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Ameliorant Application on Variation of Carbon Stock and Ash Content on Peatland South Kalimantan

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ABSTRACT

Carbon stock on peatlands are large and will be easily emitted if the land is opened or drained, therefore the measurements of carbon stocks and ash content are important to know the amount of emissions and agricultural sustainability in peatlands. This study aimed to determine carbon stock and ash content on peatlands in the Indonesia Climate Change Trust Fund (ICCTF) located in South Kalimantan on the geographic position S. 03°25'52" and E. 114°47'6.5". The experiment consisted of six treatments of ameliorant materials namely; mineral soil, peat fertilizer A, peat fertilizer T, manure, ash, and control. The results showed that the variation of peat soil properties was very high at this location. Peat thickness ranged from 36-338 cm, and this led to high variations in carbon stocks ranged between 161.8 – 1142.2 Mg ha^{-1}. Besides ash contents of the soil were also highly varied ranged from 3.4 – 28.5%. This natural variation greatly affected the ICCTF study design. Mineral soil treatment had a mean carbon stock (961.3 ± 61.5 Mg ha^{-1}) which was higher and different from other treatments. High ash content was obtained in the ash treatment (18.6 ± 2.5%) and manure (15.7 ± 3.6%). It is recommended that the analysis of plant responses and greenhouse gas emissions using a single regression analysis and multiple regression with ash content as one of the independent variables are needed.

Keywords: Ash content, carbon stock, peatland, peat thickness

INTRODUCTION

Peatland in Kalimantan reaches 5.8 million hectars or 27.7% of total peatland in Indonesia (Wahyunto *et al*. 2010), and it is located on fresh water swampland and some tidal swampland. The peatland formed by the accumulation of organic matter with rate slowly decomposition due to organic matter is not easily decomposed such as lignin (Noor 2001; White *et al*. 2002; Zhang *et al*. 2002). The slow decomposition process is supported by anaerobic conditions with low temperatures that causes the rate of accumulation of organic matter faster than the rate of decomposition, so that peat can be functioned as sink carbon and source of carbon emissions and plays an important role in the global carbon cycle. According to Joosten (2009) and Ansari (2011) total content of global carbon reserve in the peat is estimated at 550 Giga ton that is equivalent to 75% of all carbon in the atmosphere and reserves the carbon 300 – 6,000 Mg ha^{-1} that is greater than the mineral soil (30 – 300 Mg ha^{-1}) (Agus and Subiksa 2008). Tropical peatlands are estimated only 42 millions hectars, and approximately contain 70 Pg carbon or 20% of global peat soil carbon (Page *et al*. 2004). Carbon stocks in peatland are not only reserved in the soil but also from the tree vegetation (above ground biomassas), shrubs (below ground biomassas) and litters although the largest deposit of carbon is fixed in the soil. The vegetation of tropical forests in Asia have a reserve carbon between 40 - 250 Mg ha^{-1} (Lasco 2002). It is analogous with the results of the study reported by Wardah *et al.* (2011) that above ground C-stock in the complex agroforestry (combination of different types of trees, shrubs and plant) of Lore Lindu National Park, Central Sulawesi were 98.46 Mg ha^{-1}. According to Morison *et al*. (2010) the above-ground biomass (with associated debris) reached a maximum of about 150 C Mg ha^{-1}. Carbon stocks in natural forests are relatively stable unless land degradation causing emissions. If the forest is opened and drained peat subsidence will occur and release CO_2 into the atmosphere. Peat forests in general are in a state of saturation when gas emits methane (CH_4) and when the peat is drained, the dominant emission of CO_2 because the occurrence change from anaerobic to aerobic conditions. In the state of natural forests, peatlands emit between 20-40 Mg ha^{-1} $year^{-1}$ (Rieley *et al*. 2008). Carbon dioxide and CH_4 with N_2O (emissions produced mainly from fertilizer N in oxygen deficiency) have the ability to absorb long-wave radiation from the earth's surface so that atmospheric temperatures are rising and plays an important role in global warming and climate change. Extreme climate increased air temperatures and increasing sea levels could affect crop production. Increasing temperature 1 ^oC may decrease paddy crop of 0.6 Mg ha^{-1} or 10 % (IRRI 2007). Therefore gas emissions must be controlled to the concentrations as low as possible by the plant, one of them is by reforestation.

The quantity of emissions at specified intervals in an area can be expected with measurements of carbon stocks that reflect how large the potential emissions and important in the study of greenhouse gas emissions. In addition, to known how much carbon stocks in a region is useful in dealing with carbon trading. The amount of carbon stocks vary depending on the process of formation of peat, peat position, depending on the type of land use diversity and density of plants, climatic conditions, altitude above sea level, duration of the utilized land for a specific use, and the management of soil fertility. One indicator of natural fertility levels of peat soil is ash content. The ash content of maturity peat sapric is greater than hemic or fibric. The thickness of peat can be used to asses the soil fertility. In the shallow peat, peat layer formation process is affected by flooded area so it is more fertile. The deeper peat, ash content is low and increased soil acidity. In this regard the measurement of carbon stocks and ash content is important to know the amount of emissions and sustainability of agricultural on peatlands.

The purpose of this study was to determine effect application of ameliorant on carbon stock and ash content in peatland at South Kalimantan.

MATERIALS AND METHODS

Study Site and Treatment

The study was conducted in March 2011 and located in village Syamsudin Noor, District Landasan Ulin, Banjarbaru City, South Kalimantan. The geographical position was S. 03°25'52“ and E. 114°47'6.5” and the area which was 6.9 ha. Observations were carried out in the experimental area of Indonesian Climate Change Trust Fund (ICCTF). There were six treatments applied, namely: mineral soil, peat fertilizer A, peat fertilizer T, manure, ash, and control.

Observation Parameters

Some data and information at every point drilling (six point observations per treatment) where recorded. Parameters observed to determine the carbon stock were bulk density (g cm^{-3} or kg dm^{-3}, gravimetric method), carbon content (% weight, loss on ignition method), and peat thickness (directly observed in the field by using a drill peat). Several other parameters were also observed as it could assist in interpreting the data, that were wide peatlands and peat maturity (Agus 2009). Content of soil organic material (OM) was calculated based on % of soil dry weight, which is: OM (wt%) = (CB-BA)/LB × 100%, where BA is the weight of ash soils (determined by loss on ignition method in the furnace at a temperature 550 °C for 6 hours). Content of soil C-organic (% C-org) was calculated based on the conversion of organic material with a constanta 1.724 [% C-org: by weight) = OM/1.724] and C-org (% vol: Mg m^{-3}) is the weight per volume of soil carbon, [C-org (% vol) = C-org (% weight) × BD-ash]. Carbon stock in the soil is C weight in a unit volume of soil, using the formula: C-stock = C-org (vol%) × A × L, where L is the area of peatland (m^2) and A is peat thickness (m).

Data Analysis

All data obtained were analysed by standard error and drawn with a Sigma Plot program by Systat Software Inc.

RESULT AND DISCUSSION

Peatland is formed by the accumulation of organic matter with slowly decomposition rate. Process of decomposition produces organic acids, CO_2 and CH_4, which is a part of the greenhouse gases, the gas will be emitted when burned or land preparation for planting. However, conversion of forests to agricultural land will continue so that the caution is necessary in management and sustainable aspects. Knowledge of carbon stock is important to know not only to estimate amount of emissions, but also to confront carbon trading. Carbon stocks in peat consisted of below ground and above ground C-stock. In this study only measured the below ground C-stock.

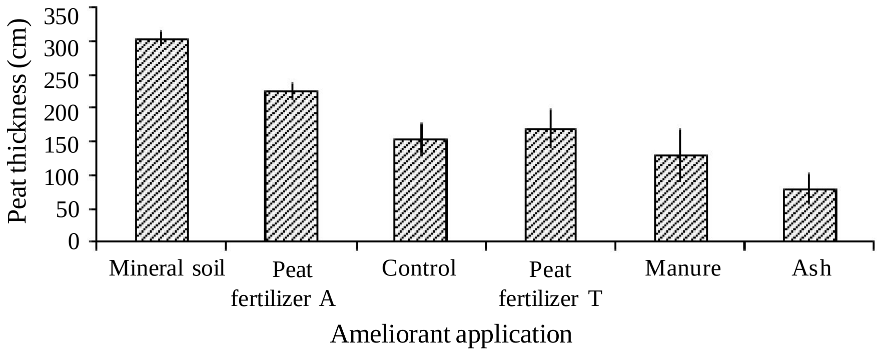

Figure 1. Variations of peat thickness with the application of ameliorants.

Peat Thickness

Peat thickness at this location was varied, not only between treatments but also in the treatment itself. In the manure treatment (Table 1) had great variations in the peat thickness that were 39 – 272 cm (mean 129.3 ± 37.5 cm). The highest peat thickness up to 338 cm (mean 304.3 ± 11.4 cm) was found in the location of mineral soil treatment plots while the highest ash content was found on the area with peat thickness 36-185 cm (mean 79.5 ± 22.8 cm). Variations in peat thickness affected the amount of carbon stock and ash content. There was a positive correlation between peat thickness and carbon stocks (Figure 3), the thick peat the higher carbon stock, so were the results of the study reported by Dariah *et al.* (2012) that peat with a thickness of > 10 m had a carbon stock 6,390 Mg ha^{-1} whereas peat thickness < 1 m (62 cm) has a carbon stock 162 Mg ha^{-1}. The results of the study reported by Kiely *et al*. (2009), Joshi *et al*. (2010), Morison *et al*. (2010), (Wellock *et al*. 2011) and Maswar (2011) that peat thickness was related to the carbon stock in the soil. But the thick peat soil the low the fertility which was characterized by low ash content.

Peat thickness to be a primary consideration in conformity assesment and land management for agricultural development. For example, peatland which has a thickness between 100-200 cm is categorized conditional according to the development of agriculture, especially paddy field (Noor 2001).

Carbon Stock

Carbon stocks in Kalimantan peatland based on Indonesia peat atlas is 11.27 million tonnes (Wahyunto *et al*. 2004). In this study the variations of carbon stock is shown in Figure 2. It can be seen that the mineral soil treatment had the highest carbon stocks and it was different from other treatments.

Average of carbon stocks at the study site were varied between 428.4 – 961.3 Mg ha^{-1} (Figure 2). The highest carbon stocks (961.3 ± 61.5 Mg ha^{-1}) was in the mineral soil treatment, it was supported also by a considerable peat thickness up to 338 cm. Similarly, the peat fertilizer A treatment, with a peat thickness between 165-245 cm had carbon stock of 790.5 ± 60.6 Mg ha^{-1}. Mineral soil and peat fertilizer A treatments showed a higher carbon stocks and different from other treatments (Figure 2). The lowest carbon stocks (428.4 ± 68.9 Mg ha^{-1}) was in ash treatment with peat thickness between 36 – 185 cm. Peat fertilizer T treatment had a carbon stock 578.8 ± 126.8 Mg ha^{-1} with a peat thickness between 70 – 226 cm, while the

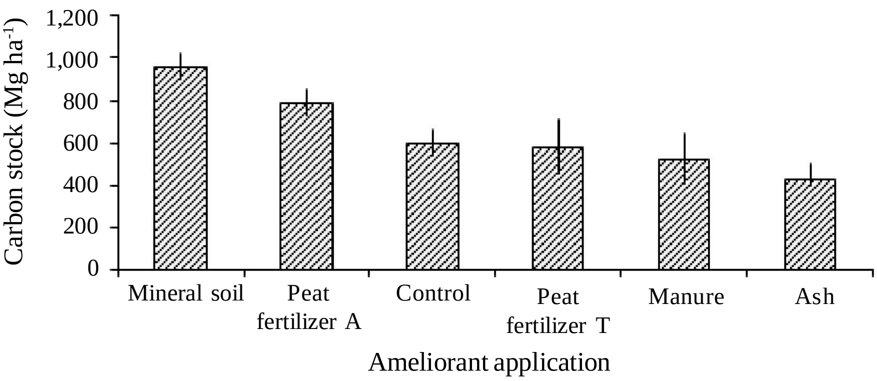

Figure 2. Variations of carbon stock with the application of ameliorants.

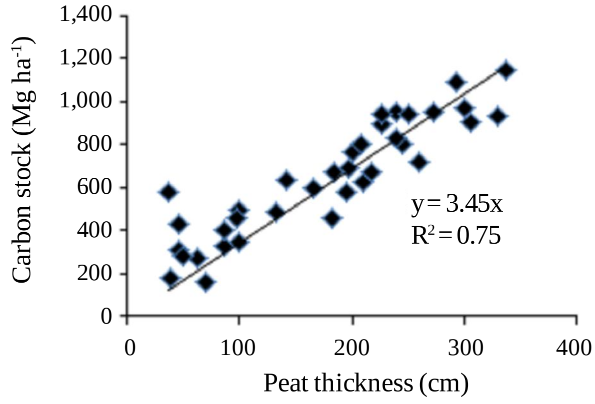

Figure 3. Regression between peat thickness and carbon stock.

control treatment had a carbon stock 600.7 ± 58.5 Mg ha^{-1} with peat thickness between 87 – 208 cm.

Figure 3 shows that in the study location, carbon stocks could be estimated from the thickness of the peat. For shallow peat, carbon stocks in this location was approximately 3.45 Mg ha^{-1} cm^{-1} or about 345 Mg ha^{-1} m^{-1}. This number was under the carbon stock cited by Agus and Subiksa (2008) about 500 Mg ha^{-1} m^{-1} or stated by Page *et al.* (2002) about 600 Mg ha^{-1} m^{-1}. This is understandable because peat at this location has a relatively high ash content, or organic matter content is relatively low. Estimation of carbon stocks can also be done with carbon density approach (Wellock *et al*. 2011). However, this approach has to do with more detail because the presence of variability in thickness and maturity of peat in the field. Carbon density values increased with increasing maturity of peat, but it was not followed by increasing carbon content as reported by Dariah *et al.* (2012), this is because the decomposition process occurring naturally or without human activity.

Ash Content

The ash content reflects the mineral material contained on peatlands. Mineral nutrient levels in the peat were 4% ash weight and it was more than elements K and Mg (Maas 1990 cited by Noor 2001). The highest of ash content was in the ash and manure treatments (Figure 4). The ash treatment with peat thickness between 36 – 185 cm had the higher ash content (18.6 ± 2.5%) than the manure treatment (15.7 ± 3.6%), although peat thickness were considerably varied of six observation points (39 – 272 cm). Higher of ash in the treatment indicated that the experimental plots land were more fertile. This is because the ash treatment can increase soil pH (Agus and Subiksa 2008) and rich in Silica (Si) that increased nutrient availability and eased plants roots to absorb nutrients. Manures contain macro and micro nutrients and decompose relatively quickly thus increasing nutrient availability. Gronlund *et al.* (2008) reported that high levels of ash caused by the loss of organic material from peat layers due to the mineralization process remains a concentrated mineral material on the top layer.

The mineral soil treatment had a low average ash content (5.7 ± 1.3%). With ash content 5.7% in which contained approximately 94.3% of C, H and O that would easy to be lost because of soil tillage or burning of the land. Similarly, the peat fertilizer A treatment had a lower ash content (7.4 ± 0.7%). The ash content in the peat fertilizer T treatment was 10.1 ± 1.9 % with peat thickness between 70 – 226 cm whereas the control treatment had a 10.2% ash content of ± 2.2 with peat thickness between 87-208 cm. Peat thickness was negatively correlated with ash content (Figure 5), meaning that the shallow peat mineral soil the higher enrichment washed out in flooding. Peat with higher levels of ash (mineral soil) are usually more fertile (Agus and Subiksa 2008).

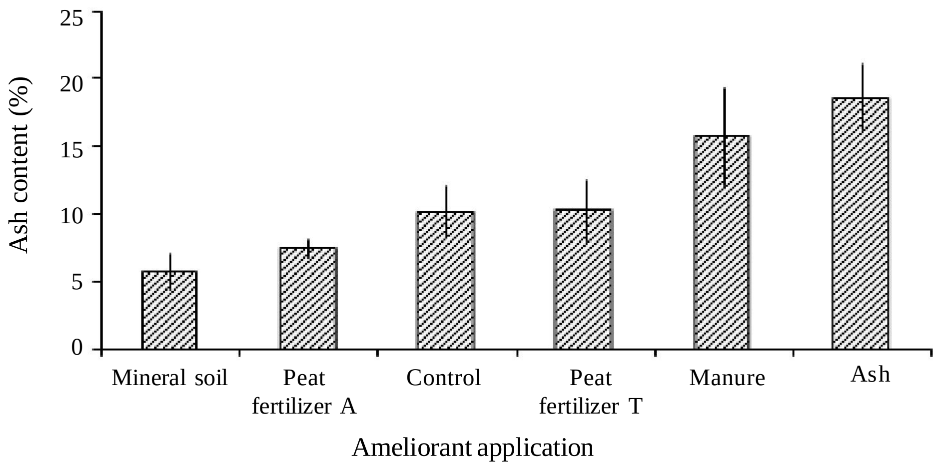

Figure 4. Variations of ash content with the application of ameliorants

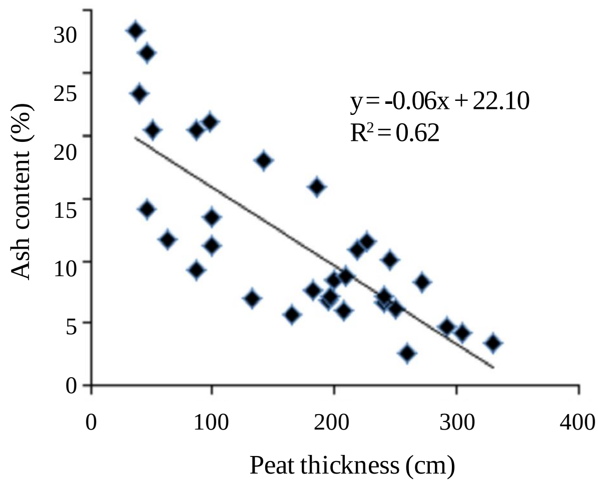

Figure 5. Regression between ash content and peat thickness.

In all treatments it could be seen that the amount of carbon stocks and ash content at the study site were strongly influenced by the thickness of the peat. This natural variation greatly affected the design of the ICCTF study. Amount of ameliorant material had given much lower ash content than the variation that already exists in this location. Assuming the soil BD 0.03 Mg m^{-3} at 0 – 50 cm layer, giving 5 Mg ha^{-1} of soil minerals, for example, would only be able to raise peat ash levels in this location about 3%, while the ash content in these study sites ranged from 2 to 29% (Table 1). Thus the natural variation in the location was more influential on various independent variables such as emissions of CO_2 and plant growth. For that variations in ash content it should be needed a 'covariate' factor in the analysis data of greenhouse gas emissions and plant growth response. Another alternative is the analysis of correlations between some of the key soil properties such as ash content and thickness of the groundwater table and the emission as well as the correlations between some soil chemical properties and the growth and crop production.

CONCLUSIONS

Properties of peat soil at the study site ICCTF were highly variable, both in the peat thickness, carbon stocks and ash content. Variations in ash content were much higher than a given amount of soil minerals which aimed to increase levels of ash. Therefore, in the statistical analysis of emission and agronomic data, variations in ash content and some other chemical properties were needed to be correlated with both response variables. There was a positive correlation between the peat thickness and carbon stock, so that carbon stocks can be estimated by using peat thickness data. While the ash content was negatively correlated with the peat thickness.

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REFERENCES

Agus F and IGM Subiksa. 2008. *Lahan Gambut: Potensi untuk pertanian dan aspek lingkungan*. Balai Penelitian Tanah dan World Agroforestry Centre (ICRAF). Bogor. Indonesia, 36 p (in Indonesian).

Agus F. 2009. *Panduan Metode Pengukuran Karbon Tersimpan Di Lahan Gambut*. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. Bogor and World Agroforestry Centre, SEA, Bogor, Indonesia (in Indonesian).

Ansari AH. 2011. Peatlands and Global Warming: A Study with special reference to South-East Asian Countries. *Aust J Basic Appl Sci* 5: 596-605.

Dariah A, E Susanti, A Mulyani and F Agus. 2012. Faktor penduga simpanan karbon pada tanah gambut. Makalah disampaikan pada Seminar Nasional Sumberdaya Lahan Topik Khusus. Pengelolaan Lahan Gambut Berkelanjutan. Balai Besar Litbang Sumberdaya Lahan pertanian. Bogor. 4 Mei 2012. (in Indonesian).

Gronlund A, H Atle, H Anders and PR Daniel. 2008. Carbon loss estimates from cultivated peat soils in Norway: a comparison of three methods. *Nutr Cycl Agroecosyst* 81: 157-167.

IRRI [International Rice Research Insititute]. 2007. Coping with climate change, climate change threatens to affect rice production across the globe-what is known about the likely impact, and what can be done about it. *Rice Today* 6: 10-13.

Joosten H. 2009. *The Global Peatland CO_2 Picture*. Peatland status and drainage related emissions in all countries of the world. Wetlands International. www.wetlands.org. 35 p. Accesed on 20 March 2012.

Joshi L, Janudianto, M van Noordwijk and P Pradhan. 2010. *Investment in carbon stocks in the eastern buffer zone of Lamandau River Wildlife Reserve, Central Kalimantan Province, Indonesia: a REDD+ feasibility study*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Office, 91 p.

Kiely G, NM McGoff, JM Eaton, X Xu, P Leahy and O Carton. 2009. SoilC – Measuring and Modelling of Soil Carbon Stocks and Stock Changes in Irish Soils. EPA STRIVE PROGRAMME 2007–2013 Report. Environmental Protection Agency. Ireland. 37 p.

Lasco RD. 2002. Forest carbon budged in Southeast Asia following harvesting and land cover change. *Sci China (Series C)* 45 Supp: 55-64.

Maswar. 2011. Kajian Cadangan Karbon Pada Lahan Gambut Tropika yang Didrainase untuk Tanaman Tahunan. [Disertasi Doktor]. Sekolah Pascasarjana, Institut Pertanian Bogor (in Indonesian).

Morison J, E Vanguelova, S Broadmeadow, M Perks, S Yamulki and T Randle. 2010. Understanding the GHG implications of forestry on peat soils in Scotland. The Research Agency of the Forestry Commission. Scotland. 55 p.

Noor M. 2001. *Pertanian Lahan Gambut: Potensi dan kendala*. Penerbit Kanisius. Jakarta. 174 p (in Indonesian).

Page SE, F Siegert, O Rieley, HDV Boehm, A Jaya and SH Limin. 2002. The amount of carbon released from peat and forest fire in Indonesia during 1997. *Nature* 420: 61-65.

Page SE, R Wuest, D Weiss, O Rieley, W Shotyk and SH Limin. 2004. A record of Late Pleistocene and Holocene Carbon accumulation and climate change from an equatorial peat bog (Kalimantan, Indonesia): Implications for past, present and future carbon dynamics. *J Quaternary Sci* 19: 625-636.

Rieley JO, RAJ Wust, J Jauhiainen, SE Page, H Wosten, A Hooijer, F Siegert, SH Limin, H Vasander and M Stahlhut. 2008. Tropical peat lands: carbon stores, carbon gas Emissions and contribution to climate change Processes. In: M Strack (ed) Peat Lands and Climate Change. International Peat Society, Vapaudenkatu 12, 40100 Jyväskylä, Finland, pp. 148-182.

Wahyunto, A Dariah and F Agus. 2010. Distribution, properties and carbon stock of Indonesian peatland. In: ZS Chen and F Agus (eds). Proceedings of International Workshop on Evaluation and Sustainable Management of Soil Carbon Sequestration in Asian Countries. Bogor. Indonesia. September 28 – 29, 2010, pp. 187-204.

Wahyunto, S Ritung, Suparto and H Subagjo. 2004. Map of Peatland Distribution Area and Carbon Content in Kalimantan, 2000 – 2002. Wetlands International – Indonesia Programme & Wildlife Habitat Canada (WHC). Bogor.

Wardah, B Toknok and Zolkhaidah. 2011. Carbon stock of agroforestry systems at adjacent buffer zone of Lore Lindu National Park, Central Sulawesi. *J Trop Soils* 16: 123-128. doi: 10.5400/jts.2011.16.2.123.

Wellock ML, B Reidy, CM Laperle, T Bolger and G Kiely. 2011. Soil organic carbon stocks of afforested peatlands in Ireland. *Forestry* 84: 441-451.

White DM, DS Garland, X Dai and CL Ping. 2002. Fingerprinting soil organic matter in the Arctic to help predict CO_2 flux. *J Cold Reg Sci Tech* 35: 185-194.

Zhang Y, C Li, CC Trettin, H Li and G Sun. 2002. An integrated model of soil, hydrology and vegetation for carbon dynamics in wetland ecosystems. *Global Biogeochem Cy* 16: 9.1-9.17. doi:10.1029/2001GB001838.