Soil Management for Maximizing Carbon Sequestration in Thailand

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Abstract: Soil Carbon is one of the important pools constituting global C budget and plays a key role in crop production and management. The amount of carbon stock is related to land use and soil management. The changing of land use from forest to agriculture in Thailand has increased rapidly in many parts of the country. This forest conversion to crop may lead to decreased or increased soil carbon storage, depending on the management techniques employed. Improving soil management has great potential to increase the amount of carbon sequestered in cropland soil. Similarly, altering the management of agricultural ecosystems can result in changes in carbon fluxes, including changes in soil organic carbon (SOC) and associated CO_2 emissions. Thus, reducing greenhouse gas emissions in agriculture can provide a window of opportunity for the other sectors to develop alternative technologies whereby their rates of CO_2 emissions can be decreased, and they can also assist in carbon sequestration. This paper reveals that the carbon sequestration managements in Thailand, especially in agriculture section are operated under the global warming mitigation of the agriculture section planned by the Ministry of Agriculture and Cooperatives of Thailand in the first phase: 2008-2011. This plan is proposed to attempt to understand the global warming impact upon agriculture and how the agriculture section can mitigate the global warming caused by these practices. These include the research, development of soil information and water and crop management related to the climate change. The Land Development Department (LDD) works as the focal point of organizations. For the achievement goals, LDD set the project for supporting this mitigation plan. There are 2 main projects: 1) The campaign projects which consist of the crop residues incorporation in soil for carbon sequestration and the perennial tree growing for mitigating of global warming, and 2) Research for supporting the campaign projects, which consisted of the soil carbon dynamics under crop residues incorporation and the effects of tillage systems on carbon sequestration. However, there are some research studies from the university such as the study on soil carbon dynamics in corn, sugarcane, rice, etc. These also included the GHG emissions from soil under different management patterns.Soil organic improvement program can be used to increase soil organic carbon. However, the accumulation rate depends on improvement and conservation measures, types of soil and land utilization. Generally, wet land soils have the highest potential in carbon sequestration. Mechanical soil conservation practices indicated the reduction of soil loss but also the soil organic carbon depletion. For the soil carbon stocks, LDD technical report in 2002 revealed that the majority soils of Thailand were classified as Order Ultisols, Alfisols, Inceptisols in 41.88, 10.85 and 10.47% of the total area (about $5{,}500\times10^6$ ha), respectively. However, the estimation of average SOC contents showed that the most of the OC content in 0-100 cm depth was classified as Order Inceptisols, Ultisols and Alfisols in 138.2, 86.3 and 81.9 ton ha^{-1} in 1 meter of soil, respectively. The estimation of the distributions of OC content in country showed that most of the soils at depth 0-25 cm. contain the amount of soil organic carbon, (SOC) 40-80 ton ha^{-1} covering an area of $2{,}222\times10^6$ ha (43.3% of country area). The SOC contents of 20-40 ton ha^{-1} covered an area of $1{,}710\times10^6$ ha (33.3% of country area) and < 20 ton ha^{-1} covering an area of 361×10^6 ha (7.03% of country area). At depth 0-100 cm, covering the area of 2065×10^6 ha (40.25% of country area) contains the soil organic carbon of 40-80 ton ha^{-1}. Most of the remainder contains the amount of organic carbon over 80 ton ha^{-1} and a small amount under 40 ton ha^{-1}. In 2008, the data of organic carbon (OC) contents were reported that the OC contents were classified as low soil OC (OC < 0.29-0.86%) covered in 38% of the total soil survey area. The suitable OC (OC = 0.86-1.73%) area covered 43.3% of the total soil survey area. This paper has concluded recommendations the network of soil carbon information study on application of policy, measures as well as research and strategy in increasing soil organic carbon to enhance agricultural potentiality of Thailand and global warming mitigation.
Keywords: Soil C stock, C sequestration, soil management, Thailand

1. Introduction

Soil C is one of the important pools constituting global C budget and plays a key role in agricultural management. The soil carbon pool comprises Soil Organic Carbon (SOC) estimated at 1550 Pg and Soil Inorganic Carbon (SIC) at about 750 Pg, both to 1-m depth. Thus the total soil C pool of 2300 Pg is three times the atmospheric pool of 770 Pg and 3.8 times the biotic pool of 610 Pg (Batjes, 1996). The atmospheric pool has steadily increased since in 1850, and is currently increasing at the rate of 0.5% yr^{-1} or 1.8 ppmv yr^{-1}. The amount of soil carbon stock is related to land use and managements. Changing of land use from forest to agriculture in Thailand has increased rapidly in many parts of the country. Corn is one of the important cash crops planted after deforestation. This forest conversion to corn plantation may lead to decreased or increased soil carbon storage, depending on the managements.

Some research has found that good soil management can increase soil carbon storage (Cerri & Andreux. 1990; van Noordwijk et al.1997; McConkey et al. 2003; Tan & Lal, 2005).

Researches in the past have offered variety of cultivation approaches to increase soil fertility. Soil management is one of such approaches that have been used for a century (Heckman 2006). Organic fertilizer application has been demonstrated to increase Soil Organic Matter (SOM) content and crop yields. The application of varieties of organic inputs was resulted in increase soil potentially available nutrients (Canali et al. 2004). Increase in carbon storages and paddy rice yields were also reported in a long term experiment using compost in lowland sandy soil in Northeast Thailand (Takai 1983; Saenjan et al. 2004). One of explanations how application of such organic fertilizer has helped to improve soil productivity and carbon storage is its ability to maintain a proper soil aggregates and to promote soil microbial activity (Canali et al. 2004; Grandy & Robertson 2007; Mueller & Koegel-Knabner 2009). Soil managements contribute not only to food production and security, but also to soil conservation and carbon sequestration through enhancing the amount of soil organic carbon (SOC) in the soil. However, to understand the carbon sequestration in the agricultural soil need to know the status of soil C stock and find out of technology and managements which increase in productivity and C sequestration as well.

2. The status of Green House Gas (GHG) emissions of Thailand

Thailand is located between 5º 40′ to 20º 30′ N latitude and from East 97 º 70′ to 105º 45′ E longitude. It borders Laos and Myanmar to the north, Kampuchea to the east, Myanmar to the west, and Myanmar and Malaysia to the south. The total area of the country is approximately 513,115 km^2.

Thailand's GHG emissions in 2000 accounted for 0.75% of World's GHG emissions ranking 31st in the World's top GHG emitters. The top 5 countries were USA (15.79%), China (11.88%), Indonesia, (7.41%), Brazil (5.37%), and Russia (4.73%). Among the 10 ASEAN countries, Thailand ranked 4th after Indonesia, Malaysia, and Burma. If we consider GHG emissions per capita, Thailand ranked number 109 in 8th amongst ASEAN countries, with only 5.1 million tons of CO_2-eq per capita of 6.8 tons of CO_2-eq. Another key GHG emissions indicator is the proportion of GHG emissions to Gross Domestic Products (GDP), which shows the carbon intensity of economies. Thailand's GHG emissions to GDP in 2000 was 454.3 tons of CO_2-eq per USD 1 million of GDP, compared with the World's average of 521 tons per million. Energy intensity from Annex 1 countries was at an average of 504.5 tons of CO_2-eq per USD 1 million of GDP, whiles non-Annex 1 countries were using 511.7 tons per million. Emissions from G-77 countries (including China) were 499.9 tons per million, while ASEAN countries averaged 430.4 (ONEP 2009).

According to the research conducted by the Ministry of Natural Resources and Environment (MNRE) in 1994, which classified Thai GHG emissions by sectors, it was found that the energy sector ranked 1st in Thailand's GHG emissions, with 129.87 million tons of CO_2-eq (representing 45.3% of the country's GHG emissions), followed by the agricultural sector with 77.39 million tons of CO_2-eq or 27% of the country's GHG emissions. Land use and forestry ranked 3rd with 61.85 million tons of CO_2-eq (21.6%), and industrial processed accounted for 15.98 million tons of CO_2-eq , or 5.6% of the country's emission. Finally, the waste sector was responsible for only 0.74 million tons of CO_2-eq, just the 0.3% of the country's GHG emissions. According to the research conducted by the Ministry of Energy (MOEN) in 2005, it was found that energy sector was still the No.1 contributor in GHG emissions, and was responsible for 193.2 million tons of CO_2-eq (56.1%). It was still followed by the agricultural sector had grown dramatically to the third place, with a total of 26.87 million tons of CO_2-eq and the 7.8% of the country's GHG emission. The emissions originated from land use change and forestry had decreased to 22.6 million tons of CO_2-eq (only 6.6% of the country's GHG emissions), while 18.7 million tons of CO_2-eq (5.4%) still were originated from industrial processes.

Recently in 2009, the office of Natural Resources and Environmental Policy and Planning (ONEP), Ministry of Natural Resources and Environment (MNRE) shows that (figure 1), which classified Thai GHG emissions by sectors, it was found that the energy sector still ranked 1st in Thailand's GHG emissions, with 155.59 million tons of CO_2-eq (representing 64.7% of the country's GHG emissions), followed by the agricultural sector with 51.05 million tons of CO_2-eq or 21.2% of the country's GHG emissions. Industrial processed accounted ranked 3rd with 16.13 million tons of CO_2-eq, or 6.7% of the country's emissions and the waste sector was responsible for 6.32 million tons of CO_2-eq, just the 3.9% of the country's GHG emissions. Finally, land use change and forestry emission was only 8.43 million tons of CO_2-eq or 3.5% the country's GHG emissions (figure 2).

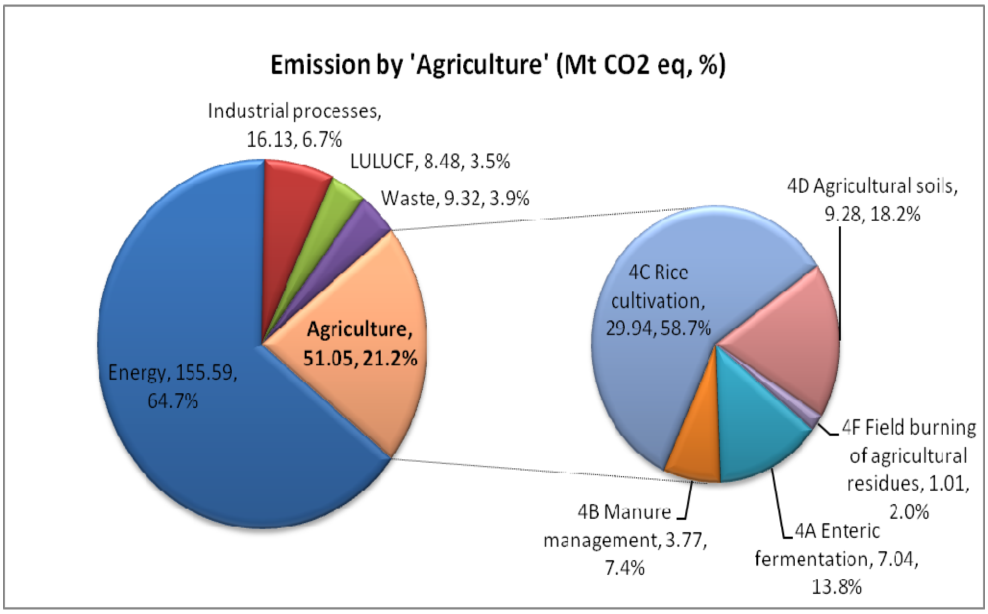

Fig. 1. GHG emissions by agriculture sector of Thailand in 2000 (from TGGMO 2010)

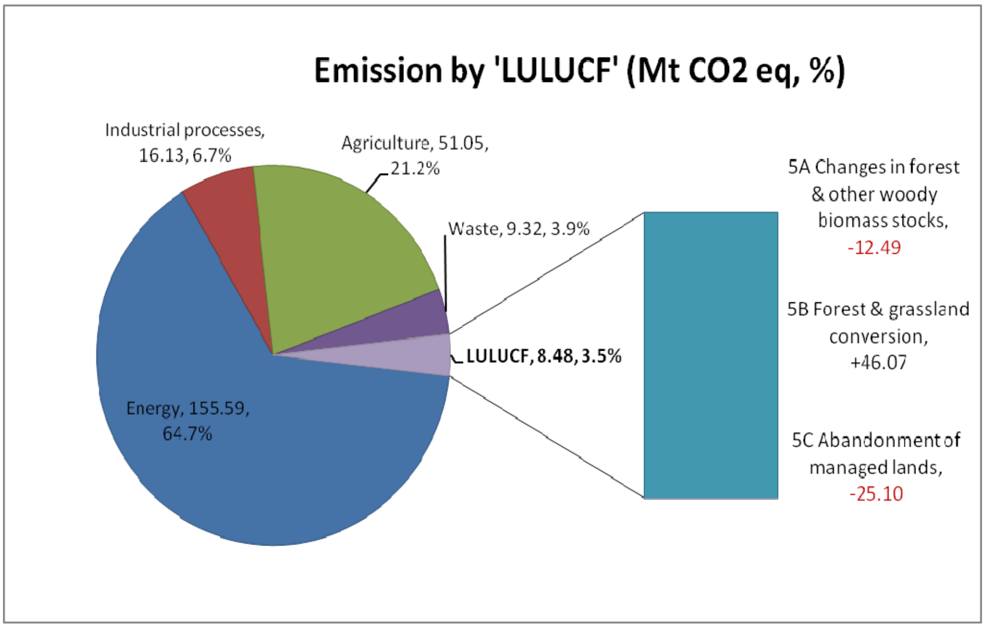

Fig. 2. GHG emissions by land use change and forestry (LULUCF) sector of Thailand in 2000 (from TGGMO 2010)

3. National Strategy on Climate Change of Thailand

The National Strategy on Climate Change of Thailand (ONEP 2009) is a revised outcome, incorporating expert advices and additional information from agencies concerned – an improvement of the original version. This new version has been submitted to and approved by the National Committee on Climate Change Policies, and has also been presented to the Cabinet for acknowledgement. The Cabinet acknowledged the new version of the national strategies on 22nd January, 2008 (ONEP 2009), has passed directives to have all public agencies concerned and to include it in the policy frameworks for further developments as action plans, and had it presented, in accordance with Section 56 of the Constitution (ONEP 2009), to the entire population for opinions in the preparation stage of such action plan (figure 3).

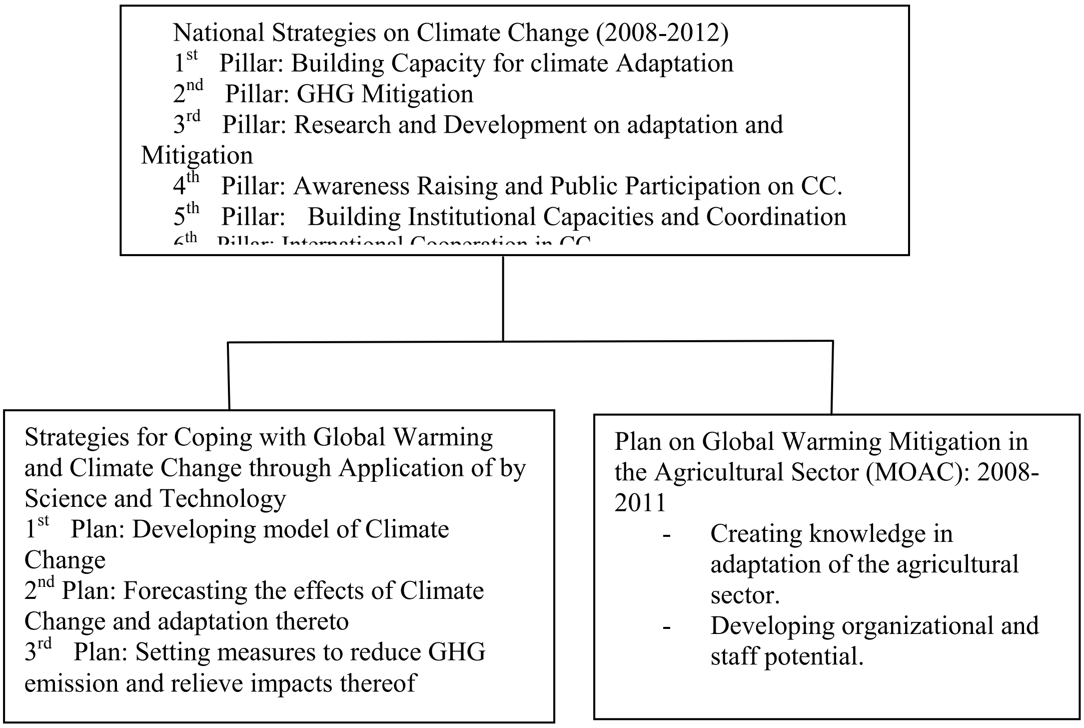

Figure 3 Linkages between policies on climate change operations

4. Master plan on global warming mitigation (2008-2011)

The ministry of agriculture and cooperatives has set the Master plan on global warming mitigation (2008-2011). The objectives are (1) Research on GHS emission, sequestration and adaptation in agriculture areas. (2) Develop efficient database, knowledgebase and warning system. (3) Identify activities and areas to improve cropping system and mitigate. (4) Capacity building for relevant organization, staffs, and cooperation system [14]. The goals of this plan are to understand the global warming impacts on agriculture and how agriculture section can mitigate the global warming. These include the research and development of the information of soil, water and crop management related to the climate change. Land Development Department (LDD) works as the focal point of organization. The initial activities are started by LDD in 2 main activities as 1) the campaign projects and 2) the research for supporting the campaign projects.

For the campaign project, LDD has operated in 2 projects:

(1) Campaign on crop residues management by incorporates into soil for carbon sequestration. The target areas are 1,645 and 1,654 ha in Fiscal year 2008 and 2009, respectively.
(2) Implementation on soil and water conservation measures and trees plantation in target areas. The target areas are 11,193and 6,463 ha in Fiscal year 2008 and 2009, respectively.

For the research projects, it is proposed to support the campaign project and to understand the status of agriculture section in global warming mitigation and its adaptation. The research projects consist of:

(1) Soil carbon dynamics in incorporation of rice stubble residues Thailand.
(2) Soil carbon dynamics in incorporation of corn stubble residues Thailand.
(3) Soil carbon sequestration and carbon dioxide emission with incorporated green manure crop in Thailand.
(4) Soil carbon dynamics and carbon dioxide emissions in different ecotypes of vetiever grass plantation in Thailand.
(5) Soil carbon dynamics and carbon dioxide emissions in different tillage systems in Thailand.

However, LDD recognizes that organic fertilizer development is the one of key element in its goal to improve infertile soils and also alleviate global warming by enhancement of OC in soils. So LDD has set the program in organic fertilizer and biotechnology development to campaign and support the farmers. These are in the national Strategies on agriculture development.

5. Soil C dynamic and C sequestration researches

For the research about soil carbon, there is some example researches showed as following:

5.1 Land use

This study aims to investigate the changes in soil carbon stocks and net carbon emissions when tropical forest is converted to corn plantation in Tha Ta Kieb (TTK) district, Thailand. The study period was during 2004-2006. The amounts of soil carbon (Cs) and its contents, consisting of C from forest and C from corn, were estimated with the isotope technique ($\delta^{13}C$). The relationship between soil C and its contents was examined by studying soil under corn cultivation and after deforestation at periods of 0, 3, 4, 5, 7, 8, 9, 10, 11 and 12 years. The results revealed that only small inputs from corn plantation were found during this time span, and thus the main component of soil carbon is still dominated by the forest-derived fraction. More than 60% of this organic carbon was found in the topsoil (0-10 cm). When the values of soil carbon content were plotted against number of years after deforestation, it was found that soil carbon was reduced at the rate of 6.97 ton C ha^{-1} yr^{-1}. The turnover time of surface soil carbon was 8.67 years, while in the subsurface soil (40-50cm) the turnover rate was 0.29 ton C ha^{-1} yr^{-1} and turnover time was 44.05 years (Jaiarree et al. 2006).

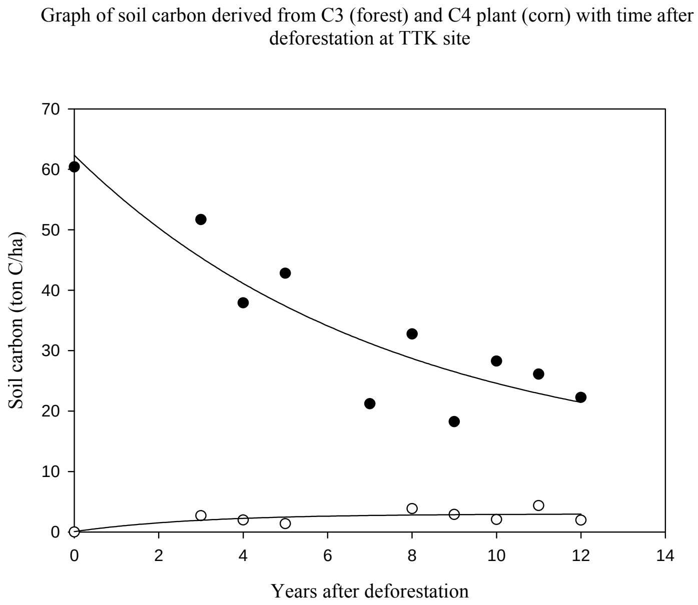

Figure 4 Soil carbon (ton C/ha) derived from C3 (forest) (●) and C4 plant (corn) (○) in 0-10 cm depth at TTK site

5.2 Net soil carbon budget

This study evaluates the carbon budget balance and roles of compost application in increasing carbon sequestration of soils. Three main plots were studied. These include native forest (NF) as reference, and corn cultivation with compost application since 1995 at the rate of 50 (HC plot) and 30 Mg ha^{-1} (CC plot). Using the bulk density and the content of soil organic carbon, soil carbon stocks were estimated to the depth of 100 cm.

The estimated amounts of soil carbon were 23.54, 41.55 and 26.47 ton C ha^{-1} in NF, HC and CC soil, respectively (table 1). For the result, the HC plot shows significant increase in soil carbon storage. It indicates that in this corn soil, turnover of soil organic carbon is quite rapid and incorporating the new sources of carbon into soil readily occurs. Applying compost at the lower rate (30 Mg ha yr^{-1} in CC plot), does not result in significant carbon sequestration. However, this has helped maintain the level of soil organic carbon at the similar level as that found for NF plot. In addition, the results indicate that field managements such as irrigation and fertilizer application have also emitted greenhouse gases into the atmosphere. But this accounted for only small fraction (<10%) of total emission from the field. In order to mitigate effectively greenhouse gas emission, the main focus should be given to soil carbon sequestration (Jaiarree 2009).

Table 1. The net carbon flux for agriculture and forest soil plots in 2005.

Plots	NF[a] (ton C $ha^{-1}yr^{-1}$)	HC[a] (ton C ha^{-1} yr^{-1})	CC[a] (ton C ha^{-1} yr^{-1})
Soil carbon stocks	23.54	41.55	26.47
C emissions from soil	+8.54	+10.14	+9.86
C from biomass forest [b]	-5.30	0	0
C from biomass (Corn)	0	-4.76	-3.20
C from biomass (*Canavalia spp.*)	0	-0.99	-0.61
C from compost	0	-8.62	-5.17
C emissions from machinery	0	+0.14	+0.13
C emissions from agricultural input	0	+1.59	+1.06
Net C budget [c]	+3.24	-2.50	+2.07

[a] Negative and positive values indicated reductions (sequestrations) and additions (emissions) to atmospheric C pool, respectively.
[b] The amount of organic C estimated in total annual litterfall from tree, shrub and ground plants of dry evergreen forest from Sahunalu (1995)
[c] Annual C budgets (ton C $ha^{-1}yr^{-1}$), excluding soil carbon stocks

However, there are many other interesting researches in soil C topic are showed in Table 2.

Table 2. The researches of soil C in Thailand

Topic	Year	Soil	Details	C stock (ton ha^{-1})	Bulk density (g cm^{-3})	References
Soil Organic Carbon Stock and Rate of Carbon Dioxide Emission of Abandoned Agricultural Land	2008	Aeric Tropaquepts	Depth 0-15 cm Depth 15-30 cm	10.5 6.2	1.75 1.88	Chaun et al., 2010 [17]
Soil Carbon Sequestration in Organic Tapioca at Tambon Maghurmai Amphur Soongnern Nakornratchasrima Province	2007	Oxic Paleustults	Depth 0-20 cm	7.11		Funglatda et al., 2010 [18]
Impact of Rice Straw Management on Carbon Sequestration in Rice Soil: The Case Study of Kampheang Sean Soil Series	2009	Typic Haplustalfs	Normal soil Straw soil Straw burning soil	Total C 1.53% Total C 1.63% Total C 1.59%	1.31 1.24 1.32	Ramnut et al., 2010 [19]
Sustainable Cultivation of Irrigated Rice Field under Climate Change Crisis	2007	Typic Tropaquepts	Local burn Mid-season burn Local incorporate Mid-season incorporate	soil C budget (-46) soil C budget (-78) soil C budget (+235) soil C budget (+199)		Jeerpasuanun et al., 2010 [20]
Carbon Stock and Net Co_2 Emission in Tropical Upland Soils under Different Land Use	2003-2004	sandy clay sandy clay loam sandy loam	Natural forest Reforestation Agriculture	118(0-50cm) 66(0-50cm) 57(0-50cm)	1.69 1.81 1.85	Lichaikul et al., 2006 [21]
Soil carbon dynamic in agro ecosystems in Thailand	2004-2005	Typic Ustipsaments	Natural forest intensive management conventional management	23.54 (0-100cm) 41.55 (0-100cm) 26.47 (0-100cm)	1.40 1.73 1.85	Jaiarree et al., 2009 [16]

6. Soil carbon stock

6.1 Soil carbon stock followed by soil taxonomic unit

The distribution of soil carbon (ton ha^{-1} in 1 m of soil depth) was shown in Table 3. Aridisols (as represent Aridic soil moisture regime) are form in an arid or semi-arid climate. Andisols (represent Andic soil properties) are soil formed in volcanic ash and defined as soils containing high proportions of glass and amorphous colloidal materials. In addition, Aridisols and Andisols are not found in Thailand. Therefore, there are 9 orders which are found in Thailand (Monchareon & Viensilp 2001).

1) Alfisols

Alfisols (Alfisols normally is found in semiarid to humid areas, typically under the forest area). Alfisols are found 10.85% of total areas (Thailand). The most of areas are distributed in other parts of Thailand, except in the Southern part. The most of areas in Thailand is Aqualfs (Alfisols) followed by the Hapludalfs and Paleustalfs (as the second most of area), and Ustalfs. Aqualfs are found in lowland of Central and Northern parts. Meanwhile Ustalfs are found Central part. The soil organic carbon (SOC) has highest in Hapludalfs and Paleustalfs (80 ton ha^{-1} in 1 m of soil depth) followed by Aqualfs and Ustalfs.

2) Entisols

Entisols are 3.60% of total areas of Thailand; the soils are found along the central coastal area in gulf of Thailand. The most of suborder are Aquents, which are poor drained. These soils are sandy particle size classes. Aquents genarally has a high organic carbon in soil compared to the others, except Histosols. This result may be due to low rate of the leaching of organic substance in soil profile as influenced by soil poorly drained. The distribution of soil carbon in the soil profile is not evident; the content of soil carbon is depended on environmental conditions and deposition patterns.

3) Histosols

These are found only 683 km^2 and distributed mainly in the South of Thailand such as Narathiwas and Songkhla provinces. It has highest SOC at 1,196 ton ha^{-1} in 1 m of soil depth.

4) Inceptisols

There are moderately distributed in Thailand, 10.47% of total areas. Aquepts are found in lowland. It is used for rice plantation (paddy field). These soils are poor drained, meanwhile some soils are found at the lowland and flooded areas as the well drained soil. These are classified in Ustepts. The SOC content is 138.2 ton ha^{-1}. The most of land-use is paddy field.

5) Mollisols

These soils are commonly found in the Central part of Thailand. The parent materails are derived from Marl. SOC is 92.5 ton ha^{-1} in 1 m of soil depth. Ustolls and Aquolls are suborders of Mollisols in Thailand.

6) Oxisols

These orders are found only 0.02% of total areas. There are in along the coastal zone of Southeast of Thailand. Basalt is found as the parent materails. Soil profiles are very deep about 2.4 meters depth. SOC is 65.5 ton ha^{-1} in 1 m of soil depth. Meanwhile, the soil which deeper than 1 m depth, the SOC should increased more compared to the estimation of SOC in 1 meter only. This is explained that the organic carbon materails are leached to sequest in the deeper soil of profile.

7) Spodosols

These soils are distributed in limited areas; in addition, they were 0.24% of total areas. SOC is 88.6 ton ha^{-1}, which is found in old beaches of the Southeastcoast of Thailand. The OC in this soil is accumulated in both surface soil and subsoil. In the soil profile, there is Spodic horizon (high accumulation of C content) which results to the high concentration of OC (17 kg m^{-1} m^{-2}).

8) Ultisols

These soils are the most distribution areas (41.88%) varied in the different topology, soil moisture regime, and parent materials. SOC is 86.30 ton ha$^{-1.}$ Aquults are found in the most areas. The contents of SOC have 61.3, 46.7, and 126.8 ton ha^{-1}of Aquults, Ustults, and Udults, respectively.

9) Vertisols

These soils covered approximately 0.53% of total areas. The SOC is 106.0 ton ha^{-1}. Uderts and Usterts are mostly found in the Vertisols. The most of areas are found in southern of Central regian of Thailand. The most areas are in the lime-stones Mountains.

Table 3. The soil organic carbon stocks following in Order, Suborder and Great Group

Order	Suborder	Great Group	Area		OC ton ha^{-1} in depth (cm)		
			ha (10^4)	%	0-25	0-50	0-100
Alfisols			55,331	10.85	40.30	57.90	81.90
		Natraqualfs			9.00	7.60	9.60
		Haplaqualfs			32.40	48.10	68.20
		Hapladalfs			83.70	109.40	135.60
	Aqualfs		28,315	5.55	41.70	55.00	71.10
		Haplustalfs			45.10	60.20	95.90
		Paleustalfs			41.70	67.80	100.30
	Ustalfs		26,854	5.27	43.40	64.00	98.10
Entisols			18,338	3.60	51.40	84.60	156.60
		Fluvaquents			61.80	82.90	173.20
		Hydraquents			95.90	132.90	173.20
		Sulfaquents			521.10	742.00	856.40
		Haplaquents			17.40	27.50	51.40
	Aquents		9,903	1.94	232.10	328.40	418.10
		Udifluvents			23.90	30.30	40.80
	Fluvents		1,645	0.32	23.90	30.30	40.80
		Quarzipsamments			16.90	26.50	45.10
		Ustipsamments			12.10	17.10	19.00
	Psamments		5,539	1.09	14.50	21.80	32.10
		Haplorthents			58.80	72.30	102.00
	Orthents		12,552	0.25	58.80	72.30	102.00
Histosols			683	0.13	296.90	601.90	1196.70
		Tropofibrists			296.90	601.90	1196.70
	Fibrists		683	0.13	296.90	601.90	1196.70

Table 3. The soil organic carbon stocks following in Order, Suborder and Great Group (continue)

Order	Suborder	Great Group	Area		OC ton ha^{-1} in depth (cm)		
			ha (10^4)	%	0-25	0-50	0-100
Inceptisols			53,366	10.47	50.60	89.10	138.20
		Halaquepts			19.20	23.80	29.10
		Haplaquepts			51.80	93.70	149.50
	Aquepts		46,145	9.05	35.50	58.80	89.30
	Udepts		6,854	1.34	21.00	32.70	47.10
		Haplustepts			128.10	176.70	215.60
		Haplustepts			68.50	104.50	124.50
	Ustepts		360	0.07	98.30	140.60	170.10
Molisol			9,493	1.86	57.80	74.50	92.50
		Haplaquolls			40.30	67.00	88.80
	Aquolls		1,829	0.36	40.30	67.00	88.80
		Calciustolls			67.30	96.30	118.40
		Haplustolls			56.90	75.10	95.10
	Ustolls		7,664	1.50	62.10	85.70	106.80
Oxisols			122	0.02	33.80	52.30	65.50
		Hapludoxs			34.20	53.40	65.80
	Udoxs		97	0.02	34.20	53.40	65.80
Spodosols			1,221	0.24	33.70	52.90	88.60
		Haplohumods			43.90	58.00	166.80
	Humods		1,221	0.24	43.90	58.00	166.80
Ultisols			213,538	41.88	38.20	55.40	86.30
		Paleaquults			21.20	31.10	43.70
		Plinthaquults			31.00	48.10	86.40
		Haplaquults			40.10	50.60	53.70
	Aquults		45,531	8.93	30.80	43.30	61.30
		Palehumullts			66.40	107.90	151.20
	Humults		440	0.09	66.40	107.90	151.20
		Haplustults			37.20	38.80	65.50
		Paleustults			37.90	52.70	74.50
		Plinthustults			23.90	36.80	91.40
	Ustults		129,534	25.40	25.00	30.50	46.70
		Hapludults			44.50	71.70	109.40
		Paleudults			37.20	38.80	65.50
		Plinthudults			118.10	161.20	205.60
	Udults		38,033	7.46	66.60	90.60	126.80
Vertisols			4,667	0.53	39.20	65.60	106.00
		Hapluderts			15.00	20.70	32.20
		Hapluderts			35.60	61.00	110.00
	Uderts		2,332	0.46	25.30	40.90	71.10
		Haplusterts			24.70	35.60	72.20
	Usterts		2,335	0.46	24.70	35.60	72.20
		Haplaquerts			78.80	133.30	410.90
	Aquerts				78.80	133.30	410.90

7. The status of OC in Thailand

Recently, in 2008, the project on the status of Thailand was carried out in 2004-2008 by Land Development Department (LDD). The 6422 soil samples were collected and analyzed in central laboratory of LDD. These soil samples resulted in the status of soil nutrients of Thailand, such as pH, organic matter or organic carbon, available P and available K. These results were shown in nutrient status map. For the data of organic carbon (OC) contents, LDD reported the status of OC contents from 2,443 soil data and showed as the OC map (figure 5). These data were classified as low soil OC (OC < 0.29-0.86%) covered in 38% of the total soil survey area. The suitable OC (OC = 0.86-1.73%) area covered 43.3% of the total soil survey area. However, LDD has a plan to continue the project by collecting and analyzing soil samples more and results in soil carbon status of Thailand. These need to get more the information of bulk density.

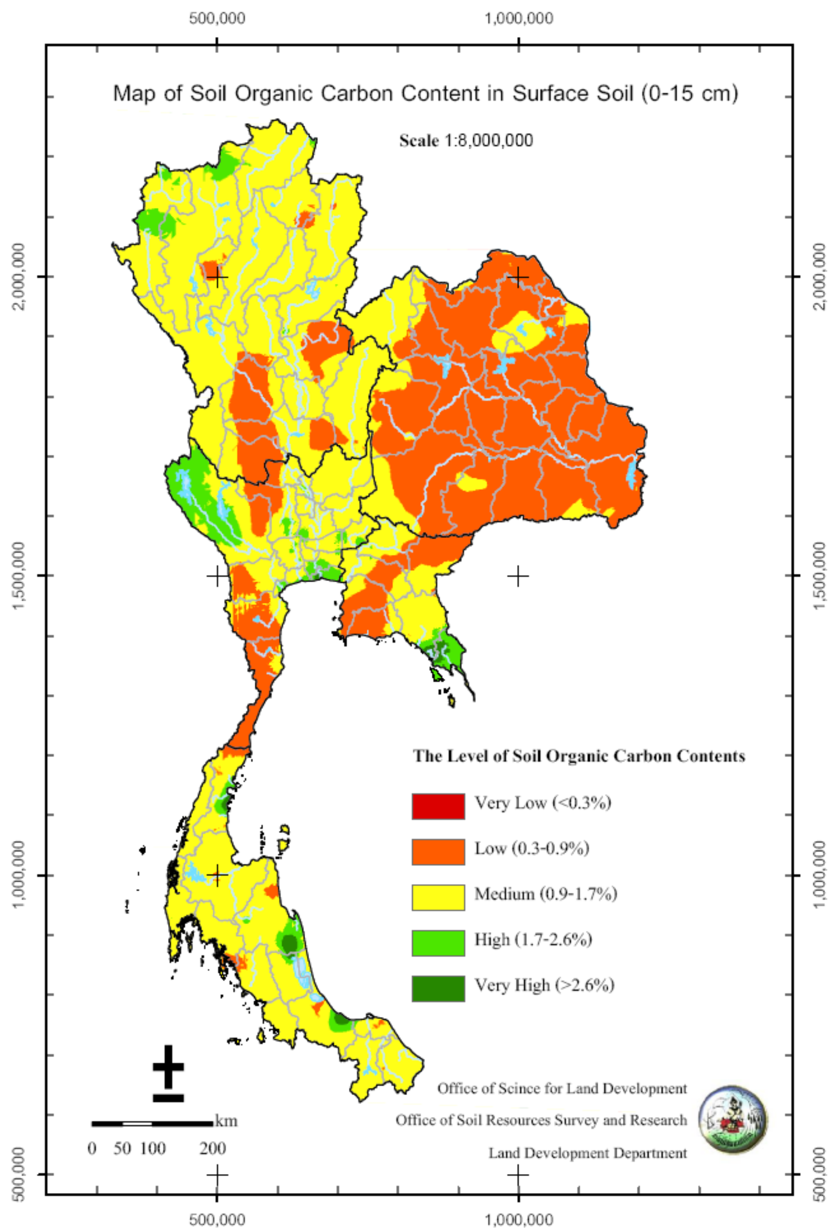

Fig. 5. The soil organic carbon status of Thailand in 2008.

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