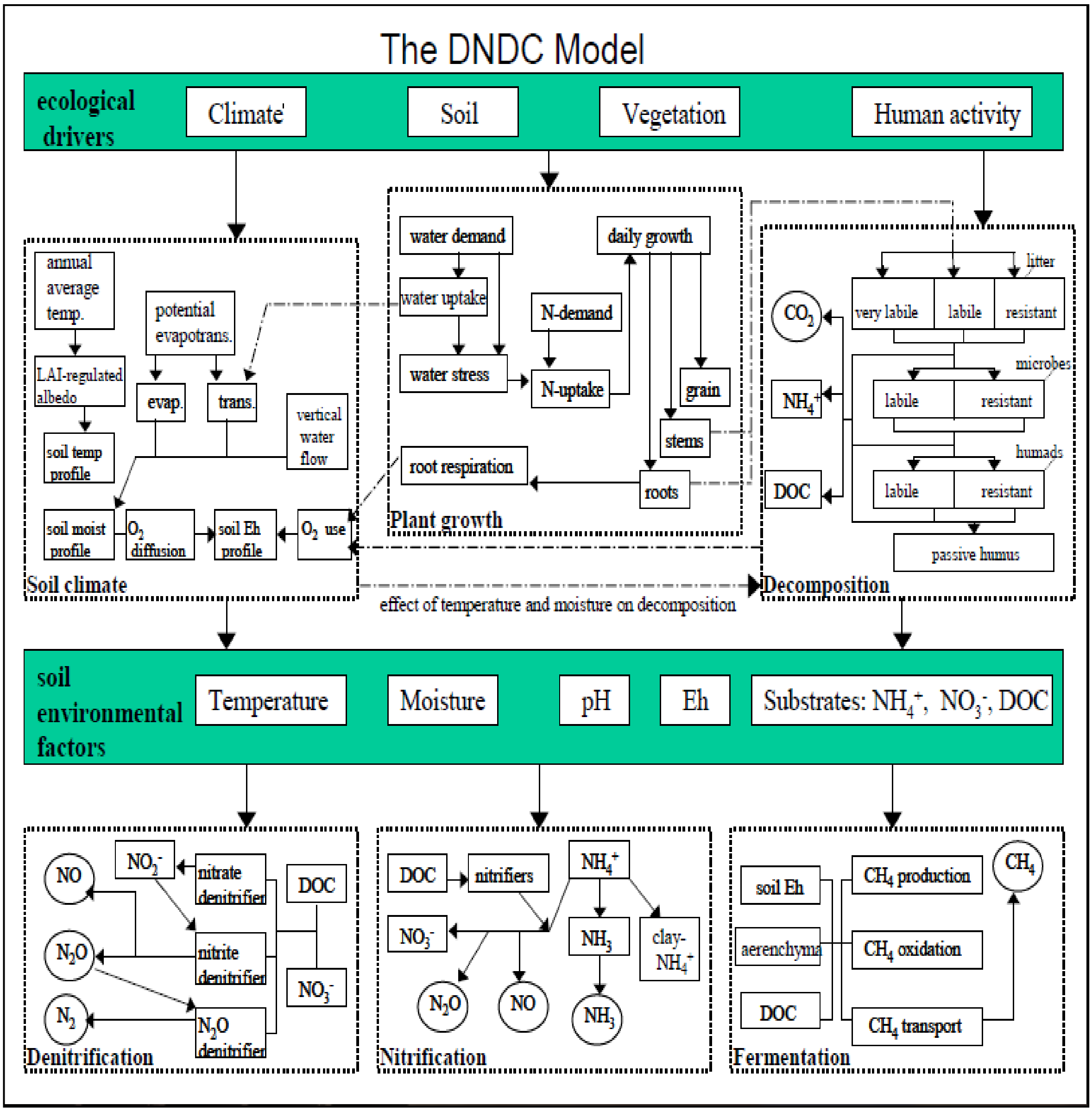


Figure 2.10 Structure of the DNDC model.

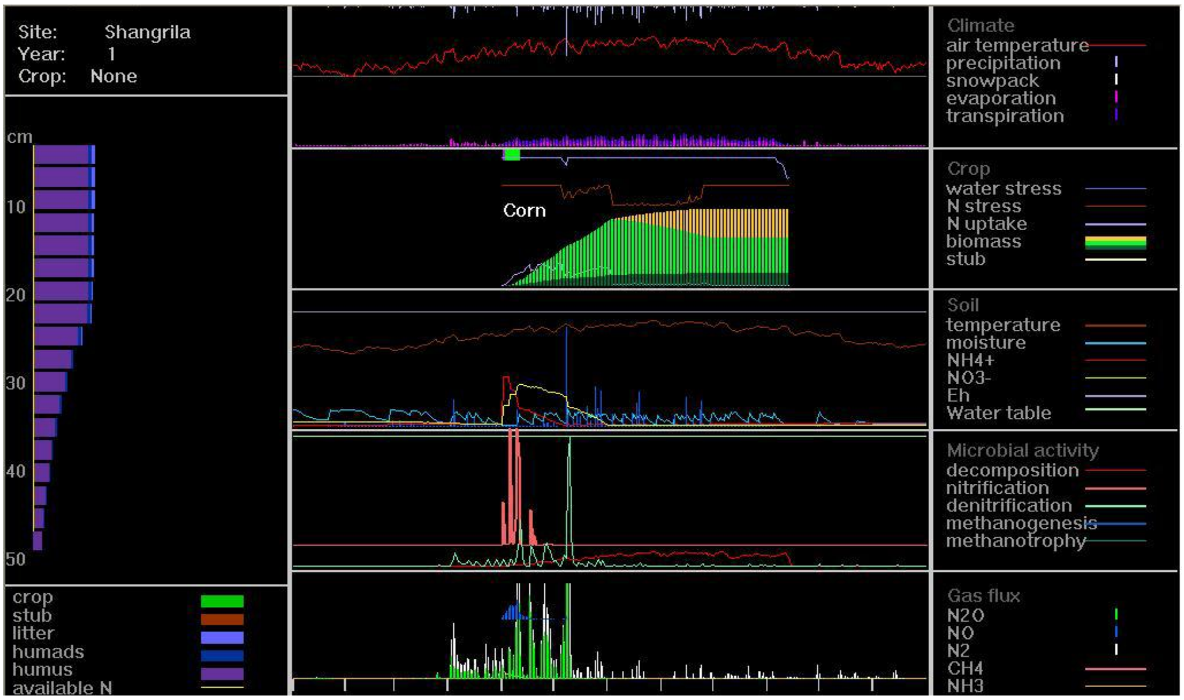


Figure 2.11 The seven windows shows results from the simulation the site under condition of the DNDC model.

The soil climate profiles are first calculated based on the daily weather data, soil physical properties and vegetation status. Therefore DNDC simulates plant growth by quantifying the growth stage based on accumulative temperature, water demand and uptake, N demand and uptake. DNDC partitions the crop biomass production increase to leaves, stems, roots and grain based on plant growth stage at a daily time step.

Decomposition is calculated based on quantity and quality of the existing SOC pools, soil climate profiles and soil N availability at a daily time step. Nitrification and denitrification are then predicted driven by dynamics of the soil Eh and relevant substrates (e.g., DOC, NH4+, NO3-, NO, N_2O). If a flooding event occurs, DNDC will track the soil Eh decrease driven by the sequential reductions of nitrate, nitrite, Mn4+, Fe3+ and sulfate. At certain low Eh conditions, the fermentation sub-model will be activated to calculate methane (CH_4) production. DNDC records modeled daily results of crop growth, soil temperature and moisture profiles, soil C pools/fluxes, soil N pools/fluxes, nitrate leaching losses, and gas fluxes at the end of each of the simulated days. DNDC continuously runs day-by-day until the last day of the year. DNDC will automatically shift to the first day of the next simulated year. The simulation will continue year-by-year until reaching the last year.

CHAPTER 3

METHODOLOGY

3.1 Location of study site

This work studies the simulation of CH_4 emission from rice field implemented with AWD by DNDC model and using the input data from the measurements of 6 sites, including Prachinburi, Ubon Ratchathani, Nakhon phathom, Chai Nat, Lop Buri and Phitsanulok rice fields (Figure 3.1).

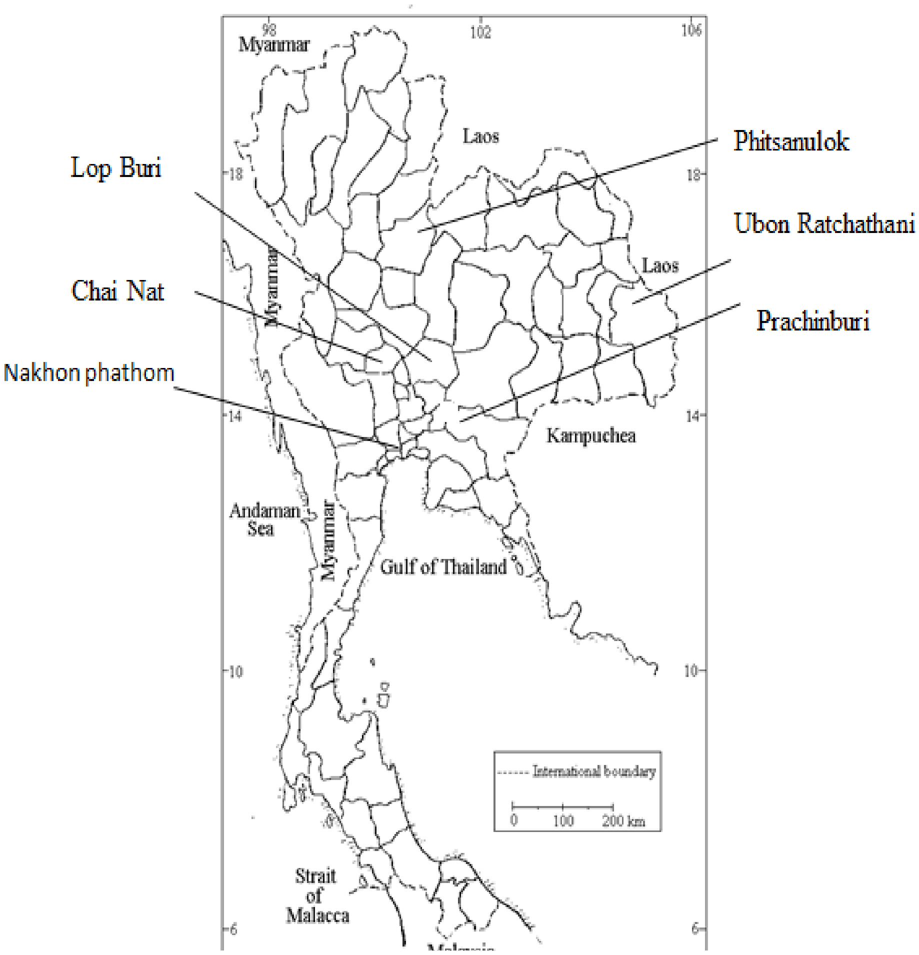


Figure 3.1 Location of study sites.

3.2. Site Description

Four out of six study sites were located in the central part of Thailand, one in east and another in the northeastern Thailand. The central sites were at Nakhon phathom (13.98 N, 99.99 E), Chai Nat (15.18 N, 100.12 E), Lop Buri (15.06 N, 100.72 E) and Phitsanulok (16.82 N, 100.42 E). The east and northeast sites were in Phachinburi (14.01 N, 101.22 E) and Ubon Ratchathani (15.25 N, 100.72 E), respectively. All sites were subject to the same agricultural practices (Table 3.1 and Table 3.2) under two water managements; AWD (10/-15cm) and continuous flooding (10 cm). CH_4 emission were weekly measured by the Rice Department, using static chamber method. Fertilizer was applied with diammonium phosphate at 20 Kg N/ha and Urea at 25 Kg N/ha, respectively. Tillage was carried out by ploughing with moldboard, depth 20 cm.

Table 3.1 Common cultivation practices at the six study sites.

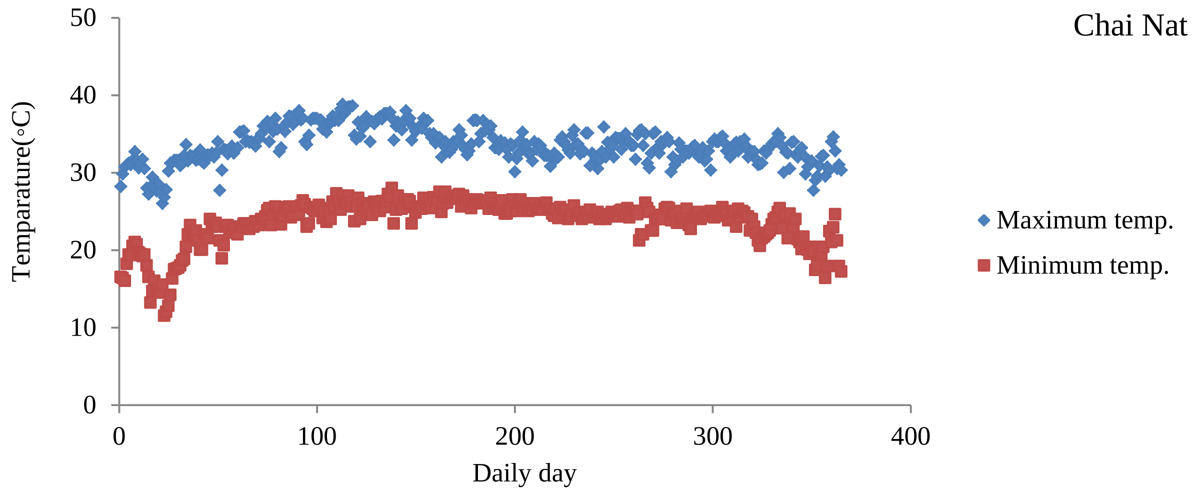
Sites	Rice variety	Planting Date (Day/month)	Harvest date (Day/month)	Tillage date (Day/month)	Fertilization
Nakhon pathom	RD41	19/6	15/9	30/4	22/1, 10/2, 24/2
Chai Nat	RD41	24/1	20/5	17/1	12/2, 3/3, 20/3
Lop Buri	RD41	24/7	14/10	10/7	13/8, 28/8, 19/9
Phitsanulok	RD41	15/1	14/5	7/1	4/2, 19/2, 11/3
Phachinburi	RD41	19/6	15/9	30/4	10/6, 31/7, 20/8
Ubon Ratchathani	RD41	31/7	28/11	24/7	20/8, 4/9, 24/8

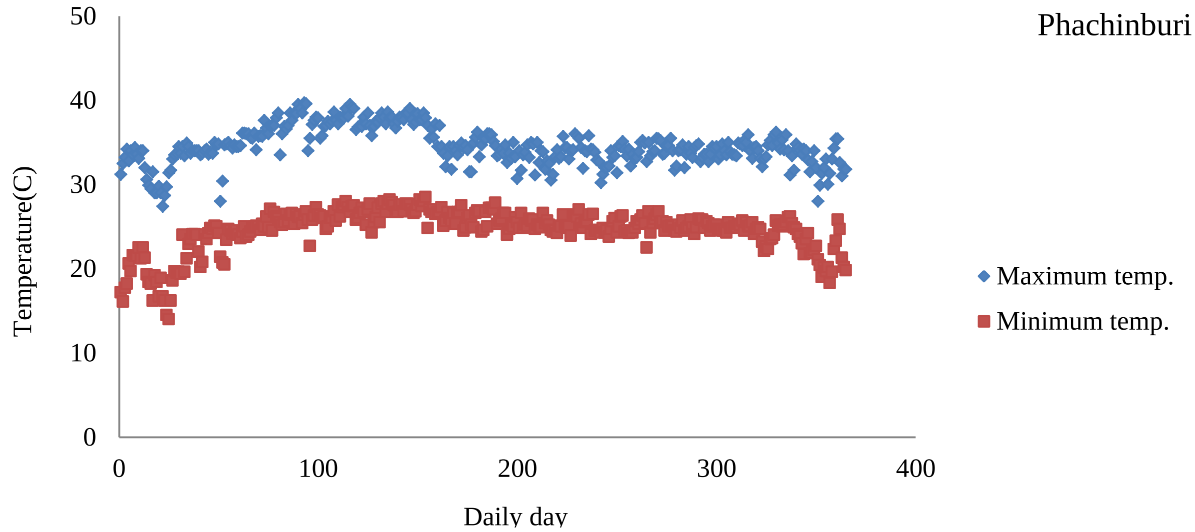
3.3. Input data for DNDC model

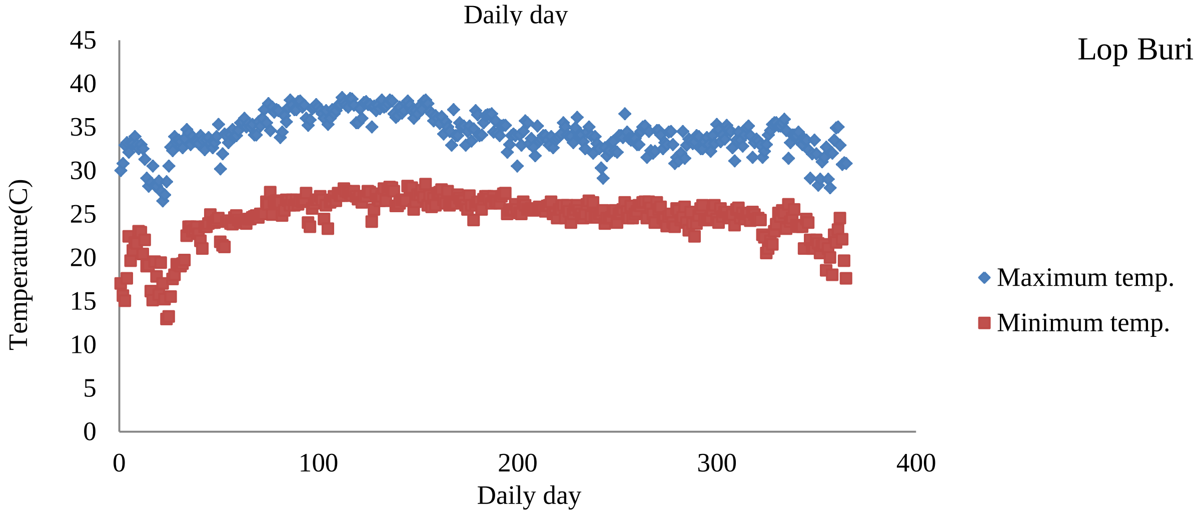
There are several input types needed to run DNDC model. These are site and climate, soil, farming management, crop type and rotation, tillage, fertilization, manure amendment, irrigation, flooding, plastic film use, grazing and grass cutting.

3.3.1 Site and climate data

The data required are daily temperature, daily precipitation, concentrations of ammonia, concentrations of carbon dioxide, N concentration in rainfall and annual increase rate of atmospheric CO_2 concentration. These were obtained from the Thai Meteorological Department (shown in Figures 3.2 and 3.3).


Chai Nat
Temparature(°C)
50
40
30
20
10
0
0
100
200
300
400
Daily day
Maximum temp.
Minimum temp.


Phachinburi
Temperature(C)
50
40
30
20
10
0
0
100
200
300
400
Daily day
Maximum temp.
Minimum temp.


Lop Buri
Temperature(C)
45
40
35
30
25
20
15
10
5
0
0
100
200
300
400
Daily day
Maximum temp.
Minimum temp.

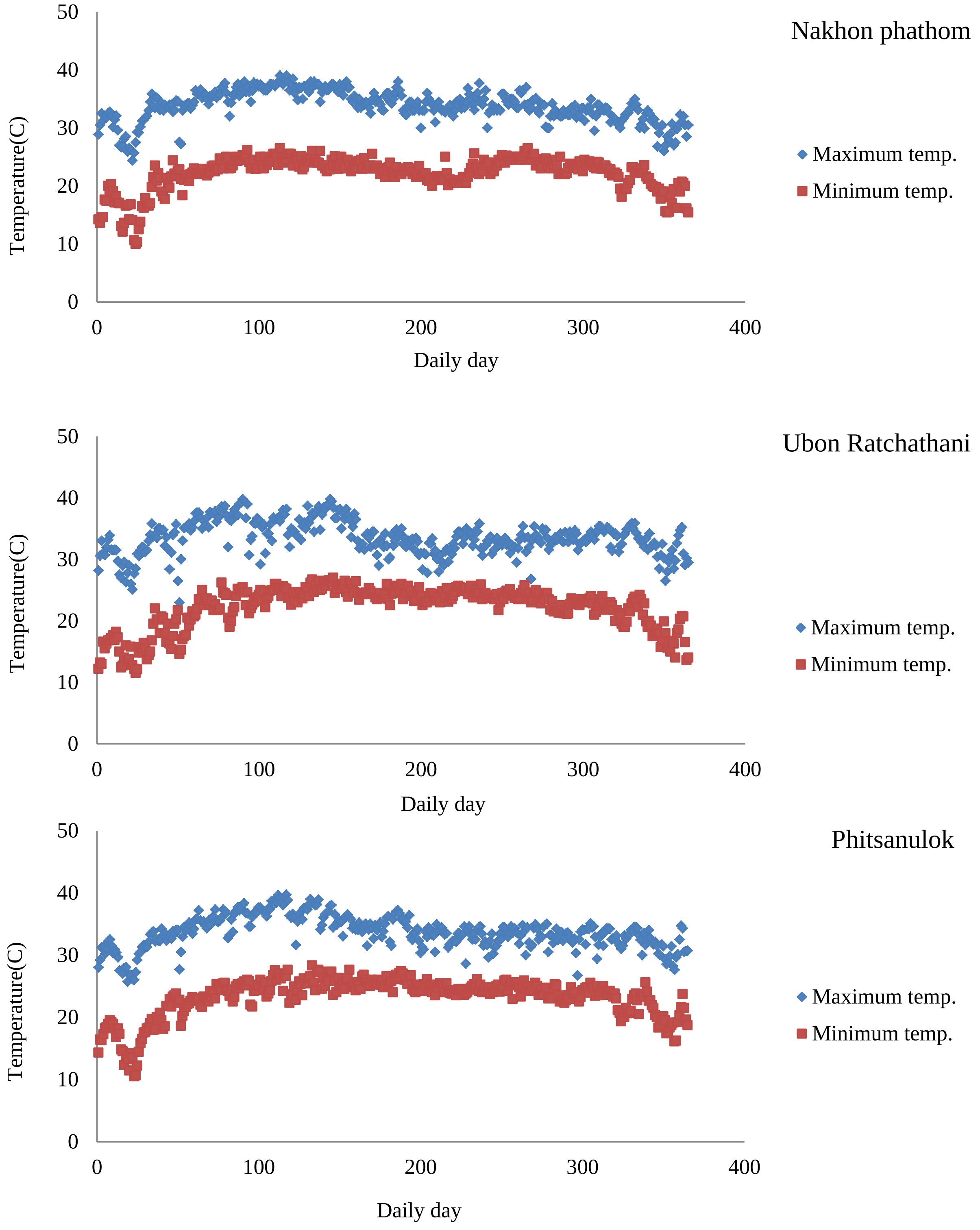
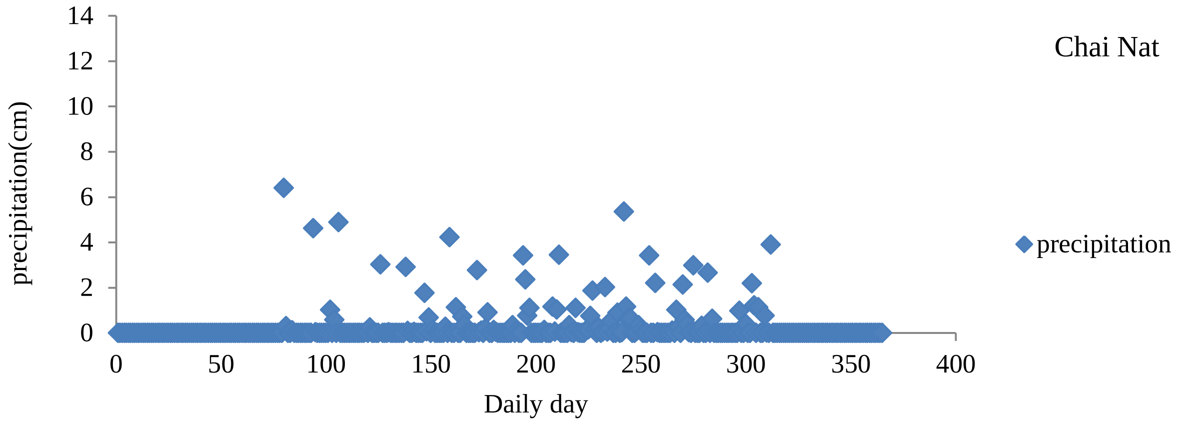
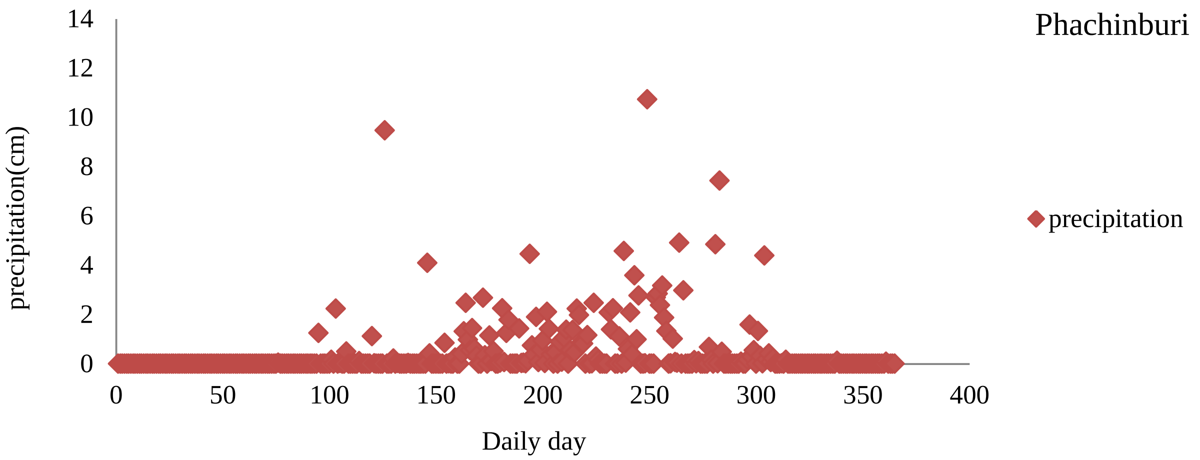
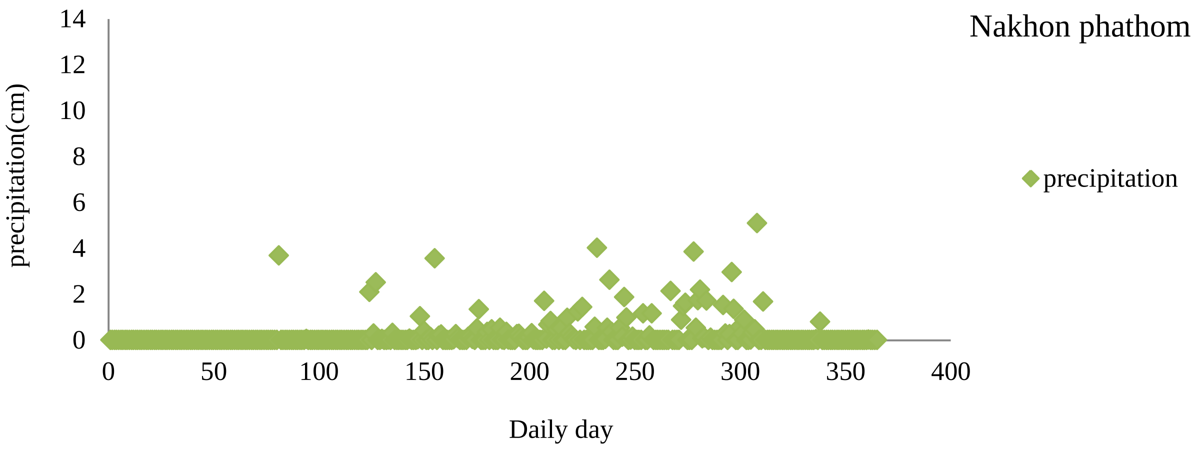


Figure 3.2 Daily temperature at six study sites.


Chai Nat
precipitation(cm)
14
12
10
8
6
4
2
0
0
50
100
150
200
250
300
350
400
Daily day
precipitation


Phachinburi
precipitation(cm)
14
12
10
8
6
4
2
0
0
50
100
150
200
250
300
350
400
Daily day
precipitation


Nakhon phathom
precipitation(cm)
14
12
10
8
6
4
2
0
0
50
100
150
200
250
300
350
400
Daily day
precipitation

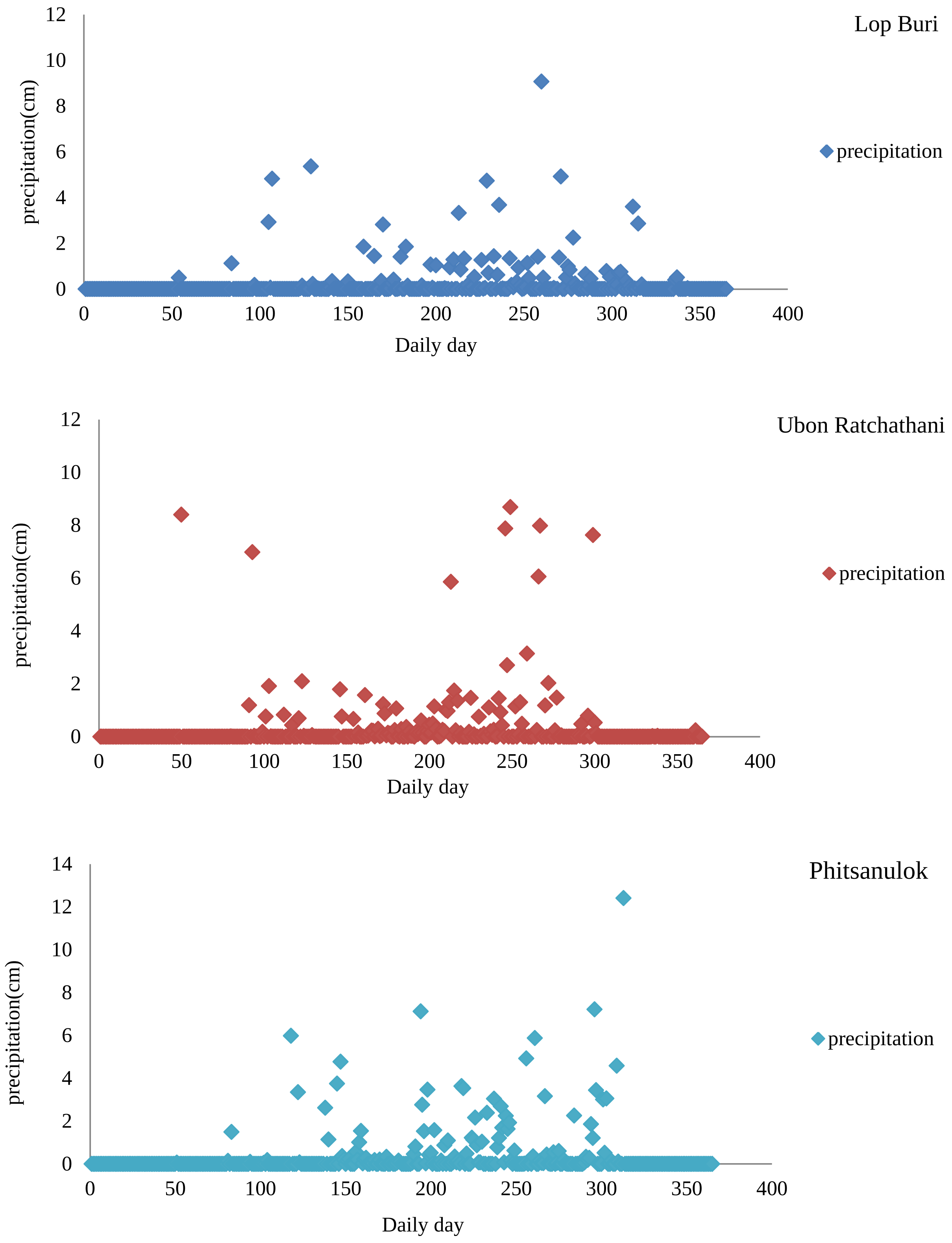


Figure 3.3 Daily precipitation at six study sites.

3.2.2 Soil

The soil data are the physical and chemical characteristics of soil. These were obtained from each sits as shown in Table 3.3. Due to some data not being available, the model default data for soil properties of rice fields were also used (Table 3.4).

Table 3.2 The physical and chemical characteristics of the soil at 6 study sites.

Sites	Soil Characteristics							
	Soil texture		pH		Bulk density (g/cm^3)		Total organic C (%)	
	AWD	CF	AWD	CF	AWD	CF	AWD	CF
Prachinburi	Heavy clay	Heavy clay	4.93	4.93	1.34	1.34	1.93	1.93
Lop buri	Sandy loam	Sandy loam	5.96	5.98	1.40	1.40	0.75	0.78
Phitsanulok	Clay	Clay	4.73	4.79	1.87	1.87	1.83	1.93
Chai Nat	Sandy loam	Loam	7.52	7.2	1.32	1.31	1.2	1.15
Ubon Ratchathani	Sandy loam	Loam	4.95	4.94	1.21	1.24	1.77	1.56
Nakhon pathom	Clay	Clay	7.38	7.76	1.41	1.34	0.72	1.07

*AWD = Alternate wetting and drying, CF = continuous flooding

Table 3.3 The default data for soil properties of rice field.

Parameter	**Default value**	**Unit**
Hydro-conductivity	0.75	m/hr
By-pass flow rate	0	-
Depth of water retention layer	0.1	m
Highest groundwater table depth	0.1	m
Depth of top soil with uniform SOC content	0	m
SOC decrease rate below top soil (0.5 – 5.0)	0	m
Initial NO_3 (-) concentration at surface soil	0.5	mg N/kg
Initial NO_4 (+) concentration at surface soil	0.05	mg N/kg

Parameter		**V.l. litter**	**Labile litter**	**Resistant litter**	**Humads**	**Humus**	**(IOC)**
Default value	Fraction	0	0	0.001	0.0139	0.9762	0
	C/N	5	25	100	10	10	500

** IOC = Inorganic carbon pool

3.3.3 Cropping data

The data inputs for cropping are number of year and amount of cropping system that include total years, number of cropping systems applied during the total simulated years, duration of this cropping system (yrs), duration of a cycle in this cropping system (yrs), cropping system and year in the cycle in this cropping system. These were also obtained from the sites.

3.3.4 Farming management

Farming management has a sub-parameter including crop type and rotation, tillage, fertilization, manure amendment, irrigation, flooding, plastic film use and grazing and grass cutting. The default values on rice field data of DNDC model (Table 3.4) and rice field management from 6 study sites shown in Table 3.1 were used. Tillage and fertilization were used as shown in Table 3.1 and 3.2, respectively. No manure was applied at these sites.

Table 3.4 The default data for crop of rice field.

Parameter	Default value	Unit
Total N demand	183.954	kg N/ha
Thermal degree days	3200	°C
Water demand	508	g water/g dry matter
N fixation index	1.2	-
Adjusting default specific leaf weight (LAI adjustment factor)	1	-
Vascularity	1	-
Optimum temperature	22	°C

3.4 Performance of DNDC model

The DNDC model could be applied in other rice fields in Thailand and it will be helpful to improve the DNDC model. We used the root-mean-square error (RMSE) for performance evaluation of DNDC model, calculated by the following equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}}$$

Where Pi and Oi are the predicted and observed values, respectively, n is the total number of data. This root-mean-square error (RMSE) examines the correlation between model predictions and field observations and the best model performance had RMSE value equal to 1.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Methane emissions from continuous flooding and from AWD conditions

The results of CH_4 emissions observed at all six study sites under continuous flooded and AWD conditions are given in Table 4.1. It was found that the average CH_4 emissions from continuous flooded and AWD conditions were 112.83 and 92.48 kgC/ha/day, respectively. The highest emission from the continuous flooded condition was around 175.61 kgC/ha/day coming from Phitsanulok and the lowest emission from AWD was around 5.46 kgC/ha/day coming from Phachinburi. At all sites both for continuous flooded and AWD conditions, CH_4 emissions gradually increased from the beginning of planting with the distinct two peaks; sowing to tillering stage (duration varies from 1 to 40 days after planting (DAP)) and reproductive stage during 60 to 70 DAP and 77 to 84 DAP (Figure 4.1,4.2). Highest CH_4 emission was found during the reproductive stage, consisting with previous reports (Smakgahn *et al*., 2003). The lowest CH_4 emission was found in tillering stage because the field was drained especially, under AWD condition. There is one exception in Phitchanulok sites where the CH_4 emission from continuous flooding condition was less than AWD condition. It is not known what reason makes the emission at this site different from others. Nevertheless, from these results it can be said that, applying AWD was resulted in the average CH_4 emission reduction of -40.37±47.18%.

Table 4.1 Observed methane emission under continuous flooded and alternate wetting and drying (AWD) condition and methane emission reduction from applying AWD.

Sites	**Methane emission (kgC/ha/day)**		**methane emission reduction from applying AWD (%)**
	Continuous flooded (CF)	AWD	
Nakhonphathom	112.11	73.05	-65.16
Chai Nat	21.83	12.61	-57.76
Lop Buri	174.41	42.35	-24.28
Phitsanulok	175.61	253.81	+44.53
Phachinburi	11.60	5.46	-47.06
Ubon Ratchathani	181.45	167.62	-92.37
Mean			**-40.37±47.18**

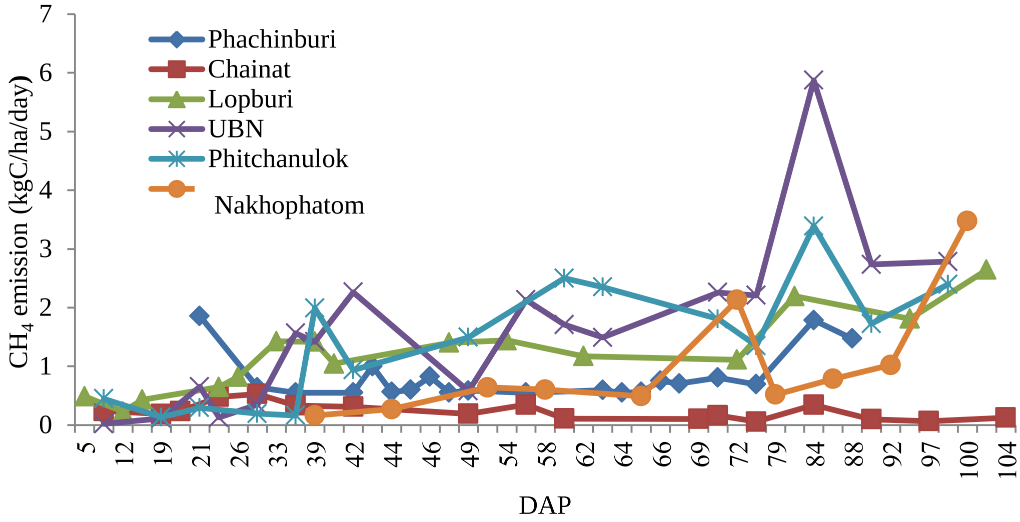


Figure 4.1 Observed CH_4 emissions under continuous flooded condition at six study sites (DAP = Day After Planting)

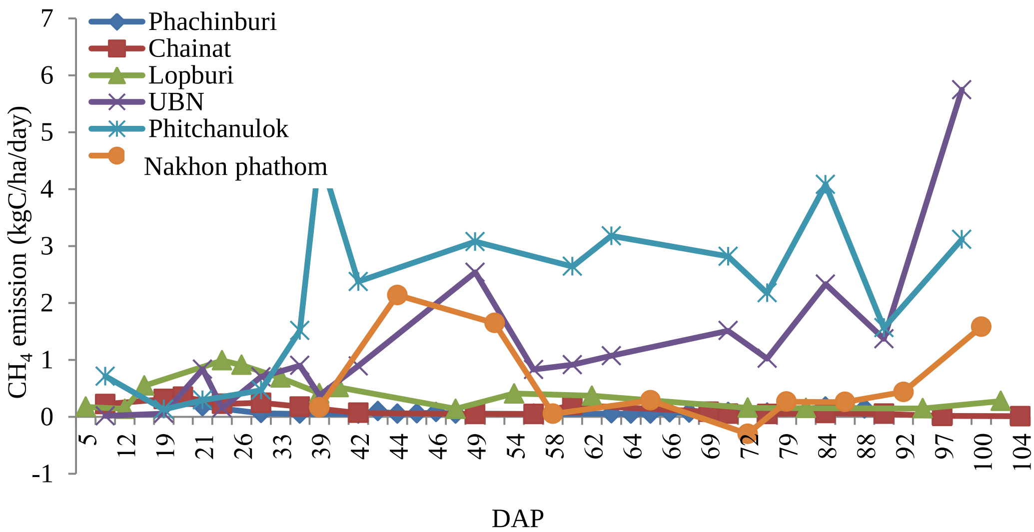


Figure 4.2 Observed methane emissions under AWD condition at six study sites.

4.2 Yields and emission per yields

Rice yields under continuous flooding conditions ranges from 2.3 to 4.6 ton/ha. Under AWD, this ranges between 2.4 and 4.8 ton/ha. There is no obvious trend for the effects of AWD on rice grain yield from these sites. However, when normalizing these to the amount of CH_4 emissions (CO_2 e) per a unit of grain yield, producing one kg of rice on average emits CH_4 1.05 and 0.80 kg CO2e for continuous and AWD conditions, respectively. Thus, AWD apparently reduce CH_4 emission intensity in rice fields.

Table 4.2 Observed CH_4 emissions under continuous flooded and AWD conditions and CH_4 emission reduction from applying AWD.

Sites	**Gain yields (kg/ha)**		**Emission intensity (kgCO2e/kg grain)**	
	Continuous flooded	AWD	Continuous flooded	AWD
Nakhonphathom	3425	2650	0.92	0.77
Chai Nat	4200	3431	0.15	0.10
Lop Buri	2656	2587	1.84	0.46
Phitsanulok	4600	4800	1.07	1.48
Phachinburi	3975	3393	0.08	0.05
Ubon Ratchathani	2268	2412	2.24	1.95
Mean			1.05	0.80

4.3 Simulation of methane emissions by DNDC model

Although in general the DNDC could simulate quite well the emissions, the capacity to simulate was different among sites and different between continuous flooding and AWD conditions (Table 4.3 and Figures 4.3-4.4). Under continuous flooding condition, high consistency between observed and simulated values were found except during the second peak or during the reproductive phase of rice growth (Figure 4.3). Exception was Prachiburi site where observed and simulation results were not consistent. At this site, the main difference was a heavy clay soil with highly acidity which pH ~ 4.93, and from time to time saline water intrusion was observed. High acidifty and salinity may be the reasons of the difference between observed and simulated results. Under such conditions, model adjustment may be needed and be the topic of further research. Thus, DNDC many be not suitable for such condition. On average, the difference between observed and simulated emission was 10.88±16%.

Under AWD conditions, the results of observed and simulated emission agree quite well. The difference between observed and simulated emission was 8.01±19%. Again, discrepancy between observed and simulated values were found mainly during rice reproduction stage. Thus, improving simulation during this growth stage will potentially help improve model performance. In general, it is thus concluded that DNDC is working well to simulate CH_4 emission under both continuous flooding and AWD conditions. Improvement in this area may be putting more efforts to find the way to enhance the simulation during the reproduction of rice.

Analysis result of the relationship between simulated and observed emission at all sites is shown in Figures 4.5-4.8. In most cases, high correlation between observed and simulated emissions was found, with the R^2 between 0.3-0.8 for both continuous flooding and AWD conditions. Howver, no significant correlation was found for Prachinburi site.

Table 4.3 Observed and simulation CH_4 emission under continuous flooded and AWD condition at six study sites.

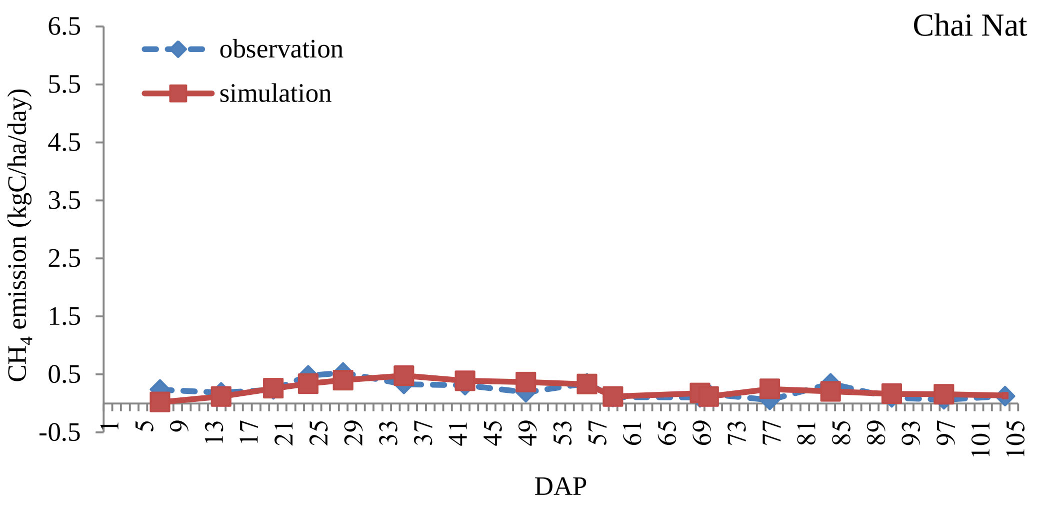
Sites	**Methane emission (kgC/ha/day)**				**The difference between observed and simulated (%)**	
	Observation		Simulation from DNDC model		Observation	Simulation from DNDC model
	CF	AWD	CF	AWD	CF	AWD
Nakhonphathom	112.11	73.05	86.61	83.57	22.75	-14.40
Chai Nat	21.83	12.61	24.06	14.57	-10.22	-15.54
Lop Buri	174.41	42.35	182.51	35.41	-4.64	16.39
Phitsanulok	175.61	253.81	166.77	233.01	5.03	8.20
Phachinburi	11.6	5.46	8.45	4.07	27.16	25.46
Ubon Ratchathani	181.45	167.62	135.69	120.72	25.22	27.98
Mean					10.88±16	8.01±19

* CF = continuous flooding and AWD = alternate wetting and drying

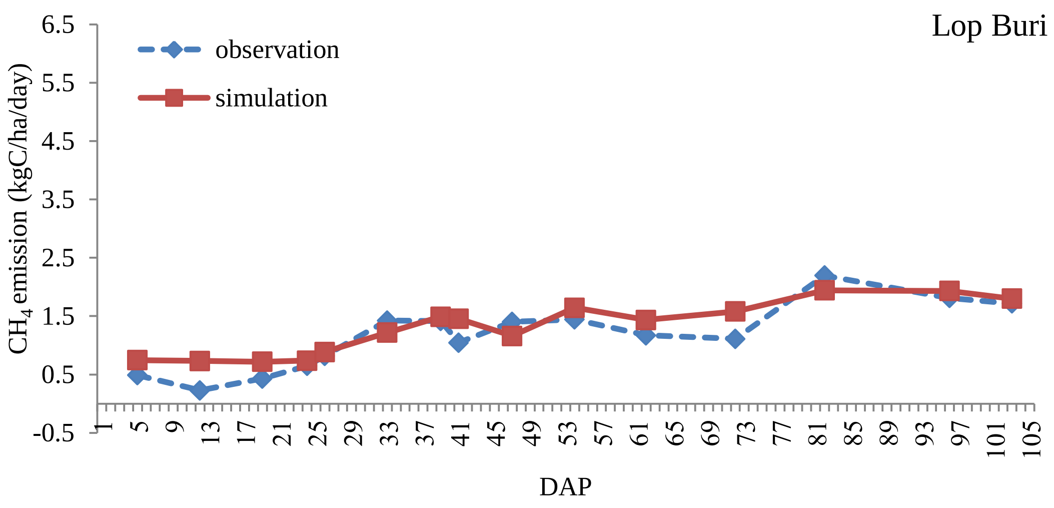
Table 4.4 The Root-mean-square-error values and the relative deviation of CH_4 emission between the observed and simulated values from six study sites under continuous flooded and AWD condition.

Sites	**RMSE values(kgC/ha/day)**	
	CF*	AWD
Nakhonphathom	0.70	0.46
Chai Nat	0.11	0.08
Lop Buri	0.31	0.18
Phitsanulok	0.55	0.83
Phachinburi	0.79	0.05
Ubon Ratchathani	1.02	1.16

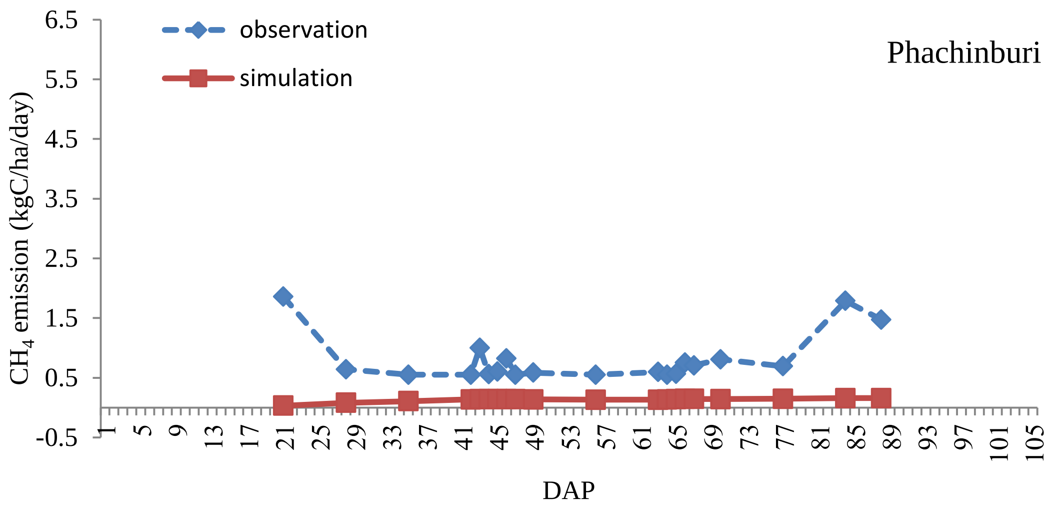
* CF = continuous flooding and AWD = alternate wetting and drying



Chai Nat
observation
simulation
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
CH_4 emission (kgC/ha/day)
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105
DAP



Lop Buri
observation
simulation
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
CH_4 emission (kgC/ha/day)
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105
DAP



Phachinburi
observation
simulation
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
CH_4 emission (kgC/ha/day)
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105
DAP

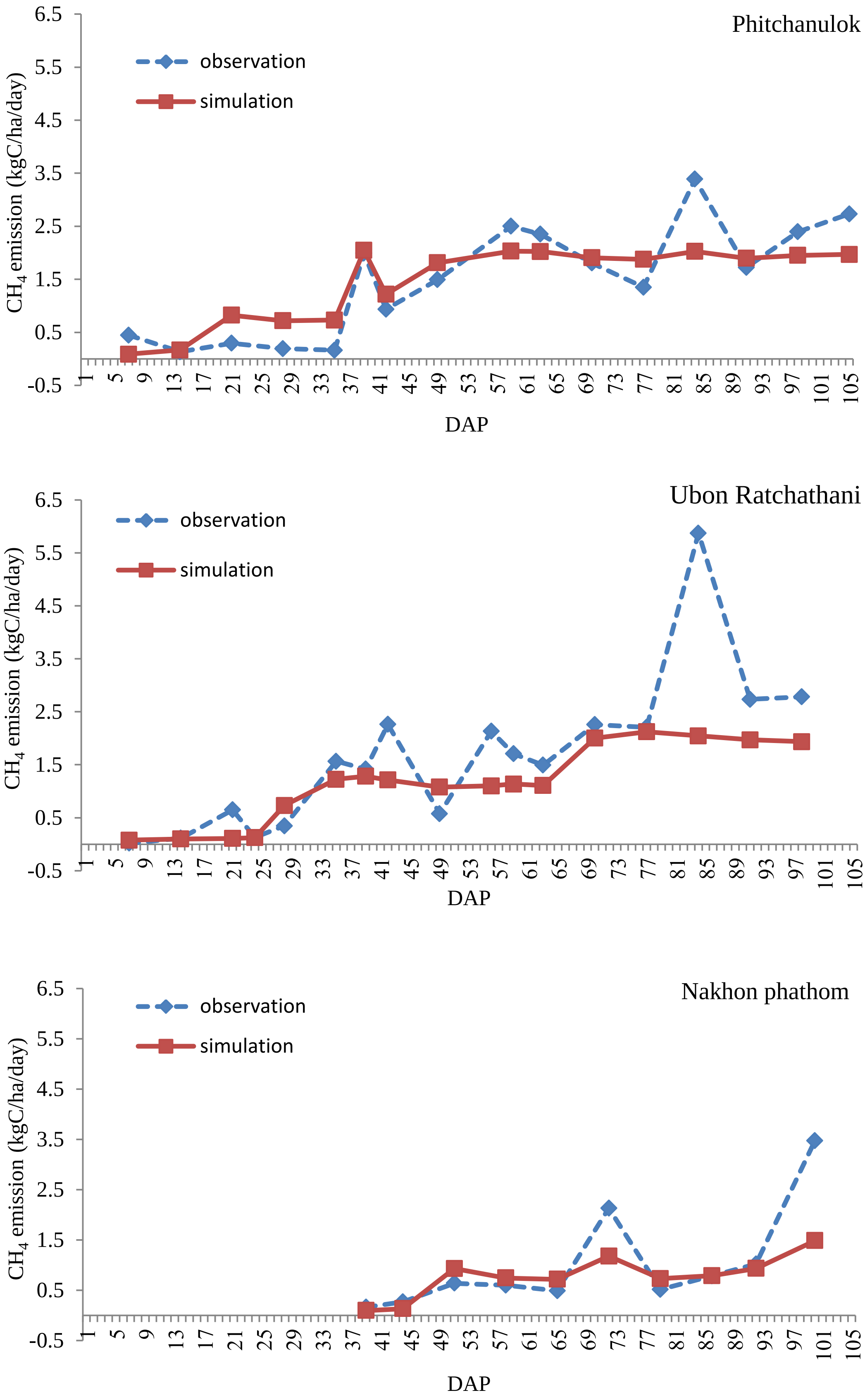
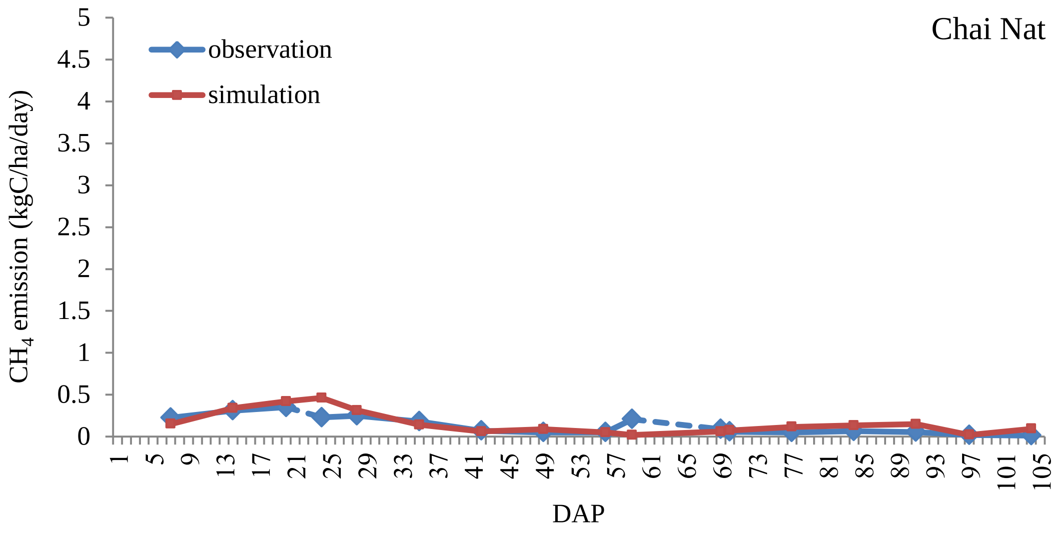
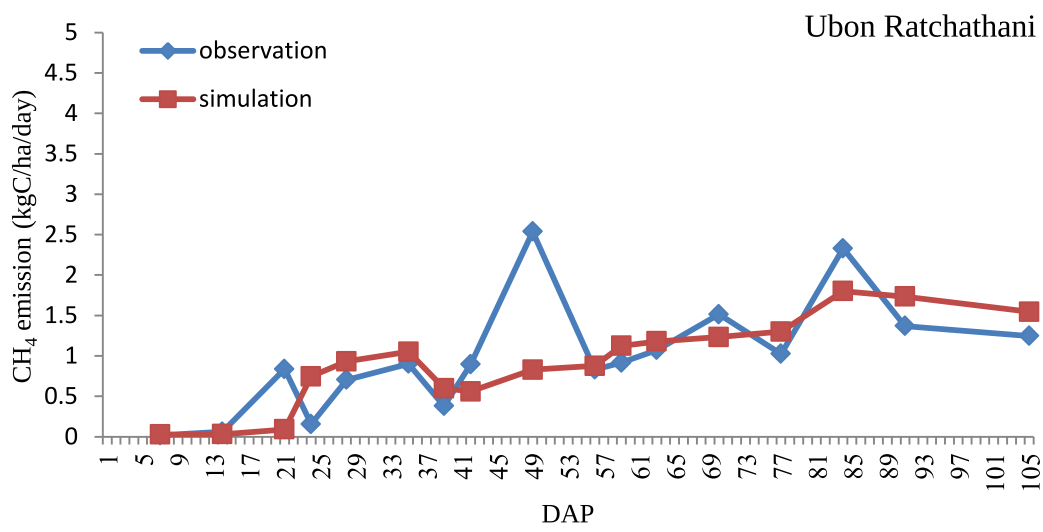
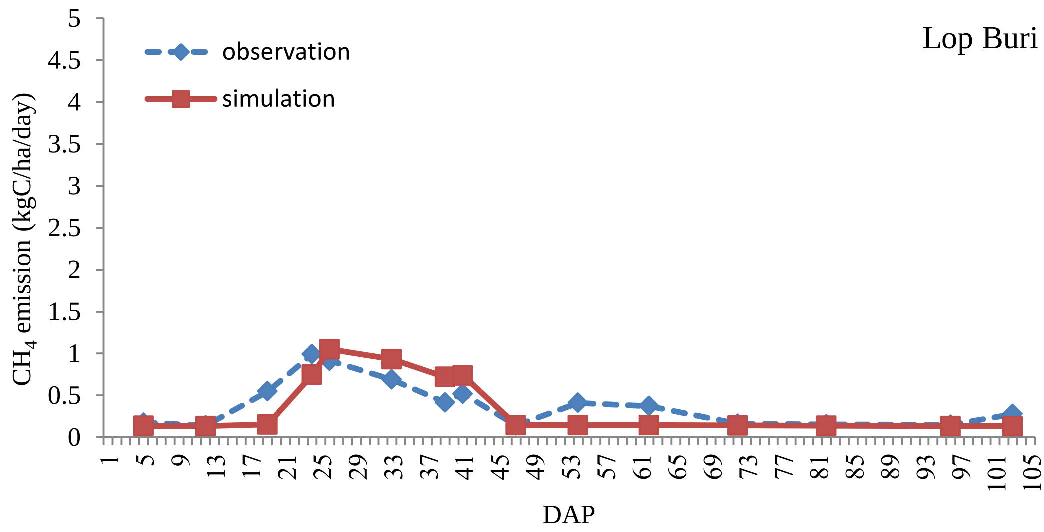


Figure 4.3 Observed and simulation CH_4 emission under continuous flooded condition at six study sites


Chai Nat
observation
simulation
CH4 emission (kgC/ha/day)
DAP


Ubon Ratchathani
observation
simulation
CH4 emission (kgC/ha/day)
DAP


Lop Buri
observation
simulation
CH4 emission (kgC/ha/day)
DAP

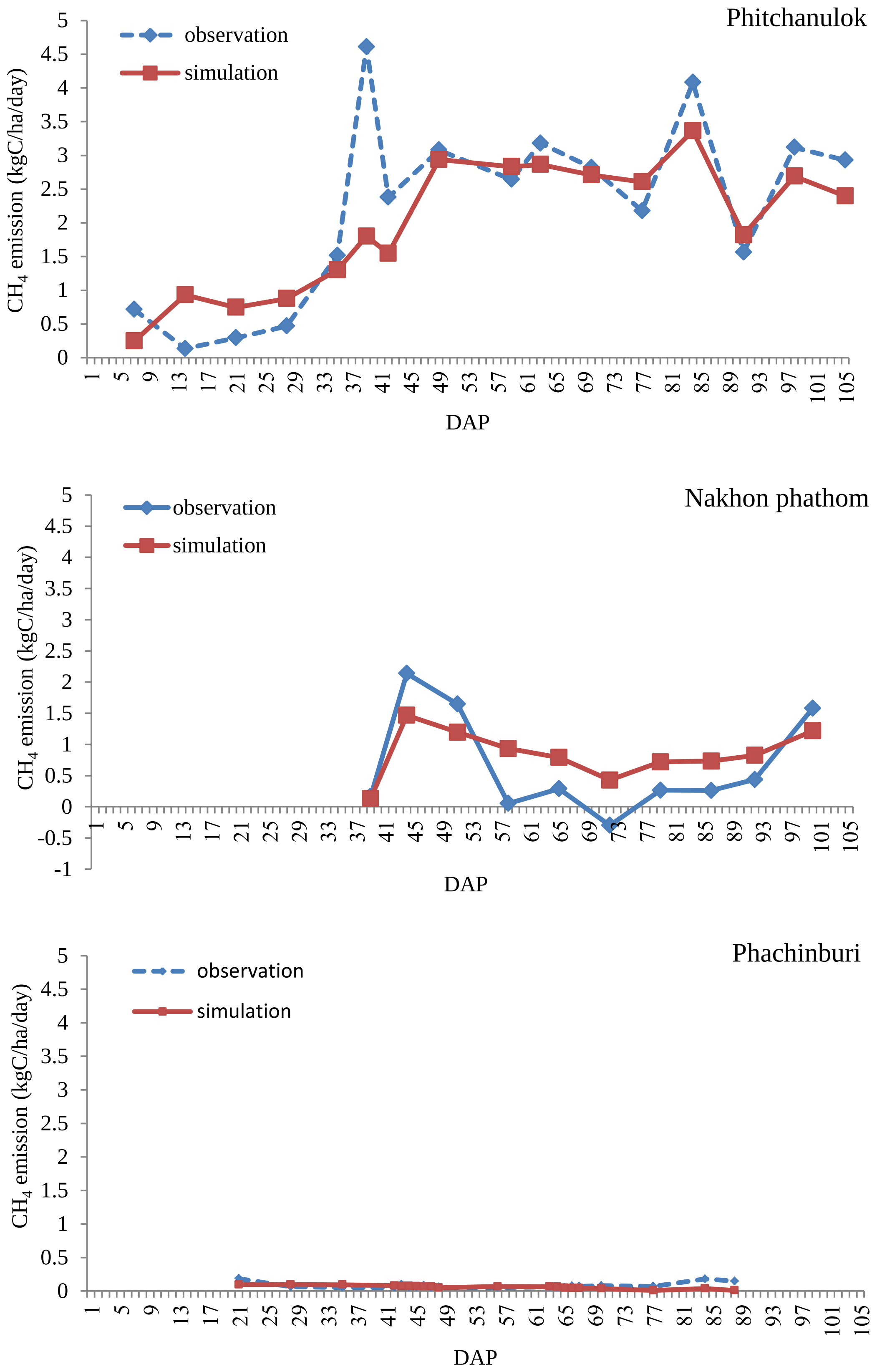
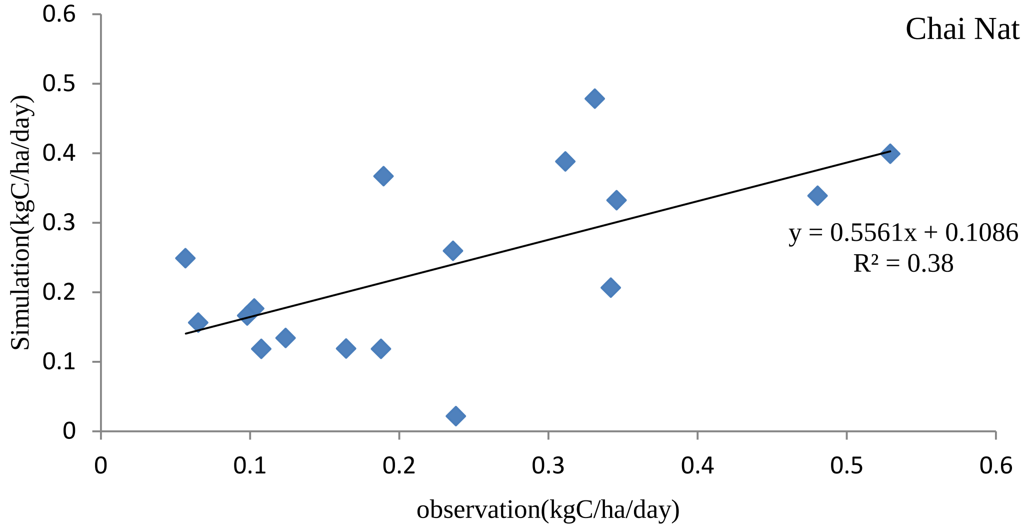
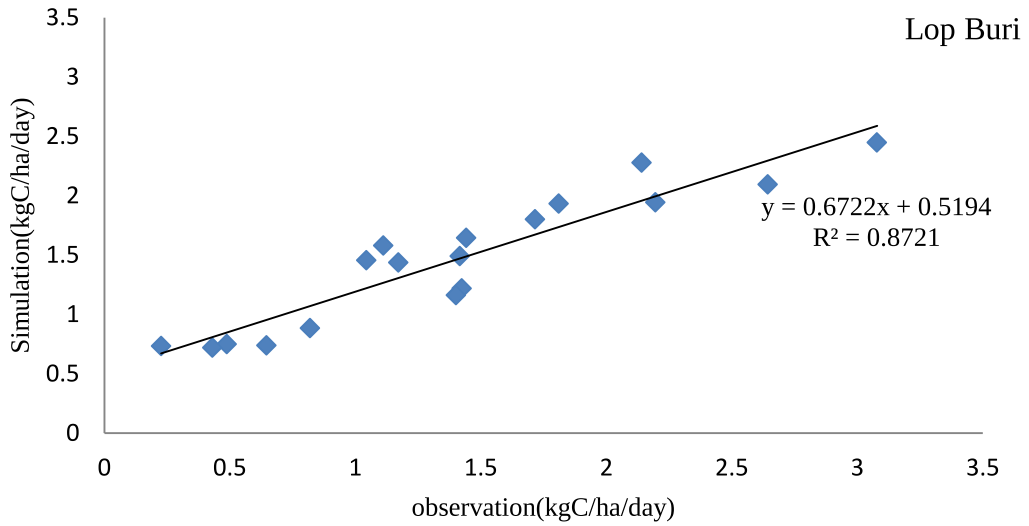
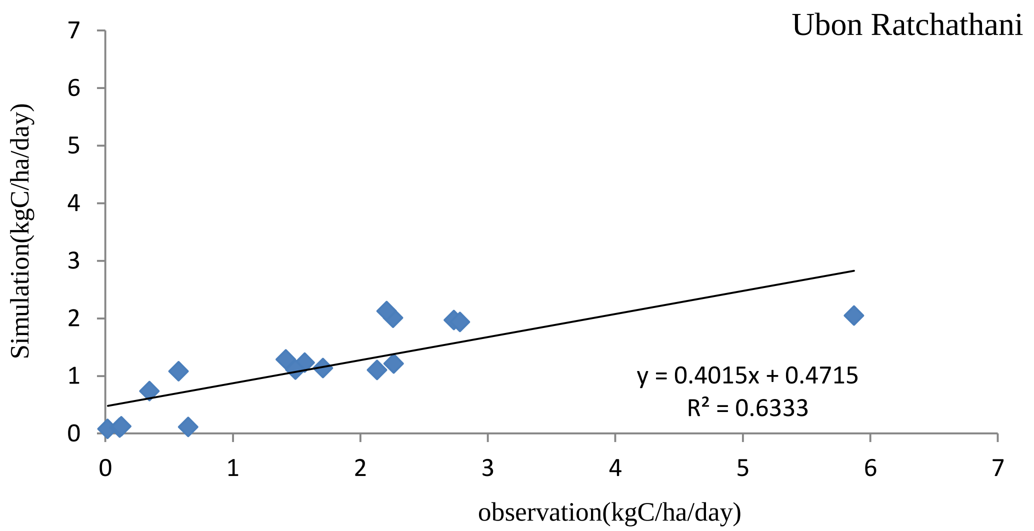


Figure 4.4 Observed and simulation CH_4 emission under AWD condition at six study sites


Chai Nat
Simulation(kgC/ha/day)
observation(kgC/ha/day)
y = 0.5561x + 0.1086
R² = 0.38
0
0.1
0.2
0.3
0.4
0.5
0.6


Lop Buri
Simulation(kgC/ha/day)
observation(kgC/ha/day)
y = 0.6722x + 0.5194
R² = 0.8721
0
0.5
1
1.5
2
2.5
3
3.5


Ubon Ratchathani
Simulation(kgC/ha/day)
observation(kgC/ha/day)
y = 0.4015x + 0.4715
R² = 0.6333
0
1
2
3
4
5
6
7

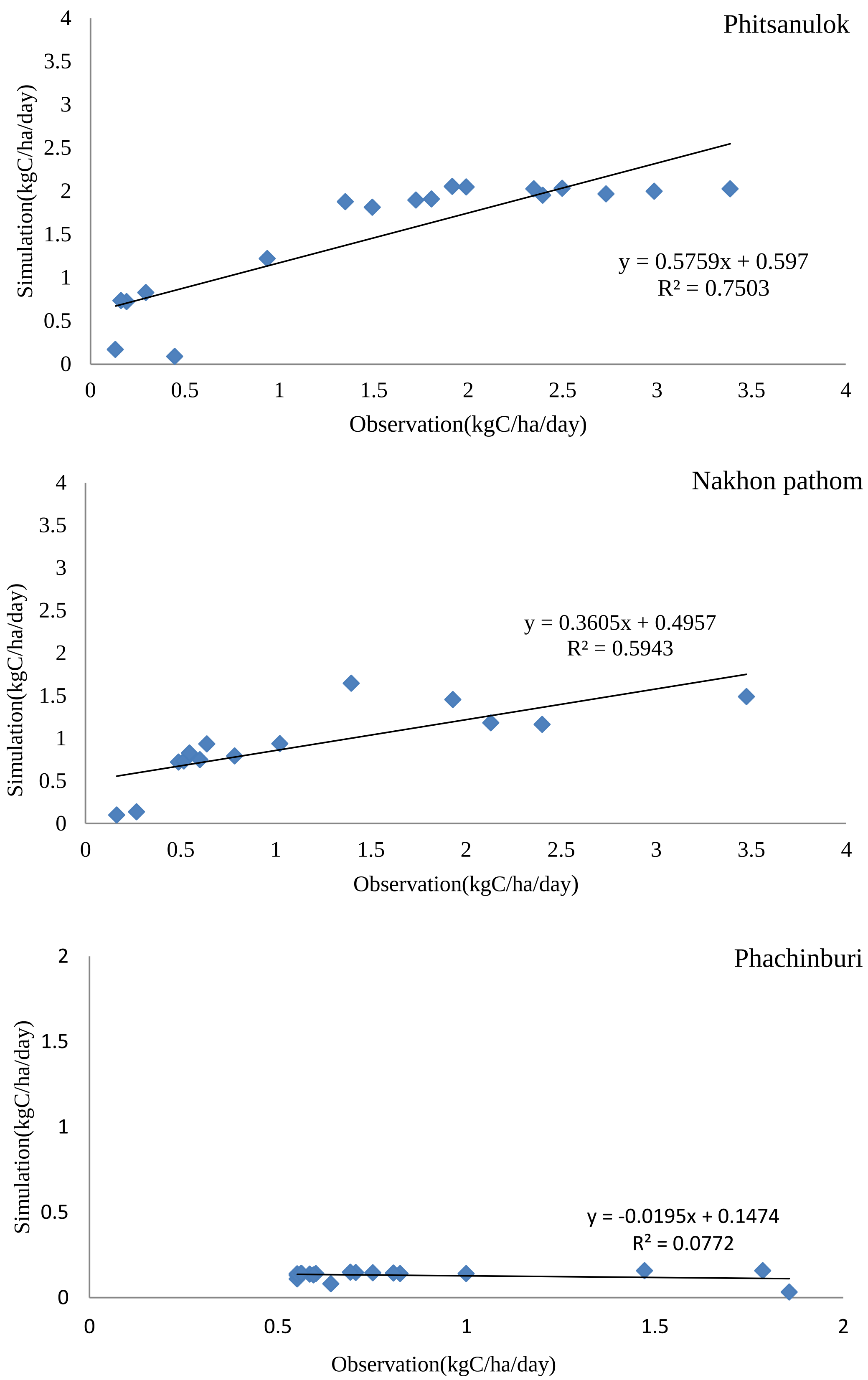
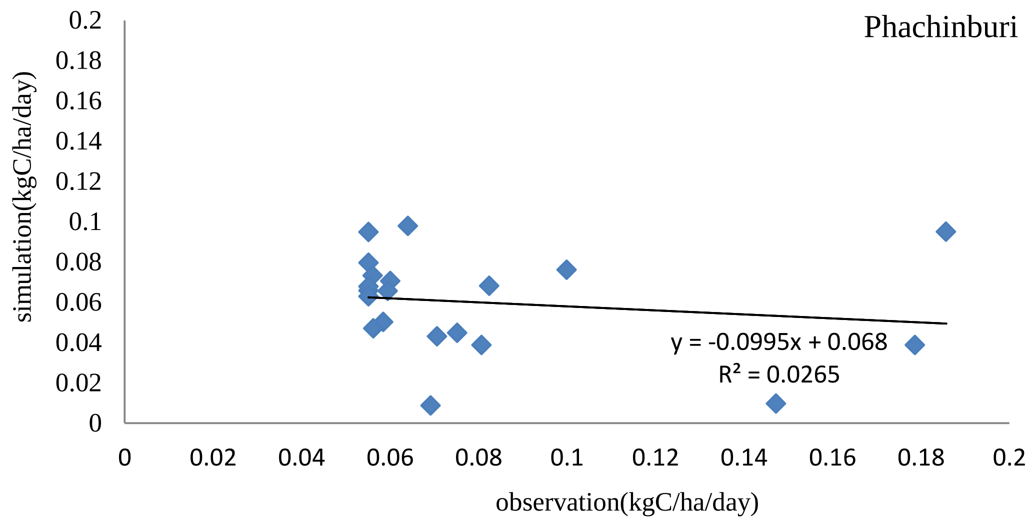
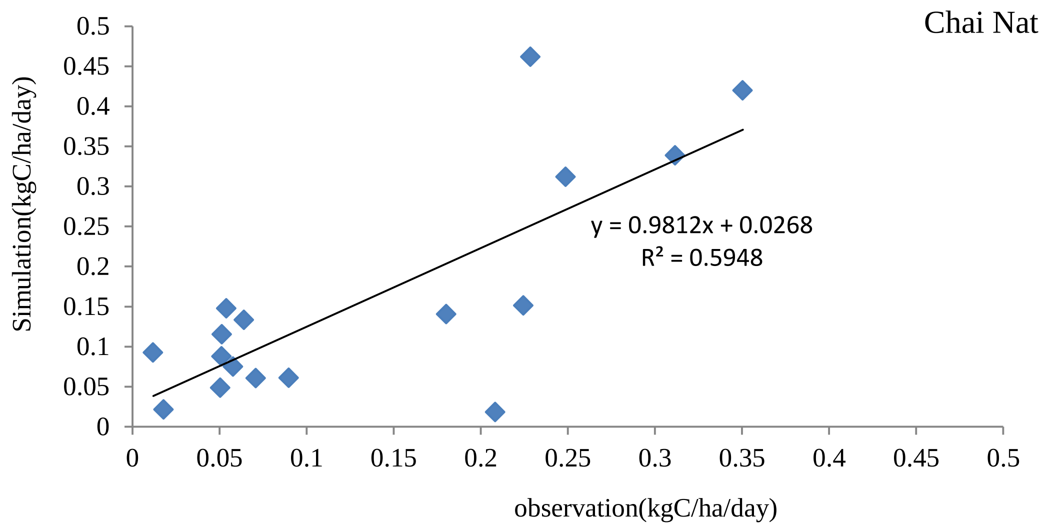
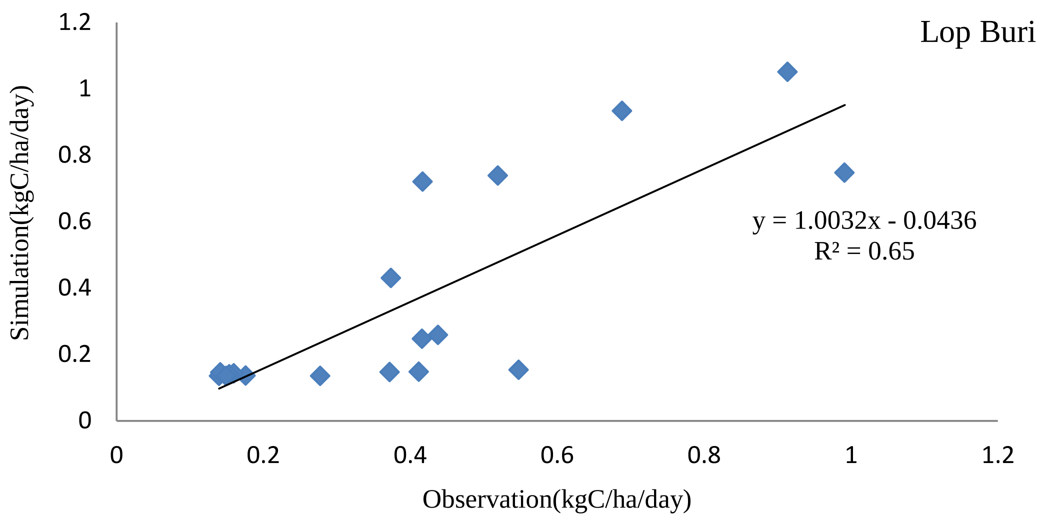


Figure 4.5 Correlation between observation and simulation CH_4 emission under continuous flooded condition at six study sites.


Phachinburi
simulation(kgC/ha/day)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2
observation(kgC/ha/day)
y = -0.0995x + 0.068
R² = 0.0265


Chai Nat
Simulation(kgC/ha/day)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5
observation(kgC/ha/day)
y = 0.9812x + 0.0268
R² = 0.5948


Lop Buri
Simulation(kgC/ha/day)
1.2
1
0.8
0.6
0.4
0.2
0
0 0.2 0.4 0.6 0.8 1 1.2
Observation(kgC/ha/day)
y = 1.0032x - 0.0436
R² = 0.65

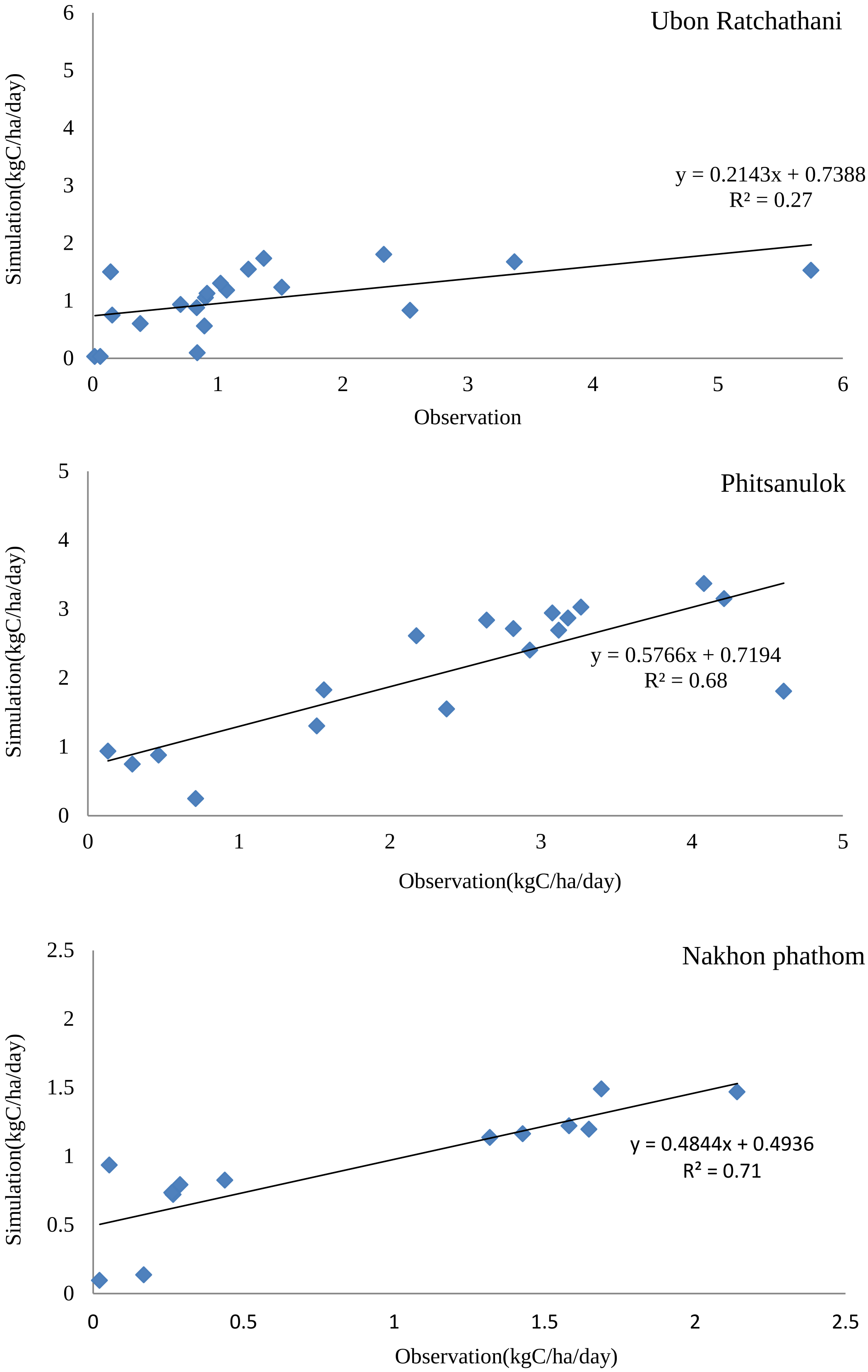


Figure 4.6 Correlation between observation and simulation CH_4 emission under AWD condition at six study sites.

4.4 **Sensitivity analysis of DNDC model**

The sensitivity analysis was carried out to find out the highest sensitive input parameter of the DNDC model that affects CH_4 simulation. It was expected that knowing this could help improve the simulation in the future through careful data collections and research. The input parameters for the DNDC model were obtained from field study sites and model's default value. This analysis focuses on microbial activities, clay fraction, soil organic carbon and water level because of there are high sensitivity. In general, CH_4 emission increases when microbial activity and SOC increase. However, the change in SOC affects more to the emission when compares to that of the microbial activities (Figure 4.7-4.7). On the other hand, CH_4 emission was negatively correlated with the clay fractions (Figure 4.9). In addition, the response in changes of clay fraction were quite different among sites. Emission in Lopburi and Ubonratchathani decreased significantly from about 12-16 kgCH_4/ha to less than 2, while at other sites these were less significant. This sensitivity analysis indicate that there is interactions between clay fraction and other factors specific for each site or group of sites. Thus, attentention should be paid on specific data collection priority and sensitivity analysis should be done for each site. This could lead to improvement in modeling performance.

Another parameter that significantly affects the simulation is the water level. The sensitivity of CH_4 emissions on the water level was tested from level 5 cm submerge soil surface and -15 cm below the soil surface because of the conditioned water of AWD was 5-(-15) cm. The result of CH_4 emission from the simulation was decreased when the water was drained, and increased after flooding (Figure 4.10). The emission was kept low as far draining was practices. This analysis also indicates the data on water level need to be obtained with high accuracy from the field to obtain good model performance.

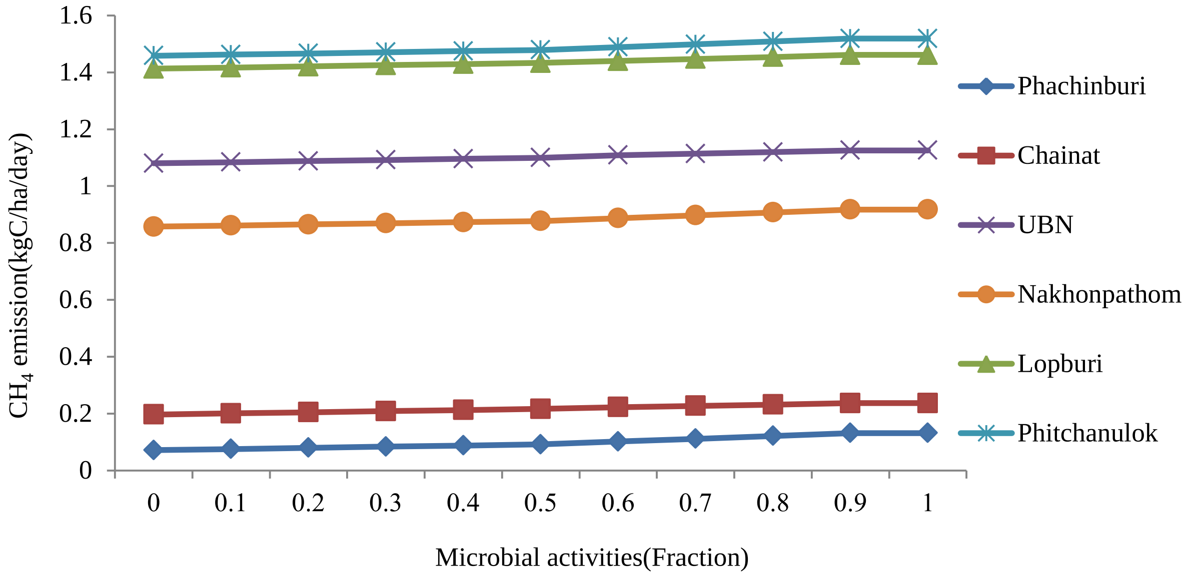


Figure 4.7 Sensitivity of DNDC simulated CH_4 emission with microbial activity.

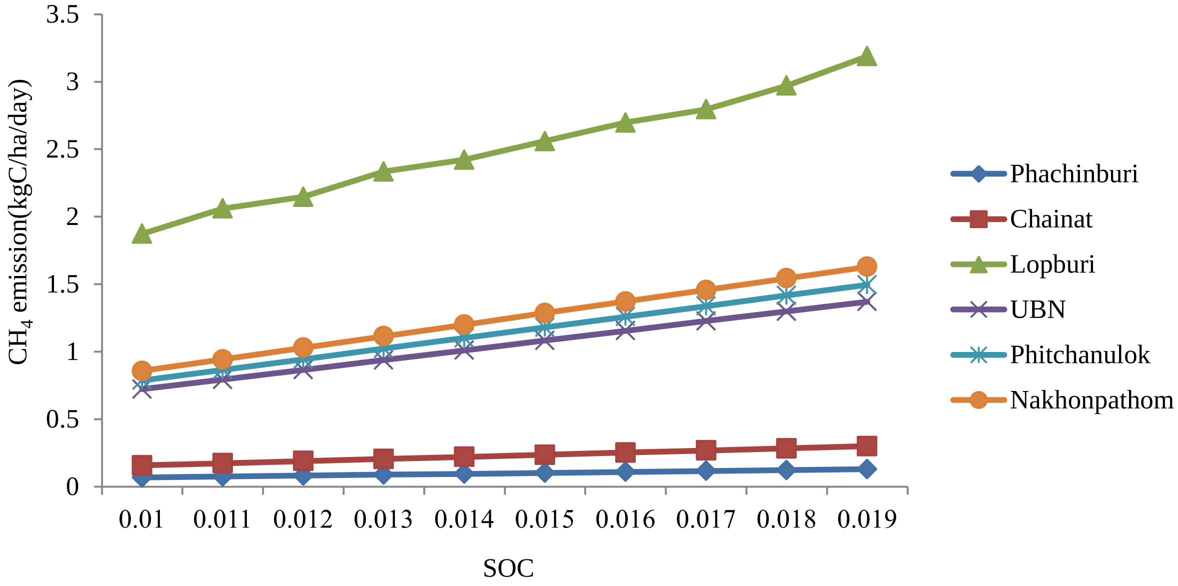


Figure 4.8 Sensitivity of DNDC simulated CH_4 emission with soil organic carbon.

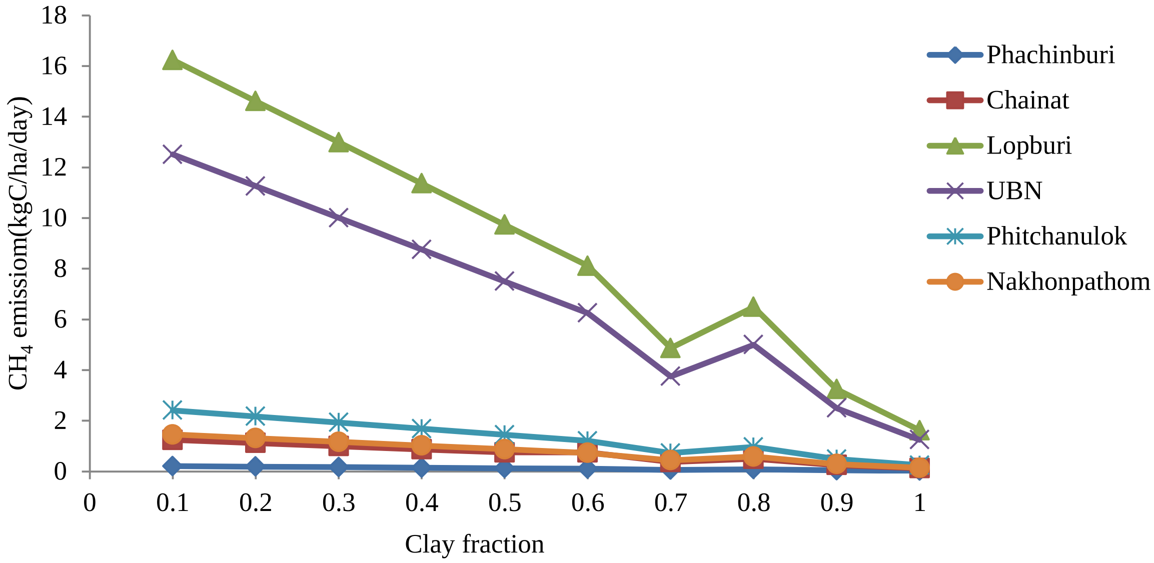


Figure 4.9 Sensitivity of DNDC simulated CH_4 emissions from rice fields with clay fraction.

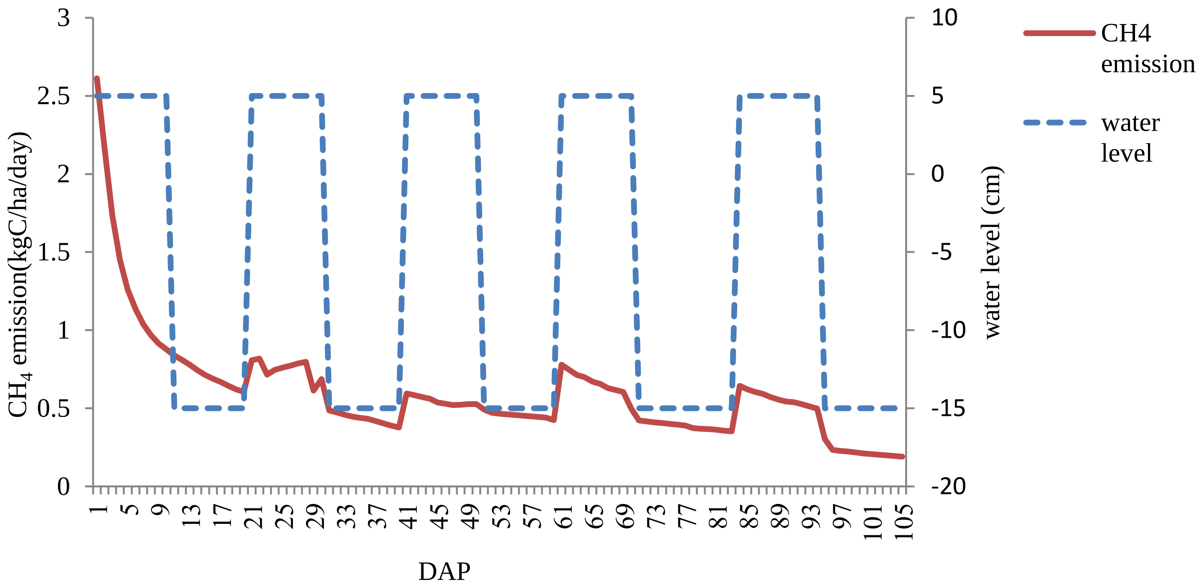


Figure 4.10 Sensitivity of DNDC simulated CH_4 emission water level.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

This study investigated the application potential of the DNDC model to simulate CH_4 emissions under different water management system that consists of AWD and continuous flooded. It was found that the average effect of water management as AWD on CH_4 emission from five sites was a reduced emission by 40%. One site (Pitsanulok) shows that CH_4 emission was higher under AWD when compared to continuous flooding conditions. Out of these six sites, DNDC could simulate the emission of CH_4 under both continuous flooding and AWD condition, with the average agreement between observed and simulated emission of 90±18%. However, an exception was for one site (Prachinbori) where no correlation between observed and simulated emission was found. This site is unique that it is an acid sulfate soil with heavy clayey texture and sea salt contamination. The processes and input parameter under such conditions may be not suitable for DNDC model. These results indicate that while AWD could effectively reduce CH_4 emissions and this could be modeled by DNDC, exception is always present. The result of sensitivity test indicate that microbial activities, clay fraction, soil organic carbon and water level have significant effect to simulation outputs. Thus, it is important that site characteristics and input parameters are obtained to test the model and thus more simulation and validation are required for further application of DNDC to estimate mitigation potential under AWD.

5.2 Recommendations and Limitations

From the experiences using the DNDC in this study, the results could be improved if the followings are considered;

1. The user cannot improve or modify the DNDC model by him/herself, while some input parameters are specific sites data, such as the type of fertilization, irrigation method. Thus, the capacity and collaboration for modifying source code may be needed.

2. The effects of specific site characteristics such as salinity and acidity/acid sultfate soil, cannot be evaluated and this could be the source of the low performance of the model at the Prachinburi site.

5.3 Future works

Basic data collections, such as cultivation practices and crop biomass and other necessary data from more sites, are needed to run DNDC and to improve the estimate of the effects of water management on CH_4 emissions in Thailand. Furthermore, the effects of AWD on crop yield and nitrous oxide (NO_2) should also be studied and simulated by the DNDC.

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Li, C., Frolking, S., Xiao, X., Moore, B., Boles, S., Qiu, J., Sass, R. (2005). Modeling impacts of farming management alternatives on CO_2, CH_4, and N_2O emissions: A case study for water management of rice agriculture of China. *Global Biogeochemical Cycles*, 19.

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APPENDIX

APPENDIX A 1: Daily maximum temperature, minimum temperature and precipitation at Chai Nat in 2014.

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
1	28.2	16.5	0	42	31.4	20	0
2	29.8	16.4	0	43	31.2	22	0
3	30.7	16	0	44	32	21.9	0
4	31	18.2	0	45	32.3	21.5	0
5	31.2	19.4	0	46	32.2	24	0
6	31	19.3	0	47	32.5	23	0
7	31.6	20.5	0	48	32	23.2	0
8	32.7	21	0	49	32.5	23.5	0
9	31.6	20.7	0	50	34	23	0
10	30.6	19.7	0	51	27.7	21.2	0
11	31	19.5	0	52	30.3	18.9	0
12	31.7	19.2	0	53	33	20.6	0
13	30.5	19.4	0	54	32.9	23	0
14	28	18	0	55	32.4	23.2	0
15	27.2	16.5	0	56	32.9	22.2	0
16	28.2	13.2	0	57	33.4	22.4	0
17	29.4	14.7	0	58	32.5	22.7	0
18	28.1	16	0	59	33	23	0
19	27.6	15	0	60	33.2	22	0
20	28.5	15	0	61	35.2	23	0
21	27.6	14.5	0	62	35.2	23	0
22	26	15.5	0	63	35.4	23.4	0
23	26.8	11.5	0	64	34	23.4	0
24	27.8	12	0	65	34.1	23.4	0
25	30.2	12.8	0	66	33.9	22.7	0
26	31.2	14.2	0	67	34	23.3	0
27	31.3	16.3	0	68	33.7	23	0
28	31.6	17.5	0	69	33.4	23.7	0
29	31.6	17.6	0	70	34.3	23.5	0
30	31.6	17.7	0	71	34.4	23.2	0
31	30.9	18	0	72	35	24	0
32	31.2	18.6	0	73	36	23.8	0
33	32.2	18.8	0	74	35.7	24.3	0
34	33.6	20.4	0	75	36.6	25.1	0
35	31.5	22	0	76	34	25.4	0
36	32.2	23.2	0	77	36.4	23.2	0
37	32.1	22	0	78	35.3	24.5	0
38	32	22.4	0	79	37	25.6	0
39	31.6	22.5	0	80	35.6	24.9	6.4
40	31.7	21.2	0	81	32.7	25.5	0.29
41	32.9	20	0	82	33.2	23.3	0

APPENDIX A 1: Daily maximum temperature, minimum temperature and precipitation at Chai Nat in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
83	35.9	24.4	0	124	36	25.2	0
84	35.3	25.4	0.11	125	37.2	25.6	0
85	36.5	25	0	126	36.7	25.6	3.02
86	37.3	25.6	0	127	34	24.5	0
87	37.2	24.2	0	128	36.6	24.5	0
88	36.2	24.5	0	129	36.3	26.2	0
89	36.6	25.4	0	130	36.8	25.8	0.02
90	37.7	25.5	0	131	37	25.4	0
91	38	24.5	0	132	37.2	25	0
92	36.8	25.7	0	133	36.9	26.3	0
93	37	26.4	0	134	37.6	25.5	0
94	34	25.9	4.62	135	37.6	26.3	0
95	33.6	23	0.02	136	37.6	27.2	0
96	34.8	23.4	0	137	37.8	26.8	0
97	36.8	25.5	0	138	37	28	2.9
98	37	25.3	0	139	34.2	23.4	0.08
99	37	25	0	140	36	25.2	0
100	37	25	0	141	36.5	27	0
101	36.8	25.8	0	142	36	25.7	0.04
102	36.8	25.4	1.02	143	35.5	25.3	0
103	35.6	24.1	0	144	36.7	26	0
104	36.2	25	0.58	145	38	26.5	0
105	35.2	23.6	0	146	36.7	26.5	0
106	36.5	24.5	4.89	147	37	26.3	1.76
107	36.4	24	0	148	34.2	23.4	0.07
108	37.3	26.2	0	149	35.8	25.5	0.68
109	36.7	25.6	0	150	35.3	24.8	0
110	37.3	27.3	0	151	35.7	25.5	0.12
111	36.7	26.4	0	152	36	25.6	0
112	38.2	25.2	0	153	35.7	25.3	0
113	38.8	27	0	154	37	26.7	0
114	37.6	26.1	0	155	36.6	26	0
115	38	26	0	156	36.7	26.6	0
116	38.5	27	0	157	35	25.8	0.26
117	38.5	26.2	0	158	34.5	25.4	0
118	38.6	25.6	0	159	35	26.8	4.22
119	34.8	23.7	0.04	160	33.8	25.5	0
120	34.3	25.6	0	161	34.5	26.5	0
121	36.5	26.7	0.23	162	34.5	27.5	1.13
122	34.7	24	0	163	32	24.9	0
123	35.7	26	0	164	33.5	26	0

APPENDIX A 1: Daily maximum temperature, minimum temperature and precipitation at Chai Nat in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
165	34	27.5	0.72	206	33.6	26	0
166	33	26.1	0.35	207	32.4	25	0
167	32.6	26.8	0	208	32.5	25.6	1.16
168	33	26.6	0	209	31.5	25.2	0.05
169	34	26.9	0	210	34	26	1.03
170	33.6	27	0	211	33	25.3	3.45
171	34.2	26.8	0	212	33.7	25.4	0
172	35.5	27.2	2.77	213	33.5	25.6	0
173	34.8	25.6	0.02	214	32.9	25.2	0
174	33.4	27	0.1	215	32.2	26	0
175	33	26	0	216	32.2	26.1	0.34
176	32.3	26.5	0.2	217	32.2	25.3	0.02
177	32.8	26	0.9	218	30.8	25.2	0
178	33.7	25.4	0	219	32	24.7	1.1
179	36.7	26	0	220	32.5	24.4	0.02
180	36.8	26	0.12	221	31.8	25.2	0
181	36.7	26.5	0.04	222	32	24.1	0
182	34	26	0	223	34.2	25.5	0
183	35	26.3	0	224	34.6	24.5	0.11
184	36.7	26.4	0	225	34	25.2	0.15
185	35.4	26.4	0	226	33.5	25	0.75
186	36.2	26.3	0	227	32.9	24	1.86
187	35.5	25.3	0	228	32.5	24.5	0.12
188	36	26.7	0	229	34.8	24.4	0
189	34.5	26	0.34	230	35.5	25.7	0.24
190	33.2	25.5	0	231	33.6	24.4	0
191	33.2	25.3	0.1	232	33.7	24.4	0.05
192	33	25.2	0	233	32.4	24.8	2.02
193	34.1	25.6	0	234	33	24	0.05
194	33.7	26.4	3.42	235	32.7	24.3	0.2
195	33.8	24.7	2.35	236	35.1	24.9	0.55
196	33	24.7	0.76	237	35.1	24.4	0
197	32	25.4	1.1	238	30.9	25.2	0
198	33.7	25	0	239	32.5	24.2	0.88
199	33.5	26.5	0	240	32.3	24.4	0
200	30.1	25.7	0	241	31.8	24.8	0.02
201	31.8	25	0	242	30.5	24.9	5.35
202	32.5	26	0	243	31.6	24	1.15
203	34.2	26.5	0	244	32.7	24.4	0.62
204	35.2	25.5	0.12	245	35.9	24.5	0.64
205	33.4	25.5	0	246	32	24	0

APPENDIX A 1: Daily maximum temperature, minimum temperature and precipitation at Chai Nat in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
247	33.9	24.3	0	288	32.5	23.2	0
248	33	24.6	0.06	289	33	22.7	0
249	33.5	24.9	0.33	290	33.3	24.2	0
250	32	24.6	0.12	291	33.5	24.5	0
251	34.5	24.5	0	292	32.5	24.5	0
252	34.4	24.3	0	293	32	24.9	0
253	34.4	25	0	294	32.6	24	0
254	33	25.2	3.42	295	33.2	24.4	0
255	34	24.4	0	296	31.5	24.3	0
256	35	24.7	0	297	31.7	24.5	0.97
257	34	25.4	2.2	298	32.8	24.5	0
258	34	24.2	0.03	299	30.3	25	0
259	33.5	25	0	300	34	24.4	0.39
260	33.5	25	0	301	34.3	24.2	0
261	31.7	25	0	302	34	24.9	0
262	34.9	24.6	0	303	34	24.7	2.19
263	35.4	21.2	0	304	34.5	24.4	1.21
264	35.5	22	0	305	34.7	25.5	0
265	33.5	22	0.09	306	33.8	25	1.12
266	35	26.1	0	307	32.8	24.5	0
267	31.2	25.4	1.02	308	32.8	23.8	0
268	30.6	24.9	0.25	309	32	24	0.76
269	32.5	22.5	0	310	32.5	24.8	0.01
270	35	22.5	2.13	311	33.7	25	0
271	35.2	24	0.57	312	33.9	23	3.9
272	33.2	24	0.36	313	32.8	25.3	0
273	32.5	24	0.03	314	34	24.2	0
274	34	24.5	0	315	34	25	0
275	33.7	24	2.98	316	34.3	24.8	0
276	34	25.3	0	317	33.4	24.3	0
277	34.5	25.5	0	318	32	24.3	0
278	34	25.4	0	319	32.6	22.5	0
279	30.1	23.8	0.3	320	32.7	24	0
280	32	24.8	0	321	32.7	23	0
281	31	24.6	0	322	31.7	22.2	0
282	31.5	23.5	2.65	323	31	21.2	0
283	33.8	25	0	324	31.1	20.5	0
284	33	23.9	0.62	325	31.2	21.5	0
285	32	24.1	0	326	32.8	21.7	0
286	32.8	23.5	0	327	32.5	22	0
287	32.8	25.3	0	328	33	22.2	0

APPENDIX A 1: Daily maximum temperature, minimum temperature and precipitation at Chai Nat in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
329	33.3	22.5	0	348	30.7	20	0
330	33.7	23.3	0	349	31.4	19.5	0
331	34	24	0	350	31.5	20.4	0
332	34	24.2	0	351	27.7	19.8	0
333	35	24.9	0	352	29	17.4	0
334	34.5	25.4	0	353	29.5	18	0
335	33.5	22.8	0	354	30.9	19.5	0
336	30	24.2	0	355	32.1	19.5	0
337	32.6	24.5	0	356	32.2	20.4	0
338	32.5	21.5	0	357	29.5	16.4	0
339	30.5	24.7	0	358	30.7	17.9	0
340	33.9	23	0	359	30.3	22.4	0
341	34	23	0	360	34	21	0
342	32.3	24	0	361	34.6	22.9	0
343	32	21.4	0	362	32.8	24.6	0
344	32.7	21	0	363	30.5	21.2	0
345	33.2	20.1	0	364	31	17.9	0
346	32.2	21.7	0	365	30.3	17.2	0
347	29.8	20.3	0				

APPENDIX A 2: Daily maximum temperature, minimum temperature and precipitation at Phachinburi in 2014.

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
1	31.2	17.2	0	42	33.7	20.8	0
2	32.5	16.1	0	43	34	24	0
3	33.2	17.7	0	44	34.2	23.5	0
4	34.2	18.2	0	45	33.6	24.2	0
5	32.8	20.6	0	46	33.8	24.8	0
6	34	19.7	0	47	33.7	24.7	0
7	33.5	21.6	0	48	35	25.1	0
8	34.4	21.5	0	49	34.7	25	0
9	33.6	21.5	0	50	34.8	24.2	0
10	33.1	22.5	0	51	28	21.4	0
11	34	21.2	0	52	30.4	20.7	0
12	34	22.5	0	53	34.7	20.5	0
13	32	21.3	0	54	34.8	23.4	0
14	30.6	19.3	0	55	35	24.7	0
15	29.9	18.4	0	56	34.6	24.5	0
16	29.5	18.2	0	57	34.3	24.1	0
17	31.5	16.2	0	58	34.7	24.4	0
18	29	19.2	0	59	34.5	24.5	0
19	29	18.4	0	60	34.5	24	0
20	29.8	16.7	0	61	34.6	23.6	0
21	29	18.9	0	62	36.1	24.4	0
22	27.4	16.7	0	63	36.1	25	0
23	28.7	16.2	0	64	36	23.8	0
24	29.7	14.5	0	65	36	24	0
25	31.4	14	0	66	35.6	24.4	0
26	31.7	16.2	0	67	35.5	24.9	0
27	33	18.6	0	68	36.1	25	0
28	33.5	19.7	0	69	34.1	25.1	0
29	33.7	19.5	0	70	35.7	25	0
30	34.5	19.6	0	71	35.8	24.6	0
31	33.7	19.4	0	72	35.7	25.3	0
32	34.5	24	0	73	37.6	25	0
33	33.4	19.6	0	74	36.7	26.2	0
34	34.9	21.2	0	75	36	24.9	0
35	34.5	22.9	0	76	36.9	27.1	0.04
36	33.7	23.5	0	77	37	24.5	0
37	34	24.1	0	78	37	26.7	0
38	34	24.1	0	79	37.9	26.2	0
39	34	24	0	80	38.5	26	0
40	34	22	0	81	33.5	25.5	0
41	33.5	20.2	0	82	36	25.2	0

APPENDIX A 2: Daily maximum temperature, minimum temperature and precipitation at Phachinburi in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
83	36.9	25.5	0	124	37.2	25.2	0
84	36.6	26.5	0	125	38.5	27	0
85	37	25.7	0	126	37	27.7	9.47
86	38.5	26.4	0	127	35.8	24.3	0
87	37.6	26.6	0	128	36.9	25.5	0
88	38.5	25.3	0	129	37.5	26.1	0
89	38.4	26.4	0	130	37.4	27.2	0.21
90	39.5	26.1	0	131	37.9	25.5	0
91	39	26.2	0	132	38.5	27.7	0.03
92	38.5	25.4	0	133	38	28	0
93	39.7	26.4	0	134	37.2	26.7	0
94	39.6	26.8	0	135	38.6	27.7	0
95	34	25.8	1.25	136	37.9	28.2	0
96	35.5	22.7	0	137	38	27.9	0.03
97	37.1	25.8	0	138	37.2	27.5	0
98	37.6	26.3	0	139	36.7	26.7	0
99	38	27.3	0	140	37.5	26.7	0
100	37.9	26.4	0	141	38	27.6	0
101	35.5	26.3	0.16	142	37.9	27.6	0
102	35.8	26	0	143	37.7	26.8	0
103	36.9	26.2	2.24	144	38.5	27.7	0
104	37	24.7	0	145	38.5	27.7	0
105	37.5	25	0.03	146	39	27.6	4.09
106	37.2	26	0	147	37.7	27	0.42
107	37.5	26	0	148	37.1	26.6	0
108	38.6	26.8	0.5	149	37.4	26.8	0
109	37.6	25.7	0	150	38.4	27.6	0
110	37.2	27.6	0	151	37.7	28.2	0
111	38	26.2	0	152	37.7	27.4	0
112	37.9	27.3	0	153	38.5	28	0
113	37.9	27.6	0	154	37.9	28.5	0.84
114	39	28	0.1	155	37	24.8	0
115	38.1	27.3	0	156	35.5	27	0.02
116	39.5	26.7	0	157	36.6	26.7	0
117	39.2	27.4	0	158	35.6	27	0
118	39	27.5	0	159	37.2	26.5	0.25
119	36.5	25.8	0	160	34.5	26.7	0
120	36.8	26	1.12	161	37	26.7	0
121	37	26.6	0.02	162	34.5	27.3	0.4
122	36.9	27.2	0	163	33.7	25.1	1.31
123	38	26.7	0	164	32.1	25.7	2.47

APPENDIX A 2: Daily maximum temperature, minimum temperature and precipitation at Phachinburi in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
165	33.4	26.7	0.97	206	33.2	25.9	0.45
166	34.5	26	0.55	207	35	25.7	0
167	31.8	25.7	1.44	208	34.8	25.8	0.89
168	34.5	26.6	0.61	209	31.1	24.7	0.08
169	34	25.3	0.33	210	35	25.2	1.05
170	33.5	26.7	0	211	32.6	25	1.38
171	34.6	26.7	0	212	34	24.9	0
172	34.9	27.5	2.68	213	33.9	26.6	0.54
173	34.4	24.5	0.34	214	31.8	25.4	1.37
174	34.6	24.9	0	215	32.8	25.7	0.45
175	34.1	26	1.15	216	32.5	25.2	2.23
176	31.5	26.3	0.11	217	30.5	24.6	1.97
177	31.5	25.2	0.51	218	31.2	24.4	0.84
178	34.9	24.9	0	219	33.3	24.5	0.82
179	35.6	26.6	0	220	34.1	24.2	0
180	36.2	26.9	0.04	221	33.1	25.1	1.16
181	33.3	26.8	2.25	222	33.3	25	0
182	34.7	24.4	0.06	223	35.7	26.4	0.02
183	35.5	24.6	1.25	224	34.4	25	2.47
184	35.4	26.7	1.78	225	34.4	24.8	0.28
185	36	25	0	226	33	25	0.14
186	36	27.2	0	227	34	23.9	0
187	35.9	27.2	0	228	34.1	26.4	0
188	35.1	27	0	229	36	26.3	0
189	34.6	27.8	1.43	230	35.8	26.2	0
190	33.4	25.3	0.03	231	35.5	27	2.08
191	33.6	25.7	0.04	232	34.4	25.3	1.39
192	34.2	25.9	0.01	233	31.9	24.8	2.25
193	33.7	26.6	0.12	234	34	25.5	0
194	34.7	26.6	4.46	235	33.9	25.7	0
195	32.6	24	0.74	236	35.8	26.4	1.1
196	33.7	24.7	0.37	237	34.2	24.1	0
197	33.1	25.2	1.9	238	34.1	26.5	4.57
198	35	25	0.06	239	33.8	24.5	0.04
199	33.3	26.1	0.57	240	32.9	24.6	0.6
200	30.7	25.5	0.93	241	32.7	24.5	2.08
201	34	24.8	0.03	242	30.2	24.3	0.38
202	31.7	26.6	2.1	243	31.2	24.8	3.58
203	33.5	24.8	1.42	244	32	24.3	0.99
204	33.8	25.2	0.38	245	32	24.5	2.77
205	34.7	25.1	0	246	32.2	23.8	0

APPENDIX A 2: Daily maximum temperature, minimum temperature and precipitation at Phachinburi in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
247	34	24.7	0	288	33.2	24.9	0
248	33.2	25.6	0.02	289	34.4	24.1	0
249	33.4	26	10.73	290	34.6	24.9	0
250	31.4	24.3	0	291	34.8	25.9	0
251	34.6	25	0	292	32.7	25.8	0
252	34.5	26.2	0	293	33.2	25.8	0.08
253	35.1	26.3	2.69	294	33.6	24.8	0
254	34.2	24.4	2.85	295	33.6	25.6	0
255	33.4	24.5	2.38	296	32.7	25.4	0.17
256	34.2	24.2	3.17	297	33.6	24.5	1.58
257	32.2	24.5	1.87	298	34.5	25	0.29
258	33.6	24.3	1.33	299	34.3	25.2	0.54
259	33.1	24.8	0	300	34.5	25.2	0
260	33.2	25.6	0.02	301	33	24.7	1.32
261	33.9	25.3	1.02	302	33.5	24.6	0.31
262	35	25.8	0.06	303	34.8	24.5	0.02
263	35.2	26.3	0.04	304	34	24.5	4.39
264	34.9	25.4	4.91	305	33.5	24.3	0.18
265	32.7	22.5	0	306	35	25.5	0.41
266	35	26.8	2.97	307	33.9	24.8	0.07
267	33.4	24.3	0	308	33.6	24.8	0.22
268	33.9	25.4	0	309	33.5	25	0
269	34	25.9	0	310	33.4	24.9	0
270	35.5	26.4	0	311	34.9	25.3	0
271	35.4	26.8	0.14	312	34.8	25.2	0.02
272	35.2	25.4	0.01	313	34.6	25.7	0
273	33.6	25.6	0.11	314	35.2	24.5	0.16
274	33.7	24.5	0	315	35	25.5	0
275	34.5	25.5	0	316	35.9	25	0
276	34.6	25	0	317	34	25.1	0
277	35.5	25.1	0	318	33.1	25.5	0
278	34	25	0.67	319	34.4	24.1	0
279	31.7	24.5	0.16	320	34.5	24.7	0
280	32.2	24.4	0	321	34	24.9	0
281	34	25.2	4.84	322	33.1	24.7	0
282	34.1	24.8	0.02	323	32.1	23.2	0
283	34.7	25.7	7.43	324	33	22.1	0
284	32	24.5	0.48	325	33.3	22.6	0
285	33.6	24.8	0	326	34.7	22.3	0
286	34.5	25	0	327	35.2	23.5	0
287	33.7	25.8	0	328	34.6	23.6	0

APPENDIX A 2: Daily maximum temperature, minimum temperature and precipitation at Phachinburi in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
329	35.9	24	0	348	32.7	21.9	0
330	36.2	25.7	0	349	34	22.2	0
331	34.9	25.1	0	350	32	22.7	0
332	34.2	25.2	0	351	28	21.1	0
333	35.3	25	0	352	29.9	20.4	0
334	34.1	25.2	0	353	31.3	19	0
335	35.9	25.5	0	354	32	20.1	0
336	34	26.1	0	355	33	19.7	0
337	31.1	26.2	0	356	30	20.2	0
338	33.4	25.4	0.12	357	31.3	18.3	0
339	31.7	24.9	0	358	33	19.6	0
340	34.8	24.7	0	359	34.3	22.3	0
341	34.4	24.1	0	360	35.4	23.3	0
342	34	23.8	0	361	35.4	25.8	0.08
343	33.6	23	0	362	32.6	24.7	0
344	34.2	21.7	0	363	31	21.3	0
345	34	23.5	0	364	31.8	20.2	0
346	32.9	24.2	0	365	31.8	19.8	0
347	31.5	21.8	0				

APPENDIX A 3: Daily maximum temperature, minimum temperature and precipitation at Phitsanulok in 2014.

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
1	28	14.3	0	42	33.5	18.5	0
2	29.2	16.4	0	43	32.3	21.8	0
3	31.2	16.3	0	44	33	21.8	0
4	31.3	17.2	0	45	33.3	22.9	0
5	30.2	18.2	0	46	32.6	21.7	0
6	31	18.4	0	47	33.8	23.3	0
7	32.2	18.9	0	48	33.4	23.5	0
8	32.5	19.5	0	49	34	23.8	0
9	31.5	19.2	0	50	34	22.3	0
10	30.3	18.9	0	51	27.7	22.8	0.05
11	30.9	18.2	0	52	30.5	18.6	0
12	30.4	16.8	0	53	32.9	20.2	0
13	29.6	18.2	0	54	34.5	21	0
14	27.5	17.3	0	55	33.9	21.6	0
15	27.4	14.8	0	56	34.2	22.1	0
16	27	14.5	0	57	35.2	22.2	0
17	27.9	12.3	0	58	34.6	22.6	0
18	28	13.7	0	59	33.4	23.2	0
19	25.7	13.2	0	60	34.2	22.9	0
20	26.8	11.4	0	61	35.7	23	0
21	26.8	14.2	0	62	35.8	22.6	0
22	26.1	13.5	0	63	37.2	23	0
23	26	10.5	0	64	35.5	22	0
24	27.2	10.6	0	65	35.3	21.6	0
25	29.2	12.2	0	66	35.4	23.3	0
26	30.2	14.4	0	67	34.7	23	0
27	30.5	15.8	0	68	34.3	22.7	0
28	31.3	16.5	0	69	35.5	22.5	0
29	31.6	17.5	0	70	34.8	24.2	0
30	31.4	17.6	0	71	35.9	23.3	0
31	31.3	18.2	0	72	36.2	24	0
32	32.1	18.3	0	73	37.3	23	0
33	33.3	19	0	74	35.5	25.3	0
34	33.6	19.7	0	75	35.3	25	0
35	33.8	17.9	0	76	35.5	24.7	0
36	32.2	18	0	77	36	24.3	0
37	32.5	20	0	78	37.3	25.4	0
38	32.3	19.4	0	79	37.1	25.5	0
39	32.3	20.7	0	80	36.8	24.4	0
40	34.2	19.5	0	81	32.7	24.2	0.14
41	33.2	18.1	0	82	33.2	23.4	0

APPENDIX A 3: Daily maximum temperature, minimum temperature and precipitation at Phitsanulok in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
83	35.7	24.3	1.49	124	35.4	24.4	0
84	33.7	22.5	0	125	36.6	25.7	0
85	36.6	23.2	0	126	35.9	25.3	0
86	37.1	24.9	0	127	35.7	23.5	0
87	37.7	25.3	0	128	37.5	26.2	0
88	37.2	24.6	0	129	37.5	25.4	0
89	37.7	25.2	0	130	37.3	25.4	0
90	38	25.4	0	131	38.1	26.3	0
91	38.3	25.7	0	132	39	26.6	0
92	36.7	25.1	0	133	38.4	28.3	0
93	36.7	26	0	134	38.2	25.5	0
94	34.6	25.8	0.09	135	38	24.3	0
95	34.6	22	0	136	38.1	27.2	0
96	36.1	21.7	0	137	38.9	27.6	0
97	36.7	24.2	0	138	34.1	27.3	2.61
98	36.9	24.3	0	139	34.8	24.5	0
99	36.9	25	0	140	36	26.2	1.14
100	37.7	25.2	0	141	36.5	25	0
101	37.6	26	0	142	36.8	26.2	0
102	37.2	24.9	0.04	143	37	25.8	0
103	36.9	24.3	0	144	37.9	27.3	0
104	36.7	25.6	0.17	145	38	27.3	3.74
105	36.2	23.3	0	146	34.4	23.6	0
106	37.5	23.8	0	147	36.5	25.8	4.77
107	37.4	24.3	0	148	34.8	24	0.36
108	38.7	25.8	0	149	35.3	26.3	0.2
109	38.7	26.7	0	150	35.5	25	0
110	38.4	27.5	0	151	35.3	25	0.14
111	38.4	26	0	152	33	25.5	0.23
112	39.6	26.7	0	153	36	24.5	0
113	39.2	27	0	154	36.1	26.2	0
114	38.4	26.2	0	155	36.5	26.2	0
115	38	24.2	0	156	36	27.6	0.56
116	39.2	26.8	0	157	35.7	25	0.19
117	39.7	26.6	0	158	34.3	25.2	1.01
118	38.8	27.6	5.98	159	34.8	24.8	1.53
119	36.3	22.3	0	160	34.1	24.3	0.02
120	36	23.7	0	161	34	25.6	0.22
121	36.6	23.6	0	162	35.2	25.1	0.28
122	36.3	24.9	3.34	163	34.4	24.5	0
123	31.6	22.8	0.06	164	33.7	26.5	0

APPENDIX A 3: Daily maximum temperature, minimum temperature and precipitation at Phitsanulok in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
165	34.4	26.8	0.06	206	34	25.2	0.15
166	35	26	0.02	207	33.3	24	0
167	31.5	25.6	0.17	208	33.1	25.1	0.86
168	34.1	25.4	0	209	30.5	23.5	0
169	35	25	0	210	34.9	25.2	1.09
170	34.3	26	0.2	211	34.1	24.7	0
171	32.6	25.4	0.01	212	34	25.4	0
172	34.8	25.6	0	213	34.4	25.2	0.07
173	34	25.6	0	214	33.7	24.8	0.34
174	34.8	26	0.32	215	33.3	24	0.06
175	35.2	25.2	0	216	33.5	25.4	0.14
176	32.9	25.9	0	217	31.2	24.3	0.02
177	33.8	24.8	0.06	218	31.7	23.9	3.62
178	35	25.1	0	219	32	23.8	3.53
179	36	26.6	0	220	32.3	23.8	0
180	36.2	25.1	0.04	221	32.3	23.8	0.48
181	32.1	25.7	0.15	222	32.1	23.5	0
182	31.5	25.8	0.08	223	33.4	24.4	0
183	35.7	24	0	224	33.5	24.5	1.22
184	36.6	26.1	0	225	33	24.5	1.12
185	37	26.8	0	226	33.3	24.3	2.16
186	37.2	26.4	0	227	34.6	23.6	0.86
187	36.7	27.1	0	228	28.6	23.8	0.06
188	35.8	27.4	0	229	34.1	24	0.06
189	35.8	27	0.04	230	34.6	24.4	1.03
190	35.2	26	0.45	231	33.3	24.7	0
191	35.4	26.1	0.81	232	32.5	25	0
192	34.4	25.3	0	233	33.4	25.3	2.38
193	36.4	26.5	0	234	32.5	25	0
194	32.9	26.7	7.11	235	34	26.1	0
195	32.4	24.5	2.75	236	34.4	24.2	0
196	33.6	24.3	1.52	237	34.6	25.2	3.04
197	33.5	24	0.02	238	33.4	24	0
198	34.2	25.2	3.46	239	31.5	24.4	0.77
199	32.3	24.2	0.42	240	32.1	24.8	1.2
200	30.3	25.1	0.51	241	31.6	24.2	2.68
201	31.3	24.2	0	242	29.6	24.7	1.69
202	30.9	25.3	1.57	243	32.3	23.7	0.07
203	33.8	25	0	244	33.4	24.8	2.24
204	32.9	26.1	0	245	30.2	24	1.63
205	34.4	24.2	0	246	31.2	24.3	1.92

APPENDIX A 3: Daily maximum temperature, minimum temperature and precipitation at Phitsanulok in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
247	31.5	25	0.16	288	32.3	22.8	0
248	32.3	25.2	0	289	32.8	22.3	0
249	33.4	24.1	0.62	290	33.5	22.7	0.05
250	32.6	24.5	0	291	33.6	23.5	0.32
251	34.5	25	0	292	33	23	0.18
252	34.4	25.9	0	293	32.3	24.8	0.28
253	33.5	26	0	294	32	23.7	1.85
254	32.9	24.2	0	295	32.6	24	1.2
255	33.5	25.1	0.01	296	30.3	22.9	7.21
256	34.6	25.5	4.92	297	26.7	23	3.44
257	33.6	22.9	0	298	32.5	22.5	0
258	34.3	25.2	0.04	299	33.7	23.2	0
259	33.7	25.6	0	300	34.1	24.3	0
260	33.5	25.6	0.35	301	34	24.3	3
261	31.8	24.8	5.87	302	31.7	24.7	0.51
262	33.1	23.3	0	303	34.2	24.8	3.05
263	34.8	25	0	304	34.2	23.9	0
264	33.8	25.9	0.14	305	35.1	25.5	0
265	30	24.5	0.04	306	34.4	24.8	0.13
266	34.4	25	0.03	307	34.6	24.7	0
267	32	24.9	3.15	308	32.9	23.4	0
268	31.3	24.2	0.43	309	29.4	25	4.58
269	31.6	25	0.02	310	31.6	23.5	0.1
270	34.3	24.3	0	311	32.9	24	0
271	34.9	25.5	0	312	33.5	24.6	0
272	34.2	25	0.54	313	31.5	25	12.4
273	32.5	23.6	0	314	33.7	23.9	0
274	33.1	24.2	0.04	315	34.3	24.2	0
275	32.9	24.4	0.59	316	34.2	23.6	0
276	34.5	23.6	0	317	34.2	24.2	0
277	34.8	24.6	0	318	32.5	23.6	0
278	35	24.7	0.18	319	32.7	23.3	0
279	30.5	23	0.02	320	32.6	23.8	0
280	33.2	23.3	0	321	33.1	23	0
281	33.1	23	0	322	32	21.1	0
282	31.9	24.6	0	323	31.5	20.7	0
283	32.7	25.3	0	324	31	19.3	0
284	34.2	25.1	2.25	325	31.5	20.7	0
285	32.4	23.5	0	326	33.1	20	0
286	33	22.5	0	327	32.6	21.5	0
287	33.7	22.7	0	328	33.1	20.6	0

APPENDIX A 3: Daily maximum temperature, minimum temperature and precipitation at Phitsanulok in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
329	33.3	20.7	0	348	30	18.7	0
330	34	21	0	349	31.7	19.6	0
331	33.8	22.9	0	350	31.4	20.1	0
332	34.5	23.5	0	351	29.3	19.5	0
333	34.5	23.8	0	352	28.5	17.4	0
334	34.3	22.7	0	353	28.9	17.5	0
335	33.2	20.5	0	354	29.8	18.3	0
336	32.4	23.3	0	355	31.4	18.7	0
337	30	23.7	0	356	28.2	19.1	0
338	33.5	23.3	0	357	27.6	16.1	0
339	31.6	25.6	0	358	29.6	16.2	0
340	32.6	24.1	0	359	30.1	19.2	0
341	34	22.6	0	360	32.5	20.3	0
342	32.7	22.7	0	361	34.7	21.6	0
343	32.1	21.9	0	362	34.3	23.7	0
344	31.7	21.5	0	363	30.5	21.5	0
345	32.1	20.3	0	364	30.6	19.6	0
346	31.5	20	0	365	30.7	18.7	0
347	30.2	18.3	0				

APPENDIX A 4: Daily maximum temperature, minimum temperature and precipitation at Ubon Ratchathani in 2014.

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
1	28.2	12.2	0	42	32.2	18	0
2	30.6	13.2	0	43	33.6	16.5	0
3	33	13	0	44	31.7	19.5	0
4	31	16.6	0	45	28.4	16.3	0
5	30.7	15.5	0	46	31.1	15.4	0
6	31.9	16.3	0	47	34	17.5	0
7	33.2	16.8	0	48	34.4	19.5	0
8	33.9	16.8	0	49	35.7	20.2	0
9	31.6	17.2	0	50	26.5	21.7	8.4
10	31.5	17.6	0	51	23	14.6	0
11	31.6	16.9	0	52	30	15.3	0
12	31.5	18.2	0	53	33	17	0
13	29.7	17.3	0	54	35.1	17.5	0
14	27.5	15	0	55	35.2	17.7	0
15	27	12.4	0	56	35.2	20.5	0
16	29	12.7	0	57	35.8	19.2	0
17	29.6	14	0	58	34.7	20.2	0
18	26.3	16	0	59	35.2	21.5	0
19	27.8	13.5	0	60	36.2	20.7	0
20	29	13.7	0	61	37.5	21	0
21	26	15.8	0	62	37.6	21.9	0
22	25.1	12.8	0	63	37.6	23.5	0
23	27.7	12.2	0	64	36.8	23.5	0
24	28.5	11.5	0	65	35	25	0
25	30.9	12.1	0	66	36.3	22.5	0
26	30.5	14.8	0	67	35.5	23.3	0
27	31.5	15.7	0	68	36.8	23.6	0
28	32	14.8	0	69	35.2	22.5	0
29	31.9	16.4	0	70	37.7	22.5	0
30	31.2	15.5	0	71	37.5	23.3	0
31	31.5	13.7	0	72	37.5	21.7	0
32	33	14.4	0	73	37.8	22.7	0
33	34	15	0	74	36.1	21.7	0
34	35.8	16.8	0	75	36.8	21.8	0
35	33.8	19.5	0	76	38	22	0
36	34	22	0	77	38.6	26.2	0
37	33.5	20.2	0	78	38.2	24.6	0
38	35	20.2	0	79	38.7	24.5	0
39	35	18	0	80	37.2	24.2	0.01
40	34.7	20.7	0	81	32	20.5	0
41	34.8	20.5	0	82	36.4	19	0

APPENDIX A 4: Daily maximum temperature, minimum temperature and precipitation at Ubon Ratchathani in 2014. (Con’t)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
83	36.3	20	0	124	33.8	23	0.02
84	37.4	21.5	0	125	36.5	24.6	0
85	38.1	22.2	0	126	33.2	24	0
86	37.2	24	0	127	35.4	23.6	0
87	37.2	25.2	0	128	36	24.3	0
88	39	25	0	129	35	25.5	0.05
89	39.2	25.2	0	130	38.7	25	0.01
90	39.8	25.5	0	131	36	24	0
91	39.5	24.6	1.19	132	36.7	26.2	0
92	36.7	22.5	0	133	37.5	26.7	0
93	39	24.7	6.98	134	34.5	24.7	0
94	30.7	21.2	0.02	135	37.5	25.8	0
95	33.2	22	0	136	38	25	0
96	33.8	22.6	0	137	38.6	26.5	0
97	35.9	23	0	138	34.8	25	0
98	35.8	23.2	0	139	37.3	25.2	0
99	36.7	23.8	0.18	140	38.5	26.2	0
100	36.4	24.2	0	141	38.2	25.7	0
101	29.2	25	0.76	142	38.8	26.4	0
102	35.2	23.2	0	143	39	26.6	0
103	35.7	24.7	1.91	144	39.8	26.2	0
104	31	22.2	0.01	145	39.4	26.4	0
105	34.2	23.7	0	146	38.4	27	1.79
106	34.2	24	0	147	36.7	24.5	0.76
107	35.7	24.9	0	148	36.7	25.2	0
108	33	25	0	149	38	25.8	0
109	36.8	25	0	150	38.2	25.7	0
110	36.5	26	0	151	35	26	0
111	36.6	26	0	152	37.5	26	0
112	36.5	25.4	0.82	153	36.5	26.5	0
113	36.2	25	0	154	38.2	24.7	0.66
114	37.3	24	0	155	37.2	23.9	0.03
115	38	25.6	0	156	36.5	26.1	0.002
116	37.3	25.3	0	157	33.6	26	0.15
117	38.2	25.2	0.43	158	35.3	25.2	0
118	34	23.7	0	159	37.4	24.7	0
119	32	23.8	0	160	36.5	26.4	0
120	35	22.6	0	161	33	24.5	1.57
121	34.8	24.5	0.69	162	31.8	23.4	0.02
122	34.5	23.2	0	163	32.2	24.5	0.03
123	34	24.7	2.09	164	32.5	24.5	0.12

APPENDIX A 4: Daily maximum temperature, minimum temperature and precipitation at Ubon Ratchathani in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
165	31.6	24.3	0.22	206	32.5	24.5	0
166	34	24.6	0.22	207	33.4	24.4	0.04
167	34.2	24.5	0	208	30.9	23.9	0.26
168	33.5	25.3	0.07	209	31.4	23.3	0.21
169	32	24.8	0.29	210	30	23.5	1.01
170	34.5	24.5	0.02	211	28	23.8	0.97
171	34.5	24.3	0.04	212	30.7	23	1.29
172	32.4	23.8	1.23	213	29.6	24.8	5.85
173	30.7	23.5	0.87	214	29	24.7	0
174	29	24	0.04	215	31.3	23.8	1.74
175	33.2	24.5	0.14	216	31.7	25.3	0.23
176	32.7	23.6	0.11	217	29.6	23.1	1.36
177	32	23.7	0	218	31.7	23.8	0
178	34.2	24.3	0	219	30.8	23.5	0.13
179	32.2	26	0.25	220	32.5	24.1	0
180	30	23.5	1.06	221	31.8	24.7	0
181	30.3	22.5	0.03	222	33.7	25.5	0
182	34	24.4	0.00	223	34.5	25.7	0
183	32.2	24.7	0.28	224	34.5	25.5	0.18
184	33	24.5	0	225	34.2	24.8	1.46
185	34.9	25.7	0	226	32.5	25.1	0
186	33.6	25.5	0.36	227	33.5	25	0.08
187	34.3	24.8	0	228	35	25.3	0
188	35	26	0.19	229	34.6	24.3	0
189	32.5	23.5	0.03	230	34.2	25.3	0.75
190	33.5	25.2	0.03	231	34.3	25.7	0.02
191	32	24.5	0.00	232	32.2	23.8	0
192	33	25.7	0.17	233	33.2	24.7	0.10
193	32.6	24.5	0.09	234	34.7	25	0.01
194	33.2	24.9	0.14	235	34.5	24.5	0
195	33.3	24	0.61	236	35.8	24.6	1.10
196	31.6	23.2	0.13	237	31.8	25.9	0.20
197	33.5	23.4	0	238	30.6	23.5	0.06
198	32.9	24.5	0	239	32	24.3	0.25
199	30.7	25.5	0.19	240	32.2	24.5	0
200	31	24	0.45	241	33	24	0.01
201	28.3	22.5	0.14	242	32.9	23.7	1.44
202	31	23	0.50	243	33.7	24.2	0.92
203	30.8	23	1.14	244	30.9	23.7	0.42
204	27.8	23	0.29	245	31.5	23.5	0
205	32.7	23.7	0	246	33	23.5	7.87

APPENDIX A 4: Daily maximum temperature, minimum temperature and precipitation at Ubon Ratchathani in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
247	33.5	24.3	2.70	288	32.8	21.2	0
248	32.3	21.7	0	289	34.4	21.5	0
249	32.7	23	8.68	290	34.2	21.1	0.08
250	32.3	24.5	0	291	32.8	21.2	0.02
251	32.5	23.5	0	292	34.5	22.7	0.47
252	33.5	24.6	1.14	293	33.6	23.6	0
253	32.4	24.9	0	294	33.2	23.3	0
254	32.8	24.5	0.08	295	34.7	22.9	0.02
255	31	25.1	1.30	296	34.2	23.5	0.79
256	32.4	24.2	0.48	297	31.5	23	0
257	31.8	24.1	0.01	298	32.5	22.5	0.02
258	32	23.7	0.01	299	32.7	23	7.62
259	29.5	24	3.14	300	33	23.5	0.53
260	31.8	23.5	0	301	33.2	23	0.13
261	33.2	23.7	0	302	32.8	23.3	0
262	34	24.5	0	303	33.7	23.1	0
263	35.4	25	0.04	304	33.5	23.6	0
264	33.5	25.8	0	305	34.5	24	0
265	31.2	24.3	0.24	306	33.8	22.8	0
266	33.6	23.5	6.05	307	33.2	21	0
267	32	24.6	7.98	308	34.5	21.4	0
268	26.8	23	0	309	34.5	22.4	0
269	33.2	23.4	0	310	35.4	22.9	0
270	35.4	24.5	1.18	311	35.4	23.5	0
271	34	25	0	312	35.1	24	0
272	33.2	23.8	2.02	313	34.5	22.9	0
273	33.4	24.5	0	314	34.8	21.8	0
274	32.7	22.8	0	315	35.2	22.4	0
275	35	23.7	0	316	35	22	0
276	34.5	23.5	0.23	317	32	23	0
277	34.8	24.5	1.47	318	31.4	22.5	0
278	33.5	24.5	0.00	319	34.2	21.7	0
279	31.6	23.5	0.00	320	34.2	20	0
280	32.3	21.8	0.04	321	33.8	21.7	0
281	32.7	23.2	0	322	31.2	21.2	0
282	33.3	21.5	0	323	32.2	20.8	0
283	33.6	22.2	0	324	32.5	19.5	0
284	33.2	21.6	0	325	33.9	19	0
285	33.5	21.3	0	326	34.2	19	0
286	34.2	22.5	0	327	34.9	19.8	0
287	33	21.7	0	328	35	22	0

APPENDIX A 4: Daily maximum temperature, minimum temperature and precipitation at Ubon Ratchathani in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
329	35.5	21.5	0	348	30.7	15.7	0
330	35.9	22.8	0	349	32.5	16.8	0
331	35	23.5	0	350	30.2	19.9	0
332	35.9	23.9	0	351	26.5	18	0
333	34.3	23.2	0	352	28	15.6	0
334	33.4	22.2	0	353	29.6	16.5	0
335	33.4	24.2	0.02	354	30.5	15	0
336	32.8	23.5	0	355	31.5	16.7	0
337	33	21	0.08	356	28.5	16.3	0
338	32	22.8	0.02	357	29.8	14	0
339	33.4	19.9	0	358	32.6	18	0
340	31.6	19	0	359	33.9	18.6	0
341	34.2	20	0	360	34.7	20.3	0
342	32	19.2	0	361	35.2	20.8	0.23
343	32.4	17.5	0	362	30.9	20.7	0
344	32.7	18	0	363	29.1	16.5	0
345	32.2	18.3	0	364	30.2	13.6	0
346	30.4	18.7	0	365	29.5	14	0
347	28.5	18	0				

APPENDIX A 5: Daily maximum temperature, minimum temperature and precipitation at Nakhon phathom in 2014.

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
1	28.9	14.2	0	42	34	17.7	0
2	30.5	13.6	0	43	33.5	21.3	0
3	32.5	14.6	0	44	33.6	20.2	0
4	31.3	14.6	0	45	34	19.7	0
5	32.1	17.6	0	46	34	21.6	0
6	31.8	17.4	0	47	32.8	24.4	0
7	32.5	20	0	48	33.1	22.1	0
8	32.8	18.9	0	49	34.7	21.8	0
9	32.1	20.3	0	50	34.6	22.6	0
10	30.2	19.1	0	51	27.6	22.8	0
11	31.4	17.1	0	52	27.2	21.2	0
12	32.1	18.2	0	53	33	18.4	0
13	29.6	17.1	0	54	33.8	21	0
14	27	17	0	55	34	21.9	0
15	26.7	13.1	0	56	34.2	21.2	0
16	27	12.1	0	57	34.2	20.8	0
17	28.1	13.6	0	58	33.3	22	0
18	28.5	16.6	0	59	33.9	22.3	0
19	25.9	16.7	0	60	34.5	23	0
20	26.5	14.2	0	61	36.5	22	0
21	26.2	16.8	0	62	35.9	22.2	0
22	24.4	14.1	0	63	36.2	22.2	0
23	25.7	10.6	0	64	36.6	22.2	0
24	27.5	10	0	65	35.2	22.9	0
25	29.3	10.3	0	66	35.7	22	0
26	29.2	12.5	0	67	35.8	22.1	0
27	30.2	13.8	0	68	35	21.8	0
28	31.2	16.5	0	69	34.1	22.3	0
29	31.4	16.2	0	70	35.5	22.5	0
30	31.7	17.9	0	71	35.4	23.3	0
31	32.1	16.6	0	72	35.5	23.5	0
32	33	16.6	0	73	36.2	22.5	0
33	34.5	17	0	74	35.2	23.1	0
34	35.9	19.8	0	75	35.8	22.8	0
35	35	21.5	0	76	35.7	24.7	0
36	33.4	23.5	0	77	37	24.5	0
37	35.2	20.9	0	78	37	23	0
38	33.9	22.2	0	79	37.7	24.5	0
39	33.1	21.4	0	80	36	25	0
40	34.3	19	0	81	34.5	24.9	3.69
41	33	18.2	0	82	32	23	0

APPENDIX A 5: Daily maximum temperature, minimum temperature and precipitation at Nakhonphathom in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
83	34.3	23.1	0	124	34.8	24.4	2.09
84	35.7	23.5	0	125	37	23.3	0
85	35.6	24.3	0	126	36.9	25.1	0.29
86	37	25	0	127	35	22.8	2.52
87	37.6	24.3	0	128	37.2	23.3	0
88	35.5	24.5	0	129	37	24.4	0
89	36	24.5	0	130	37.2	24.2	0.04
90	36.6	25.3	0	131	36.2	24.2	0
91	38	25	0	132	38	24.9	0
92	36.2	25.3	0	133	37	26	0.02
93	37	26.2	0	134	38	24	0
94	36.2	24.1	0.05	135	37.5	24.5	0.31
95	34.5	23	0	136	37.5	24.6	0
96	36.4	23.5	0	137	37.5	24	0
97	37.8	24.5	0	138	34.5	26	0
98	37.5	22.9	0	139	36.1	23.5	0
99	37.6	23	0	140	36.5	23.5	0
100	37.2	24.5	0	141	37.2	23	0
101	37.5	25	0	142	36.5	22.5	0
102	37	23.5	0	143	36.6	22.8	0.06
103	36.5	23	0	144	37	22.8	0
104	36.5	25	0	145	37.5	24.5	0
105	36.5	23.6	0	146	37.5	23.5	0
106	36.9	24.1	0	147	37.2	25.1	0.03
107	37.5	24.5	0	148	36.7	23.5	1.03
108	37.5	25	0	149	36.2	22.9	0
109	37.5	25.5	0	150	37.5	23.5	0.4
110	37.2	25.5	0	151	36.5	25	0
111	37.5	25	0	152	35.6	24	0
112	38	23.6	0	153	37.5	23	0.13
113	39	26.5	0	154	38	24.5	0
114	37.8	24.9	0	155	36.9	24.5	3.56
115	37.5	24	0	156	37	23.5	0
116	38.4	24.5	0	157	35	22.5	0.18
117	39	24.5	0	158	34.5	23	0.24
118	38	25.5	0	159	35.5	23.3	0
119	36.5	25.5	0	160	35	23	0
120	37.5	25.5	0	161	33.5	24.2	0
121	38.5	23.5	0	162	35	24.3	0
122	36	24.7	0	163	33.5	24.5	0
123	37	25	0	164	34.2	22.9	0.03

APPENDIX A 5: Daily maximum temperature, minimum temperature and precipitation at Nakhonphathom in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
165	34	24.8	0.26	206	34.5	21.3	0
166	34.5	23	0.09	207	34	20	1.7
167	34.1	23.5	0	208	33	21	0.06
168	33.5	23	0	209	31	21.5	0.67
169	32.5	23.5	0	210	34.1	21.7	0.83
170	34.9	25.5	0	211	34.5	21.5	0
171	36	23	0.14	212	33.4	21.2	0
172	34.5	23	0.14	213	33	21	0.45
173	35	23.5	0.04	214	33	21	0
174	34.5	23	0	215	32.7	25	0.52
175	34	22	0.51	216	33	22.2	0
176	33.1	23	1.34	217	33.5	20.1	0
177	33	22.5	0	218	33.9	21.1	0.97
178	35.5	21.5	0	219	32.5	20.5	0.3
179	36	22.6	0	220	32	20.5	0.15
180	36	23.2	0.35	221	33	20.7	0.03
181	34.5	24	0	222	34.5	20.5	0
182	34.2	22.3	0.46	223	34.5	21	1.25
183	35	22	0	224	35	20.5	0
184	36	21.5	0	225	33.3	21	1.44
185	37	23.2	0	226	34.5	21.5	0
186	38	22	0.54	227	33.5	21.1	0
187	36.5	22	0.02	228	34.5	20.5	0
188	35.5	22	0	229	36.8	21.5	0
189	33	23	0.36	230	35.8	22.2	0
190	32.5	22.5	0.02	231	35	23.1	0.57
191	32.2	22.5	0	232	34	23.8	4.02
192	33.8	23.2	0	233	33.1	25.6	0
193	34.5	23	0	234	35.3	23.2	0
194	34.5	22.5	0.26	235	36	23.2	0
195	33	22	0.27	236	37.7	22	0.04
196	33	22.4	0.15	237	34.5	23.5	0.54
197	34	21.5	0	238	34	22.5	2.62
198	34.5	22	0	239	35	24.5	0.36
199	33	23.4	0	240	36.5	23.5	0
200	30	21.5	0.12	241	30	24	0
201	33	21.6	0.3	242	32.5	24	0
202	33	22	0.02	243	33	22	0.54
203	34.5	22.2	0	244	34	22.5	0.15
204	36	21	0	245	33	22.5	1.88
205	35	20.8	0	246	33.5	23.5	0.98

APPENDIX A 5: Daily maximum temperature, minimum temperature and precipitation at Nakhonphathom in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
247	33	23.5	0	288	33	22.1	0
248	33.3	24.5	0.02	289	32.4	22	0
249	33	24	0.14	290	32.7	22.2	0
250	35.9	25.3	0	291	32.2	23.1	0
251	35.9	25.1	0.01	292	32.3	23.8	1.53
252	35.2	24	0	293	33.5	23.8	0.28
253	34.6	25.2	0	294	32.8	23.5	0
254	34	24.5	1.16	295	33.9	23.2	0.26
255	35	24.5	0	296	31.8	23.2	2.96
256	35	25	0	297	32.3	22.8	1.36
257	34.9	24.5	0.2	298	32	24.2	0
258	34.5	24.5	1.16	299	33.3	23.5	0
259	33.5	25	0	300	33.4	22.5	0.58
260	33.5	24.9	0	301	31.2	24.5	0.28
261	36.5	25	0	302	33	23.5	0.88
262	36	24.5	0	303	33.5	24	0
263	36.5	25	0	304	33.5	24.2	0
264	34	26	0	305	35	24	0.02
265	37	25.5	0	306	32.4	23.7	0.32
266	34.1	26.5	0	307	29.5	23.2	0.47
267	33	25	2.14	308	32	23	5.1
268	33.5	24.5	0	309	34	24.1	0
269	34.8	25.4	0	310	34	24	0
270	34.8	25.5	0	311	33	23	1.68
271	35.1	23.5	0	312	33.1	22.9	0
272	33	24	0.88	313	33	23.5	0
273	32.5	23.6	1.49	314	33.5	23.5	0
274	34.2	23	1.62	315	33.4	23	0
275	34.1	23.5	0	316	32.5	22.2	0
276	33.9	24.6	0	317	31	22.8	0
277	30.2	24.7	0	318	32	21.8	0
278	30	23.5	3.85	319	31.8	22	0
279	30	24.2	0.54	320	31.5	22.3	0
280	32	23	1.74	321	31	22	0
281	34.2	24	2.2	322	30.5	21.5	0
282	32	23.6	0.07	323	30	19.5	0
283	33	24.5	0.12	324	31.2	18.1	0
284	32.4	23.5	1.72	325	31.6	19.5	0
285	32.2	22	0	326	32.3	19.5	0
286	32	25	0.1	327	32.3	19.4	0
287	32	22	0	328	32.6	20.5	0

APPENDIX A 5: Daily maximum temperature, minimum temperature and precipitation at Nakhon phathom in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
329	33.2	21	0	348	30.2	17.8	0
330	34.2	23.2	0	349	30.5	19	0
331	34	23.2	0	350	26	19	0
332	35	22.5	0	351	27	15.6	0
333	34	22.3	0	352	28.5	15.4	0
334	33.1	22.7	0	353	28	15.5	0
335	30	22.2	0	354	29	18	0
336	30.6	23	0.03	355	30.7	17	0
337	31.5	22.2	0	356	27	19.4	0
338	29.9	23.6	0.8	357	27.5	16.2	0
339	32.5	21.6	0	358	29.8	16.2	0
340	33	21.2	0	359	30.5	20.5	0
341	32.5	21.3	0	360	32.3	19	0
342	31.3	20.3	0	361	31.1	20.7	0.02
343	31.5	20	0	362	32	20.5	0
344	31.5	19.8	0	363	30.5	20	0
345	30.5	19.8	0	364	28.5	16.1	0
346	26.8	19	0	365	30.5	15.4	0
347	29.1	19.5	0				

APPENDIX A 6: Daily maximum temperature, minimum temperature and precipitation at Lop buri in 2014.

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
1	30	17	0	42	33.5	21	0
2	30.8	15.6	0	43	32.4	23.5	0
3	32.9	15	0	44	33.5	23.5	0
4	33.2	17.6	0	45	33.8	23.9	0
5	32.1	22.4	0	46	33.1	24.9	0
6	33.2	19.6	0	47	32.6	24	0
7	33.1	20.8	0	48	33.2	24	0
8	33.9	21.7	0	49	33.9	24.2	0
9	33	21.6	0	50	35.3	24.5	0
10	32.5	23	0	51	30.2	21.8	0
11	33	22.9	0	52	31.9	21.4	0
12	32.5	20.4	0	53	34.2	21.2	0
13	31.3	22	0	54	34	24.1	0.5
14	29.1	19	0	55	33.2	24.2	0
15	28.2	19.1	0	56	34.1	23.9	0
16	28.6	16.1	0	57	34.7	23.8	0
17	30.5	15.1	0	58	33.9	24.6	0
18	28.3	19.5	0	59	34	24.8	0
19	28.2	17.8	0	60	34.6	24.3	0
20	28.8	15.7	0	61	35.5	24	0
21	27.6	19.4	0	62	35.6	24	0
22	26.5	17	0	63	36	24	0
23	27.2	15.2	0	64	35	23.9	0
24	28.7	12.9	0	65	35.4	24.4	0
25	30.5	13.2	0	66	35	24.4	0
26	32.7	15.5	0	67	35.3	24.6	0
27	32.3	17.5	0	68	34.1	24.7	0
28	33.9	18	0	69	34.1	24.8	0
29	33.5	19.2	0	70	35.6	24.6	0
30	33.5	19.1	0	71	35.1	25	0
31	33.3	19	0	72	36	25	0
32	32.6	19.3	0	73	37	25	0
33	33.7	19.7	0	74	35.5	26.4	0
34	34.7	22.5	0	75	37.7	26.1	0
35	34.3	23.5	0	76	34.6	27.5	0
36	33	23.5	0	77	37.3	24.9	0
37	33.9	23	0	78	36.7	26.4	0
38	33.4	23.2	0	79	37	26.5	0
39	33.3	23.5	0	80	36.9	26.5	0
40	33.1	22.7	0	81	33.8	26.3	0
41	34	21.9	0	82	34.4	24.8	0

APPENDIX A 6: Daily maximum temperature, minimum temperature and precipitation at Lop buri in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
83	36.3	25.4	0	124	37.9	27	0.14
84	35.6	26.6	1.12	125	37.6	27.6	0
85	37.2	26.5	0	126	37.6	27.5	0
86	38.1	26	0	127	35	24.1	0
87	37.5	26.6	0	128	37.4	25.5	0
88	37	26	0	129	36.9	27.3	5.36
89	37	26.6	0	130	37.5	26.7	0.22
90	37.9	26.1	0	131	37.1	26.5	0
91	38	26.5	0	132	38.1	27	0
92	37.3	26.4	0	133	37.3	27.9	0.02
93	37.5	26.6	0	134	37.4	26.5	0
94	36	27.4	0	135	37.7	27.8	0
95	35.2	24	0	136	38.1	28.1	0.01
96	35.8	23.5	0	137	38	28	0
97	37.1	25.6	0.18	138	36.5	27.6	0
98	37.3	26.2	0	139	36.1	25.9	0
99	37.6	26.6	0	140	36.3	25.9	0.07
100	37.3	26.6	0	141	37.3	26.2	0.34
101	36.9	27	0	142	36.6	26.6	0
102	36.5	26.6	0	143	36.9	26.6	0.04
103	36	24.4	0	144	37.7	26.5	0
104	36.9	26	0	145	38	28.2	0
105	35.3	23.3	2.93	146	37.5	27.9	0
106	36	26.3	0.06	147	36.9	28	0
107	37	26.5	4.82	148	36	25.5	0
108	36.5	27	0	149	36.9	26.4	0
109	36.9	26.5	0	150	36.5	27.2	0.33
110	37.5	27.4	0	151	37.4	27.2	0
111	37.6	27.1	0	152	37	27.7	0
112	38.4	27.1	0	153	38	26.9	0
113	37.8	27.9	0	154	38.1	28.4	0
114	37.5	27.6	0	155	37.7	26	0
115	37.3	27.5	0	156	36.8	27.1	0
116	38.3	27.4	0	157	36.5	25.8	0
117	38.2	27.1	0	158	35.7	26.8	0
118	37.5	27.6	0	159	36.3	26	1.85
119	35.5	27	0	160	36	27.4	0
120	35.5	26.7	0	161	35.4	27.5	0
121	37.1	27	0	162	36.2	27.8	0
122	36	26.3	0	163	34.2	26.6	0
123	37.8	27	0.04	164	35.6	26.2	0

APPENDIX A 6: Daily maximum temperature, minimum temperature and precipitation at Lop buri in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
165	35	27.6	1.44	206	33.1	25.5	0
166	34.5	26	0	207	33.7	25.6	0
167	32.9	26.2	0	208	32.7	25.4	0.95
168	37	26.3	0.04	209	31.7	25.5	0
169	34	26.2	0.35	210	35.1	25.6	1.29
170	34	27.2	2.82	211	33.4	25.8	0
171	35.5	26.8	0	212	33.6	25.5	0
172	35	26.5	0	213	34	25.5	3.33
173	35.1	26.5	0	214	34	25.3	0.85
174	32.9	26	0.02	215	33.5	25.9	0
175	34.5	25.5	0.26	216	32.9	26	1.33
176	35.1	27.1	0.41	217	33.9	26.4	0
177	33.4	26	0	218	32.6	25	0.17
178	34.8	24.3	0	219	33.5	25	0
179	36.9	26	0.02	220	33.7	24.5	0
180	36.4	26.3	1.41	221	33.9	25.5	0.09
181	34	26.4	0	222	34.2	25.5	0.53
182	34.1	25.5	0	223	35.5	26	0
183	35.5	26.7	1.85	224	35	24.5	0
184	36.3	27	0.15	225	34.1	26	0
185	36.4	27	0	226	33.9	25.3	1.27
186	36.4	26.7	0	227	33.9	24	0.01
187	36.5	26.2	0	228	33.2	25	0.05
188	34.4	27	0	229	34.9	25.5	4.73
189	35.7	26.5	0	230	36.1	26	0.71
190	34.3	26.3	0	231	34	25.4	0
191	34	26.2	0	232	34.1	25	0
192	35.1	27	0.16	233	33.3	24.5	1.43
193	35.2	27.3	0	234	32.5	25	0
194	35.2	27.4	0	235	34.4	26.1	0.62
195	32.1	25	0	236	35	26.5	3.68
196	33	25.4	0	237	34	24.7	0
197	34	25.5	1.07	238	32	26.3	0.02
198	34.2	25.5	0.06	239	33.9	24.6	0
199	34	26.1	0	240	33.1	24.6	0
200	30.5	25.5	1.04	241	32.5	25	0
201	34.1	25.1	0	242	30.3	25	1.34
202	32.9	25	0	243	29.1	25.4	0.18
203	34.5	26.4	0	244	32.6	23.9	0.08
204	35.7	26	0	245	31.7	24.5	0.22
205	35.5	25.5	0.03	246	32.3	24.5	0.31

APPENDIX A 6: Daily maximum temperature, minimum temperature and precipitation at Lop buri in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
247	33.2	24.6	0.94	288	33.1	23.9	0.45
248	33.3	25.3	0.15	289	33.3	22.4	0
249	32.3	25.4	0	290	34	23.9	0
250	32.1	24	0.02	291	33.9	24.8	0
251	34	25	0.09	292	32.5	25.6	0
252	34	25.1	1.13	293	32.5	26	0
253	33.8	25.5	0.49	294	33.3	24.3	0
254	36.5	26.3	0	295	33.8	24.3	0
255	34.4	25.3	0	296	33	24.3	0
256	33.7	24.5	0	297	32.2	24.5	0.78
257	33.5	25.9	0	298	34	25.4	0
258	33.7	24.5	1.41	299	33.1	26	0.53
259	33.7	25	0.01	300	35.3	24.4	0
260	33	25.3	9.07	301	34.7	24	0.18
261	33	26	0.5	302	33.3	25.6	0
262	34.5	25.9	0	303	34.1	24.7	0.19
263	35	26.3	0	304	33.6	25.2	0.71
264	35.1	26.4	0	305	35.2	25.2	0.75
265	31.5	24.5	0	306	34.8	24.6	0.02
266	34.5	26.4	0	307	34.5	24.5	0
267	32.3	25.7	0.05	308	32.6	24.9	0.37
268	32	25	0	309	31.1	23.7	0
269	32.2	24	0	310	33.5	25.5	0.15
270	34.6	26.3	1.38	311	34.4	25.7	0
271	34.6	25.5	4.92	312	33.5	24.5	3.6
272	34.1	25.8	0	313	32.8	25.1	0.02
273	32.5	24.5	0	314	34.1	24.4	0
274	33.2	24.4	0.51	315	34.9	25	2.86
275	33	23.6	0.99	316	35.1	25	0.05
276	34.4	24.7	0.84	317	34	24.2	0.2
277	34.5	25	0	318	31.5	25.2	0
278	33	24	2.25	319	33.2	24.9	0
279	30.8	23.5	0.24	320	33.6	24.4	0
280	31.5	25.6	0.06	321	33.4	24.5	0
281	31.1	25.4	0	322	32.9	24.3	0
282	32	24.3	0	323	31.5	22.6	0
283	34.5	24.6	0.04	324	32.2	22.3	0
284	31.4	25.8	0	325	33	20.5	0
285	32.9	24	0.65	326	34.1	21	0
286	33.6	23.1	0	327	34.6	21.9	0
287	33.4	25.2	0.16	328	35.3	21.5	0

APPENDIX A 6: Daily maximum temperature, minimum temperature and precipitation at Lop buri in 2014. (Con't)

Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)	Julian day (2014)	Maximum temp.(C)	Minimum temp.(C)	Precipitation (cm)
329	35.5	23	0	348	31.9	21	0
330	35.5	23.8	0	349	33.5	21	0
331	35.1	25.1	0	350	31.9	22	0
332	35.1	24.7	0	351	28.3	21.6	0
333	35.5	25.4	0	352	29	20.5	0
334	35.9	25.1	0	353	31	21.3	0
335	34.6	23.3	0	354	31.5	21.5	0
336	31.4	26.1	0.4	355	32.7	18.5	0
337	33.2	24.1	0.51	356	29	21	0
338	34.1	24.5	0	357	28	20	0
339	34.1	25.5	0	358	32	18	0
340	34	23.7	0	359	33.5	22.6	0
341	34.4	23.5	0	360	34.9	21.7	0
342	33.3	23.6	0	361	35	23.2	0
343	33	23.5	0.04	362	32.9	24.5	0
344	33.6	21	0	363	30.7	22.1	0
345	33.5	24.4	0	364	30.9	19.6	0
346	32.4	24	0	365	30.8	17.6	0
347	29.1	22	0				

APPENDIX B 1: Water table depth at Chai Nat in 2014 under continuous flooding.

Chai Nat			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
31	1.7	69	3
38	1.5	73	3.5
42	2.6	77	3.3
44	1.8	80	3.2
48	2.8	84	3.4
52	2.8	87	3.5
59	3.3	91	3.4
62	3.1	100	4.1
66	3.4		

APPENDIX B 2: Water table depth at Lop buri in 2014 under continuous flooding.

Lop buri			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
210	2.5	283	0.5
231	1	284	1.5
238	1.5	287	1.2
244	3	288	1.6
246	1	289	6.3
252	0.5	290	1.8
259	1	291	5.3
267	1	292	1.3
277	3.5	293	1.2
278	1.2	294	0.7
279	4.8	301	0.8
281	0.5	308	1.3
282	0.5		

APPENDIX B 3: Water table depth at Nakhon phathom in 2014 under continuous flooding.

Nakhon phathom			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
1	10	66	10
3	10	70	10
4	10	71	10
24	10	76	10
25	10	77	10
34	10	88	10
35	10	89	10
41	10	93	10
42	10	94	10
50	10	101	10
51	10	102	10
57	10		
58	10		
65	10		

APPENDIX B 4: Water table depth at Phachinburi in 2014 under continuous flooding.

Phachinburi			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
179	4.03	219	9.67
180	3.35	220	9.83
181	9.88	221	9.83
182	8.30	222	10.00
183	8.78	223	9.50
184	8.75	224	9.17
185	8.78	225	9.33
186	8.03	226	9.33
187	8.83	227	9.33
188	8.58	228	9.83
189	8.50	229	9.33
190	8.42	230	9.33
191	8.83	231	9.08
192	8.25	232	9.33
193	8.33	233	9.17
194	8.58	234	9.67
195	9.17	235	9.75
196	10.00	236	10.00
197	8.58	237	9.58
198	8.83	238	9.25
199	9.33	239	9.75
200	8.83	240	9.42
201	9.00	241	9.50
202	10.00	242	12.33
203	10.00	243	11.67
204	8.92	244	11.58
205	9.17	245	10.67
206	9.17	246	11.75
207	9.08	247	12.08
208	9.33	248	11.67
209	9.17	249	10.83
210	9.50	250	11.83
211	9.33	251	14.33
212	9.33	252	12.92
213	9.83	253	11.83
214	9.33	254	11.50
215	9.33	255	11.67
216	9.67	256	15.00
217	9.83	257	17.00
218	10.33	258	41.00

APPENDIX B 5: Water table depth at Phitchanulok in 2014 under continuous flooding.

Phitchanulok	
Julian_day	WaterTable_cm
30	3
37	3
44	2.5
47	5
51	8
58	8
65	8
72	8.5
79	8.5
82	8.5
86	9.3
93	10
100	10
103	9.5

APPENDIX B 6: Water table depth at Ubon Ratchathani in 2014 under continuous flooding.

Ubon Ratchathani			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
218	2.5	293	3
225	1.9	295	2.4
232	1.9	296	3.1
235	2.2	297	3.3
239	2.4	298	3.4
246	1.6	299	2.4
250	2.1	300	3.2
253	1.6	301	2.1
260	2.3	302	3
267	3	303	2.2
270	0	304	2.7
274	3.2	305	2.3
281	2.3	306	4
288	3.2	307	4.6
289	2.5	308	2.3
290	1.8	309	3.2
291	2.4	310	2.5
292	2.7	311	2.3

APPENDIX C 1: Water table depth at Chai Nat in 2014 under AWD.

Chai Nat			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
31	1.4	69	3.1
38	2	73	0
42	2.7	77	3.6
44	0	80	0
48	0	84	3
52	3.6	87	0
59	0	91	3.5
62	3.5	100	3.7
66	0		

APPENDIX C 2: Water table depth at Lop buri in 2014 under AWD.

Lop buri			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
210	1.1	287	-0.3
231	1.1	288	-4.7
238	2.7	289	-7
244	2.2	290	3.7
246	1	291	0.3
252	1.7	292	-5
259	-3.7	293	-3.5
267	-7	294	-0.7
277	-1	301	3.7
278	-1	308	1.3
279	-1	309	-8.8
281	-5	310	7
282	1	311	-3.7
283	2.3	312	-9.7
284	2		

APPENDIX C 3: Water table depth at Phachinburi in 2014 under AWD.

Phachinburi			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
179	4.22	220	8.75
180	3.52	221	8.58
181	9.50	222	8.08
182	8.08	223	7.75
183	5.33	224	7.08
184	4.83	225	6.50
185	4.08	226	6.33
186	3.60	227	5.83
187	2.92	228	6.33
188	2.17	229	5.75
189	2.00	230	5.25
190	-1.25	231	4.17
191	-1.75	232	3.67
192	8.75	233	3.58
193	7.67	234	3.33
194	6.83	235	3.42
195	6.33	236	3.33
196	8.00	237	2.42
197	7.08	238	1.33
198	6.75	239	-1.33
199	9.00	240	-3.00
200	7.75	241	-6.33
201	7.50	242	12.17
202	8.00	243	11.92
203	8.17	244	11.42
204	8.00	245	10.67
205	7.75	246	11.00
206	7.58	247	11.50
207	7.17	248	11.00
208	6.75	249	10.17
209	6.50	250	13.33
210	6.42	251	15.00
211	6.08	252	13.33
212	6.58	253	12.42
213	7.75	254	11.92
214	7.17	255	12.25
215	7.25	256	15.67
216	8.08	257	17.67
217	8.75	258	41.17
218	9.67	259	44.33
219	8.83		

APPENDIX C 4: Water table depth at Phitchanulok in 2014 under AWD.

Phitchanulok	
Julian_day	WaterTable_cm
30	2
37	2
44	4.5
47	4
51	3
58	2
65	-2
72	1
79	-15
82	8.5
86	9
93	9
100	5.5
103	3

APPENDIX C 5: water table depth at Nakhon phathom in 2014 under AWD.

Nakhon phathom			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
1	10	58	10
3	-15	66	-15
4	10	70	10
24	-15	71	-15
25	10	76	10
34	-15	77	-15
35	10	88	10
41	-15	89	-15
42	10	93	10
50	-15	94	-15
51	10	101	10
57	-15	102	-15

APPENDIX C 6: Daily water table depth at Ubon Ratchathani in 2014 under AWD.

Ubon Ratchathani			
Julian_day	WaterTable_cm	Julian_day	WaterTable_cm
218	5	289	2.3
225	2.6	290	1.1
232	1.8	291	1.5
235	1.2	292	0.9
239	2.7	293	0.9
246	1.6	294	3
250	1.1	295	3
251	0	296	4.6
253	1	298	2.1
254	1.7	299	1.3
255	1.5	300	3.1
256	1.2	301	1.7
257	1.7	302	2.4
258	1	303	2.3
260	1.7	304	2.8
261	2.9	305	1.1
263	2.4	306	1.7
268	0.6	307	2.5
270	0	308	2.6
274	0	309	2.8
281	3.9	310	1.1
288	1.1	311	1.7

APPENDIX D 1: CH_4 emission from observation and simulation at Chai Nat under continuous flooding and AWD(mgC/m^2/day).

DAP	Continuous flooding		AWD	
	Observation	Simulation	Observation	Simulation
7	23.82	2.13	22.46	15.12
14	18.78	11.78	31.17	33.86
20	23.61	25.91	35.05	41.96
24	48.06	33.86	22.86	46.16
28	52.92	39.85	24.88	31.21
35	33.11	47.81	18.03	14.05
42	31.16	38.75	7.09	6.07
49	18.97	36.65	5.12	8.76
56	34.58	33.17	5.05	4.85
59	10.78	11.78	20.84	1.81
69	10.29	17.63	8.99	6.11
70	16.45	11.84	5.78	7.48
77	5.69	24.87	5.14	11.55
84	34.20	20.59	6.41	13.34
91	9.83	16.58	5.41	14.76
97	6.54	15.59	1.79	2.13
104	12.41	13.39	1.19	9.27

APPENDIX D 2: CH_4 emission from observation and simulation at Nakhon phathom under continuous flooding and AWD(mgC/m^2/day).

DAP	Continuous flooding		AWD	
	Observation	Simulation	Observation	Simulation
39	16.44	9.89	16.86	13.35
44	26.93	13.50	214.05	146.78
51	63.92	93.27	164.84	119.46
58	60.18	74.63	5.47	93.44
65	48.92	71.96	28.92	79.06
72	213.19	117.97	-29.62	42.93
79	51.76	73.24	26.66	71.96
86	78.47	79.06	26.21	73.24
92	102.19	93.44	43.80	82.47
100	347.55	148.86	158.16	121.89

APPENDIX D 3: CH_4 emission from observation and simulation at Lop Buri under continuous flooding and AWD(mgC/m^2/day).

DAP	Continuous flooding		AWD	
	Observation	Simulation	Observation	Simulation
5	48.80	74.73	17.61	13.50
12	22.68	73.24	13.97	13.42
19	43.16	71.96	54.77	15.21
24	64.70	73.80	99.14	74.63
26	81.97	88.47	91.37	104.99
33	142.52	121.89	68.87	93.27
39	141.72	148.86	41.72	71.96
41	104.45	145.49	51.93	73.80
47	140.21	116.09	14.14	14.45
54	144.24	164.45	41.17	14.63
62	117.17	143.61	37.19	14.54
72	111.19	157.93	16.00	14.14
82	219.59	194.31	15.37	13.86
96	181.07	193.08	14.94	13.43
103	171.66	180.04	27.76	13.38

APPENDIX D 4: CH_4 emission from observation and simulation at Phachinburi under continuous flooding and AWD(mgC/m^2/day).

DAP	Continuous flooding		AWD	
	Observation	Simulation	Observation	Simulation
21	185.70	3.21	18.57	9.50
28	64.05	8.08	6.41	9.79
35	55.13	10.83	5.51	9.48
42	55.13	13.73	5.51	7.96
43	99.98	13.97	10.00	7.61
44	56.10	14.03	5.61	7.32
45	60.08	14.01	6.01	7.05
46	82.43	13.97	8.24	6.82
47	55.13	13.91	5.51	6.58
49	58.50	13.67	5.85	5.02
56	55.13	13.05	5.51	6.78
63	59.48	13.24	5.95	6.57
64	55.13	13.73	5.51	6.29
65	56.25	14.20	5.63	4.70
66	75.23	14.48	7.52	4.48
67	70.65	14.59	7.07	4.31
70	80.70	14.31	8.07	3.87
77	69.23	14.77	6.92	0.87
84	178.65	15.75	17.87	3.87
88	147.30	15.75	14.73	0.97

APPENDIX D 5: CH_4 emission from observation and simulation at Phitsanulok under continuous flooding and AWD(mgC/m^2/day).

DAP	Continuous flooding		AWD	
	Observation	Simulation	Observation	Simulation
7	44.72	8.67	71.44	24.62
14	13.36	16.83	13.36	93.27
21	29.45	82.47	29.45	74.63
28	19.25	71.96	46.93	87.66
35	16.25	73.24	151.62	129.98
39	199.14	204.56	460.91	180.13
42	93.68	121.89	237.71	154.49
49	149.33	181.22	307.78	293.88
59	249.94	202.99	264.26	283.32
63	234.97	202.37	318.01	286.44
70	180.66	190.68	281.89	271.01
77	135.06	187.70	217.72	260.81
84	338.86	202.60	408.07	336.65
91	172.43	189.59	156.45	182.21
98	239.65	195.06	311.90	268.97
105	273.20	196.78	292.80	239.82

APPENDIX D 6: CH_4 emission from observation and simulation at Ubon Ratchathani under continuous flooding and AWD(mgC/m^2/day).

DAP	Continuous flooding		AWD	
	Observation	Simulation	Observation	Simulation
7	1.83	7.80	1.70	2.79
14	11.49	9.97	6.03	3.09
21	65.01	11.02	83.62	9.15
24	12.70	12.34	15.61	74.63
28	34.72	73.24	70.37	93.27
35	156.51	122.69	90.23	104.99
39	141.76	128.31	38.07	59.88
42	226.36	121.27	89.44	56.01
49	57.66	107.78	253.84	82.94
56	213.21	110.19	83.20	87.66
59	170.83	113.53	91.53	112.39
63	149.22	110.76	107.28	117.97
70	225.67	200.42	151.43	123.30
77	220.86	212.33	102.47	129.98
84	587.27	204.48	233.02	180.13
91	273.44	196.93	136.97	173.44
98	278.23	193.49	574.71	152.50
105	17.05	113.53	124.62	154.49