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Discussions

Interactive comment on "Effects of multiple environmental factors on CO_2 emission and CH_4 uptake from old-growth forest soils" *by* H. Fang et al.

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Thanks for the referee's comments concerning our manuscript entitled "Effects of multiple environmental factors on CO2 emission and CH4 uptake from old-growth forest soils". We found the referee's comments most helpful and constructive, and have made some correction which we hope meet with his/her approval. The revised portions are underlined in red and added in the revised manuscript.

1. In the abstract, the authors mentioned that soil CO2 flux in the old-growth forests were mainly driven by soil temperature (P7822, L12). I agreed with the opinion. But, I can't agree with the speculation that CO2 fluxes will increase with increase in air tem-

perature (P7835, L5). This speculation is a just speculation, not scientific. This study was conducted in various climate conditions from boreal to tropical zone. When air temperature will be changed, the response of soil temperature will be different among zone. Not only scientist but also many people are concerned with an increase in carbon emission from soils due to an increase in air temperature. Therefore, the speculation should be deleted.

Our initial conclusion is not exact. Presently, both warming manipulative experiments and models suggest that there are conflicting conclusions on soil CO2 emission to warming including acceleration and acclimation (Tian et al., 1998; Mellilo et al., 2002) depending on C substrate availability. In the warming experiment of Harvard forest, it took about ten years to observe the decrease of soil CO2 emission, which was mainly attributed to limited size of the labile soil carbon pool (Mellilo et al., 2002). Contrast to warming experiment, the increase of ambient air temperature will not rapidly exhaust soil C substrates such as labile C pools within a short period regardless of temperate or tropical forests (Tang et al., 2006; Schwendenmann and Veldkamp, 2006).

Our results showed that soil CO2 efflux increase with soil temperature. Moreover, the temperature sensitivity of soil CO2 emission in the boreal and temperate forests is significantly higher than those in the subtropical and tropical forests. In the future, if boreal and tropical forests would be turned into temperate and subtropical forests due to climate warming, respectively, soil CO2 emission will increase within a short period. Therefore, the original sentence was substituted by "Based on the gradient theory of exchange of time and space, increase in air temperature in the future would promote soil CO2 emission in the old-growth forests within a short period, and northern forest soils were more sensitive than southern forest soils".

Tian H Q, Melillo J M, Kicklighter D W, et al. 1998. Effect of interannual climate variability on carbon storage in Amazonian ecosystems. Nature, 396, 664-667 Mellion J M, Susan E T, Ronald A. 2002. Soil warming and carbon cycle feedback to the climate system. Science, 298: 2173-2176

Tang X L, Liu S G, Zhou G Y, Zhang D Q, Zhou C Y. 2006. Soil-atmospheric exchange of CO2, CH4, and N2O in three subtropical forest ecosystems in southern China, Global Change Biol.,12, 546-560.

Schwendenmann L, Veldkamp E. 2006. Long-term CO2 production from deeply weathered soils of a tropical rain forest: Evidence for a potential positive feedback to climate warming. Global Change Biology, 12, 1878-1893.

2. I agreed with the result that there were relationships between soil C fluxes and mineral N (Fig. 6). However, I can't agree the authors' opinion that increasing in N deposition in eastern China would increase soil CO2 emission but decrease soil CH4 uptake in the old-growth forests (P7822, L21). In this study, CH4 uptake was highest in subtropical forest (Table 2), where N deposition was highest (Table 1). How can you explain this result? In addition, it is necessary more explanation to assess the effect of mineral N on soil C flux in the discussion (4.3&4.4). The authors mentioned that NO3 promote CO2 emission and NH4 inhibit CH4 uptake (P7822, L16). In fact, figure 6 showed the clear relationship between soil C flux and mineral N. However, NH4+ is consumed and NO3 is produced via nitrification process, and NO3 is consumed via denitrification process. Generally, nitrification rate is high under high temperature and mesic condition. These conditions would enhance a decomposition of soil organism and CO2 emission from soil. The authors need to explain the considerable mechanism. As for CH4, the authors mentioned CH4 uptake was inhibited due to both the competitive and toxic inhibition (P7822, L19). But, in the subtropical forest soil, it is an acceptable explanation that high CH4 uptake was observed due to that NH4 oxidizers can oxidize CH4. Anyway, the effect of mineral N on soil C flux should be discussed based on various possibilities.

We completely agree with the referee's opinions. Indeed, our results can only deduce the effect of soil N availability rather than nitrogen deposition on soil C effluxes. Warming, precipitation variation and N deposition can all result in change of soil mineral N storage along the environmental gradient. Because of covariation among these envi-

ronmental variables, we can not attribute variation of soil mineral N to one of them. Therefore, we revised the original sentence as follows. Soil NO3–N increase and NH4+-N decrease resulting from environmental change would increase soil CO2 emission and CH4 uptake.

Due to relative high N deposition rate (more than 30kgN ha-1 yr-1) and the climax of forest succession, the subtropical monsoon evergreen broadleaf forest at Dinghushan site has already reached N saturation (Mo et al., 2008), where soil mineral N is dominated by soil NO3–N (Fig. 3) and soil N leaching and gaseous emission is very high (Fang et al., 2008, 2009; Zhang et al., 2008). However, the tropical seasonal rain forest in Xishuangbanna where economy is undeveloped and N deposition is low, soil mineral N is still dominated by soil NH4+-N and is not unsaturated yet (Fig. 3). Because NH4+-N rather than NO3–N has the inhibitory effect on CH4 production, the subtropical forest soil has the highest CH4 uptake capacity. In addition, although the mean annual precipitation is the highest at subtropical forest site, the soil moisture content is the lowest in vegetative season from May to October (Table 1 and Table 2). Forest soil CH4 uptake is generally driven by soil moisture or soil WFPS (water-filled pore space), which also result in subtropical forest soil has the highest capacity of CH4 consumption.

If forest types were not taken into account, positive relationships between soil CO2 efflux and soil NO3–N as well as between soil CH4 efflux and soil NH4+-N were found (Fig.6 and Table 3). So we concluded that NO3- can promote CO2 emission and NH4+ inhibit CH4 uptake. Besides, there are significant difference for relationship between soil C effluxes and mineral N content among four forests. According the referee's advices, we added many explanations on these differences in discussion section.

(1) Nitrification rate and NO3–N content are higher in the tropical and subtropical forests than in the boreal and temperate forest soils. NO3–N accumulation will decrease C/N ratio of litter, debris and soil organic matter. Moreover, decomposition of soil organism and CO2 emission from soil would be enhanced under high temperature and mesic conditions. On the other hand, soil CO2 efflux increase with soil

NO3–N, which could be partly explained by the difference in fine-root biomass. Forest with higher soil NO3–N content has higher fine-root biomass (Table 1). Cleveland and Townsend (2006) also suggested that the increase in soil respiration in the N-fertilized plots may have been driven, at least in part, by changes in fine-root dynamics. However, inconsistent effects of N on soil CO2 effluxes (decrease or no change) generally occur in the laboratory and field-fertilization experiments, which are mainly attributed to rapidly decline of soil microbial activities and decrease of root-biomass within a short period (three to five years)(Mo et al., 2008).

(2) Soil CH4 uptake is controlled by soil temperature, moisture, soil mineral N, thickness of O-horizon etc. Contrast to the tropical and subtropical forests, soil NH4+ in the boreal and temperate forests was mainly assimilated by plants or immobilized by soil clay mineral, the relatively lower CH4 uptake was attribute to other reasons such as substrate availability or diffusion rather than NH4+ inhibition. For example, low temperature and frozen layer in winter as well as the thicker O-horizon obstruct the diffusion of CH4 in atmosphere to soil, which will indirectly decrease the uptake of soil CH4 (Grsso et al.ïijŇ2000). However, in the tropical and subtropical forest soils, the observed higher CH4 uptake should be mainly attribute to the competitive and toxic inhibition of NH4+.

Cleveland CC, Townsend AR (2006) Nutrient additions to a tropical rain forest drive substantial soil carbon dioxide losses to the atmosphere. PNAS, 103: 10316-10321

Fang YT, Gundersen P, Mo JM, Zhu WX (2008) Input and output of dissolved organic and inorganic nitrogen in subtropical forests of South China under high air pollution. Biogeosciences 5: 339-352

Fang YT, Zhu WX, Gundersen P, Mo JM, Zhou GY, Yoh M (2009b) Large Loss of Dissolved Organic Nitrogen from Nitrogen-Saturated Forests in Subtropical China. Ecosystems 12: 33-45

Grosso S J D, Parton W J, Mosier A R, et al. (2000) General CH4 oxidation model and comparisons of CH4 oxidation in natural and managed systems. Global Biogeochemi-

cal Cycles, 14:999∼1019

Mo J, Zhang W, Zhu W, Gundersen P, Fang Y, Li D, Wang H (2008) Nitrogen addition reduces soil respiration in a mature tropical forest in southern China. Global Change Biology 14: 403-412

Zhang W, Mo JM, Yu GR, Fang YT, Li DJ, Lu XK, Wang H (2008a) Emissions of nitrous oxide from three tropical forests in Southern China in response to simulated nitrogen deposition. Plant and Soil 306: 221-236

Specific comments P7824, L17: The study sites were classified in boreal, temperate, subtropical, and tropical zone. However, I think the temperate site should be classified cool temperate zone, not temperate forest. Because mean annual temperature and precipitation (Table 1) are too low to be classified into temperate forest. In addition, soil was relatively wet due to the soil moisture data and vegetation (Franxinus mandshurica), so that, this forest was not ordinal temperate forest. As same as temperate region, according to figure 1, the tropical region is too cool to regard as the tropical. Are the classification correct?

Based on Chinese climate and vegetation classification (mainly considering mean annual temperate, extreme temperate, annual accumulated temperate etc.), mean annual temperature of cool temperate, temperate, subtropical and tropical zone ranges from -2.2∼-5.5oC, 2∼8oC, 14∼22 oC and 22∼26 oC, respectively. Annual accumulated temperature ranges from 1100-1700oC, 1600-3200 oC, 4500-8000 oC and 8000-9000 oC, respectively. Therefore, the Daxinganling Mountains belong to cool temperate zone. Its vegetation is Chinese Larch (Larix Gmelini) ecosystem and is the southern margin of Taiga forest regions, which is also involved in boreal forest. The Changbai Mountain belongs to temperate zone. Its vegetation is a typical temperate needle-broadleaved mixed forest. Moreover, Manchurian ash (Franxinus mandshurica) is a frequently constructive species in the temperate mixed forest. Dinghushan site belongs to southern subtropical climate zone, and its vegetation is monsoon evergreen broad leaved forest.

Xishuangbanna site is within the south of tropic of cancer, influencing by tropical monsoon climate. The vegetation is typical tropic seasonal rain forest. Due to higher altitude of Yunnan-Guizhou plateau, the mean annual temperate is slightly less than the lower bound of classification indexes. After comprehensive consideration of geomorphology, climate, vegetation, Xishuangbanna site customarily is ascribed to tropical forest.

P7825, L8: The authors mentioned soil classification, but the classification was very old. Soil classification was very important information. If the authors want to refer FAO/UNESCO taxonomy, soil classification should be conducted due to WRB 2006.

Comparing Chinese soil Taxonomy (Gong et al., 2007) and World reference base for soil resources (2006), we carefully compared and classified the four forest soils again. The soils are greyzems, luvisols, ferralsols and lixisols (IUSS Working Group WRB, 2006.) from north to south, respectively.

Zitong Gong, Ganlin Zhang, Zhicheng Cheng, et al. 2007. Pedogenesis and soil Taxonomy. Science press, Beijing.

IUSS Working Group WRB. 2006. World reference base for soil resources 2006. 2nd edition. World Soil Resources Reports No. 103. FAO, Rome.

P7826, L7: The measurement season was separated growing and non-growing season. But I think that the separation is not suitable for subtropical and tropical region. If the classification of subtropical and tropical region was incorrect, the authors can use growing and non-growing season, or summer and winter.

The boreal and temperate forest ecosystems are two northern forests with obvious growing and non-growing seasons, while subtropical and tropical forests are two evergreen forests, where there are no rigid division between growing season and non-growing season. However, there exists obvious cool-dry season from November to April and warm-humid season from May to October. According to season separation

by Yu et al. (2008), we consider the vegetative season from May to October and non-vegetative season from November to April for soil C effluxes comparison among the four forest ecosystems.

Yu GR, Song X, Wang QF, et al. Water use efficiency of forest ecosystems in eastern China and its relations to climatic variables. New Physiologist, 2008, doi: 10.1111/j.1469-8137.2007. 02316.x

Technical comments CO2 and CH4 flux: The authors use various words to express CO2 and CH4 flux. For example, CO2 emission, CO2 exchange, soil CO2 flux, CO2 efflux etc. In discussion, sometimes, it is correct to use CO2 emission or CH4 uptake, but the authors should take care of how to use the terms.

According the referee's suggestion, most of expressions about CO2 and CH4 fluxes were unified for soil CO2 and CH4 effluxes, except in discussion section where CO2 emission and CH4 uptake were used sometimes.

Table 1: Temperature mixed forest > temperate mixed forest. It is better to write forest vegetation name not Latin name, briefly. For example, larch in boreal forest. What is the measurement depth or range of soil texture, Total N, C/N and soil pH? Please write down as SOC density like as "0-20 cm".

"Temperature mixed forest" was replaced with "Temperate mixed forest". In each forest site, typical trees were expressed as English name and Latin name. For example, Chinese larch (Larix gmelinii) in boreal forest, Korean pine (Pinus koraiensis), basswood (Tilia amuresis), Manchurian ash (Fraxinus mandshurica) and oak (Quercus mortgolica) in the temperate forest, guger-tree (Schima superba), rose apple (Syzygium jambos), henry chinkapin (Castanopsis chinensis) in the subtropical forest, and downy malugay (Pometia tomentosa), bayberry waxmyrtle-fruit (Terminalia myriocarpa), Yunan nutmeg (Myristica yunnanensis), South-Yunnan horsfieldia (Horsfieldia tetratepala), glabrous Homalium (Homalium laoticum) in the tropical forest.

All of soil properties showed in Table 1 are 0-20 cm soil layer, so the title of Table 1 is changed into "Stand characteristics and surface soil (0–20 cm) properties of the four old-growth forest sites". In addition, some soil properties in Table 1 were added standard error to express their range.

Table 2 & Fig. 2: Unit of soil moisture is not "%" but "m3 m-3". Please use SI unit. Reference: the authors sited "Hashimoto et al. 2004" (P7831, L13), but it is not showed in the reference list. Add in the list or delete from the text.

The unit of soil moisture has now been corrected in Table 2 and Fig. 2 replacing "%" with "m3 m-3". In addition, the lost reference was added in the list. Hashimoto, S., Tanaka, N., Suzuki, M., Inoue, A., Takizawa, H., Kosaka, I., Tanaka, K., Tantasirin C., and Tangtham, N.: Soil respiration and soil CO_2 concentration in a tropical forest, Thailand, Jap. Forest Res., 9, 75–79, 2004.

Please also note the Supplement to this comment.

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