Abstract No: A-371

EMISSIONS OF METHANE AND NITROUS OXIDE FROM PEATLANDS

Ryusuke Hatano*

Research Faculty of Agriculture, Hokkaido University

** Corresponding author: hatano@chem.agr.hokudai.ac.jp*

SUMMARY

Peatland is a significant storage of carbon (C) and nitrogen (N) on the earth surface. Human activities in peatlands influence significantly the emissions of greenhouse gases, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Methane and N_2O are produced through oxidation-reduction reactions, so their emissions essentially influenced by ground water level. This paper reviews the characteristics of CH_4 and N_2O emissions. There were different trends of CH_4 and N_2O emissions from between tropical peatland and boreal and temperate peatlands. Methane emission increased significantly with the rise of ground water level above -20 cm, and larger in boreal peatland with plant mediated CH_4 emission than tropical peatland with plant mediated oxygen supply. Forest disturbance in tropical peatland increased CH_4 emission. On the contrary, N_2O emission increased with a drop of ground water level below -40 cm. The increase of N_2O emission was significantly lager in tropical peatland than in boreal and temperate peatlands. Nitrous oxide emission increased with N mineralization, and further increased with N fertilizer application. High N_2O emission in tropical peatland was induced by denitrification. Increase of soil nitrate-N (NO_3-N) content in rainy season increased N_2O emission. Maintaining ground water level between -20 and -40 cm minimizes CH_4 and N_2O emissions from peatland.

Keywords: ground water level, methane, nitrogen fertilizer, nitrous oxide, peatland

INTRODUCTION

Peatland has been generated at the rate of 100 to 200 kg C ha^{-1} yr^{-1} of organic matter accumulation for past 10,000 years due to lower microbial decomposition than plant production in wetland. The area is around 4 million km^2 in boreal and temperate region and around 0.4 million km^2 in tropical region. Although the area occupies only 3 % of terrestrial area, it contains 612 Gt C (547 Gt C in northern boreal and temperate peatland, 50 Gt C in tropical peatland) (Yu et al., 2010), accounting for 25 % of total soil carbon.

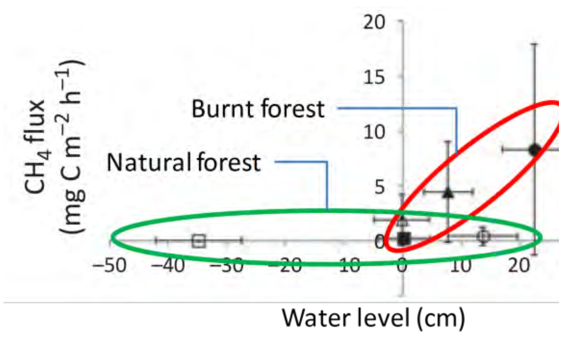
Wetland is a major source of CH_4. Natural wetland emits 217 Tg CH_4 yr^{-1}, accounting for 63 % of total natural CH_4 emission, and rice paddy field emits 36 Tg CH_4 yr^{-1} accounting for 11% of total anthropogenic CH_4 emission (IPCC, 2013). In wetland, CH_4 is produced in reductive sub soil, is transported to top soil and is emitted from the surface of the soil. However, 90% of CH_4 produced is oxidized during the transportation (Kolb and Horn, 2012). In well drained peatland, CH_4 emission is almost trace (Couwenberg et al., 2010).

On the other hand, wetland is not a source of N_2O, rather a sink of N_2O. This is because of slow N mineralization, low nitrification activity, high denitrification activity in the reductive condition (Kolb and Horn, 2012). But, drained and agriculturally used peatland emits N_2O significantly, and large N_2O emission is recorded in NO_3-N accumulated upland fields in tropical peatland (Takakai et al., 2006, Repo et al., 2009. This is because of denitrification with NO_3-N leaching (Kolb and Horn, 2012).

This paper reviews CH_4 and N_2O emissions from peatland to understand appropriate use of peatland

METHANE EMISSION

Ground water level is major controlling factor of CH_4 emission. Methane emission increases significantly when ground water level rise above -20 cm (Couwenberg et al., 2010). However, the increase of CH_4 emission is higher in boreal and temperate peatland than in tropical peatland. Recent global model uses 0.2 to 0.25 for the CH_4/CO_2 mole ratio in boreal natural peatland and 0.0052 in tropical natural peatland (Spahni, et al., 2011). This is because of strong oxidizing power in natural tropical peatland induced by the



plant mediate oxygen supply through aerial roots (Adji et al., 2014) and fast water flow in well water permeable peat layer (Kelly et al., 2014). Peat fire or clear tree cutting increases CH_4 emission in tropical peatland due to the disappearance of plant mediate oxygen supply and the rise of ground water level with subsidence, while drainage decreases CH_4 emission due to the drop of ground water level (Fig. 1) (Jauhiainen et al., 2008、Adji et al., 2014). On the other hand, vegetation in boreal and temperate wetlands accelerates CH_4 emission. An observation in a thermokarst depression of 63.7 ha in East Siberia for four years from 2006 to 2009 showed that 95.4 ± 5.4 % of total CH_4 emission was emitted from thermokarst pond (60.7 ± 19.2 % of the total area) and plant mediated CH_4 emission from the pond vegetation accounted for 45.4 ± 23.2 % of total CH_4 emission (Desyatkin et al., 2014).

NITROUS OXIDE EMISSION

Natural peatland with high water level is not a source of N_2O due to its low activities of N mineralization and nitrification, high activity of denitrification in reductive condition (Kolb and Horn, 2012). But, by drainage for agricultural use, N_2O emission together with increase of CO_2 emission increases (Mu et al., 2014). Comparing emission data published previously, CO_2 emission was significantly higher in tropical peatland than boreal and temperate peatlands, and increased with N fertilization significantly (3815 ± 2900 and 4822 ± 2313 kg C ha^{-1} yr^{-1} in unfertilized and fertilized boreal and temperate peatlands, respectively, and 7382 ± 3558 and 13001 ± 3027 kg C ha^{-1} yr^{-1} in unfertilized and fertilized tropical peatland, respectively). N_2O emission increased with N fertilization significantly, especially in tropical peatland (4.93 ± 10.04 and 17.76 ± 21.15 kg N ha^{-1} yr^{-1} in unfertilized and fertilized boreal and temperate peatlands, respectively, and 8.08 ± 15.69 and 178.59 ± 218.28 kg N ha^{-1} yr^{-1} in unfertilized and fertilized tropical peatland, respectively).

Furthermore, in all peatlands, CO_2 and N_2O emissions increased with the drop of ground water level, and much larger increase was found in N fertilized peatlands (Fig. 2). Increase of CO_2 emission with the drop of water level was larger in tropical peatland than in boreal and temperate peatlands, and maximum CO_2 emission was found at -80 cm of water level. Increase of N_2O emission with the drop of water level was distinct below -40 cm of water level. Especially in tropical peatland, maximum N_2O emission of 700 kg N ha^{-1} yr^{-1} was found from -60 to -70 cm of water level. There was a significant relationship between mineral N input which is sum of mineralized N (CO_2 emission / CN ratio) and applied fertilizer N) and N_2O emission (Fig. 3). This indicates that increase of peat decomposition with a drop of water level and N fertilizer application increases N_2O emission.

In an upland field of tropical peatland where large N_2O emission was observed, there was a significant relationship between NO_3-N content in top soil and N_2O flux at the water filled pore space more than 60 %, suggesting N_2O emission was caused by denitrification after mineralization and nitrification (Takakai et al., 2006). Soil microbes which are adopted to low pH of tropical peatland and obtain nitrate respiration ability, fungi (*Fusarium oxysporum and Neocosmospora vasinfecta*) (Yanai et

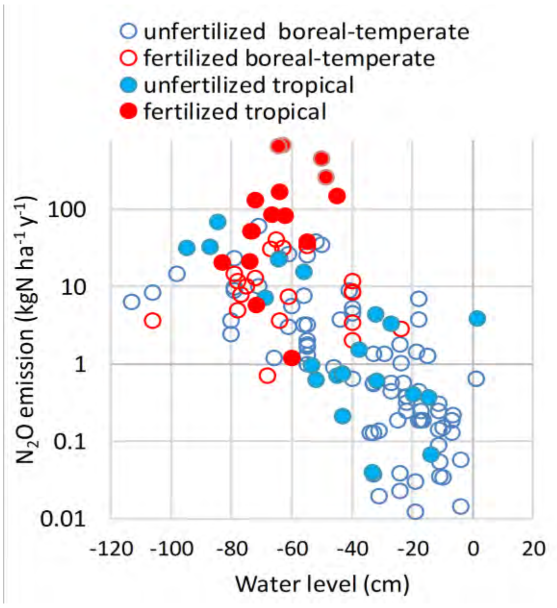


Figure 2: Relationship between N_2O emission and water level in peatlands (modified from Mu et al., 2014 by addition of Melling et al., 2007, Takakai et al., 2006, Toma et al., 2011)

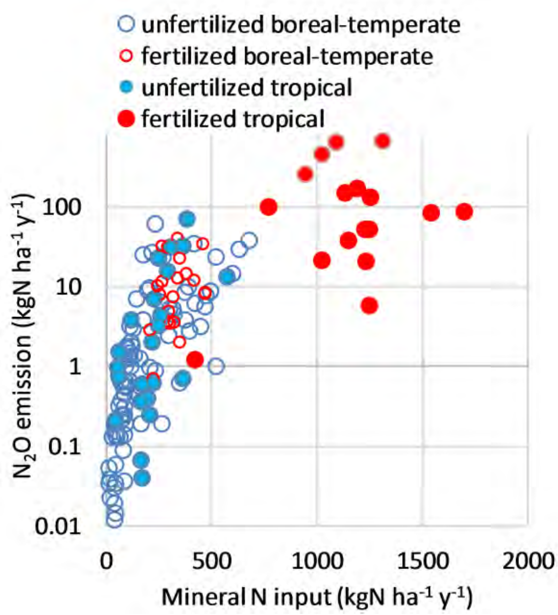


Figure 3: Relationship between N_2O emission and mineral N input in peatlands (modified from Mu et al., 2014 by addition of Melling et al., 2005, 2007, Takakai et al., 2006, Toma et al., 2011)

al., 2007) and bacteria (*Janthinobacterium*) (Hashidoko et al., 2008), were identified.

CONCLUSION

From the findings above, following conclusion can be drawn. Ground water level is major controlling factor of CH_4 and N_2O emissions from peatland. Ground water level above -20 cm increases CH_4 emission. The increase of CH_4 emission is lager in boreal peatland than in tropical peatland. However, in tropical peatland, loss of natural vegetation increases CH_4 emission significantly due to loss of plant mediated oxygen supply. On the other hand, ground water level from -40 to -70 cm stimulates N_2O emission together with CO_2 emission. Nitrogen fertilizer application increases N_2O and CO_2 emissions. The increase of N_2O and CO_2 emissions is larger in tropical peatland than in boreal and temperate peatlands. Overall emission data show the lowest emissions of CH_4 and N_2O are achieved in the range of -20 to -40 cm of ground water level.

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