ESTIMATION OF GLOBAL CO_2 EMISSION FROM SOIL USING TEMPERATURE AND WATER CONTENT MEASURED BY MODIS

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ABSTRACT

Soil is a major carbon (C) reserve in terrestrial ecosystems, and the CO_2 flux from soil (soil respiration: SR) is an important component of the C balance between terrestrial ecosystems and atmosphere. SR rate was affected by soil temperature and/or soil water content, therefore with their spatial and temporal variations. Few studies had estimated the global annual soil respiration based on experimental equations by field observation and actual climate data. The object of the this study is to estimate the annual SR on the global scale using the experimental equations and climate products of land surface temperature and Keetch-Byram drought index from MODIS measurements. The empirical equations for estimation of SR rate were selected from field observations at 14 ecosystems. The field observation studies indicated that SR rates in boreal and tropical region were dependent on soil temperature and soil water content respectively. SR in temperate region was deminated by temporal variation of both soil temperature and water content. Annual mean SR at 14 ecosystems were estimated, although they ranged from 291 to 1883 gC m^{-2} y^{-1}. In the future work, we will compare the result of biogeochemical model (VISIT) and previous studies (e.g. Bond-Lamberty and Thomson, 2010) with that of this study.

1. INTROSUCTION

Soil is a major carbon (C) reserve in terrestrial ecosystems, the amount of global soil carbon was estimated about 2500 Gt (Lal, 2004). Soil respiration (SR) is the second large carbon flux and an important component of the C balance between terrestrial ecosystems and atmosphere. SR is a result of integration of autotrophic (root) and heterotrophic (soil organic matter and litter) respiration processes, therefore it has a spatial variation. SR rate was affected by soil temperature and/or soil water content, therefore it had a temporal variation. Amount of annual soil respiration were estimated to be from 68 to 98 Pg on a global scale (Bond-Lamberty and Thomson, 2010; Raich and Schlesinger, 1992). However, there were few studies which estimated global SR using experimental equations at each ecosystems and actual climate data for a long time. The objectives of this study are to estimate soil respiration based on experimental equation at 14 ecosystems using MODIS product (land surface temperature: LST and Keetch-Byram drought index: KBDI) to evaluate the global soil respiration for 13 years.

2. METHODS

According to land cover map by FAO, the research which measured soil respiration rate in the field were selected at 14 ecosystems (Figure 1). LST (Takeuchi et al., 2012) and drought index (KBDI: Takeuchi et al., 2010) at 4km resolution were used to estimate SR from 2000 to 2013. LST data were directly used as soil temperature data. Soil water content (θ) was estimated using KBDI (X) as follows;

$$\theta = (\theta_{max} - X/X_{max}) \qquad (2)$$

where θ_{max} is maximum soil water content at each study site from research papers and X_{max} is maximum KBDI at each point from MODIS data.

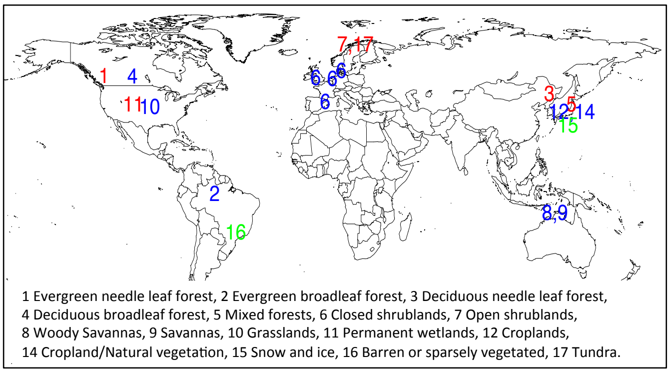

Figure 1. Selected points and ecosystems to estimate soil respiration around the world. Red numbers are the ecosystems where soil respiration related with soil temperature. Blue numbers are the ecosystems where soil respiration related with soil temperature and water content, and No.2 is only soil water content. Green numbers did not have seasonal variation (constant value). Land cover was based on FAO map, and No.13 "Urban and build-up" did not show in this figure.

3.RESULT AND DISCUSSION

SR was estimated by soil temperature at 6 ecosystems estimated using LST from 2002 to 2013 as shown in Figure 2. SR in open shrub land (No.7) and Tundra (No.17) in Sweden need to correct LST data because seasonal variation in LST was larger than the actual soil temperature data (0 to 12 °C; Sjögersten and Wookey, 2002). Soil temperature in these ecosystems varied from 0 to under 15 °C, and SR was varied from about 0 to 4.0 gC m^{-2} d^{-1} (Sjögersten and Wookey, 2002). However LST data in this area were around -25 to 20 °C in 2002, and SR was over 10 gC m^{-2} d^{-1} and negative rate during summer and winter season, respectively (Figure 3). Therefore, seasonal variation in soil temperature was assumed to be from zero to 12 °C in this study. Therefore, SR in open shrub land and Tundra in Figure 2 were estimated using this assumption.

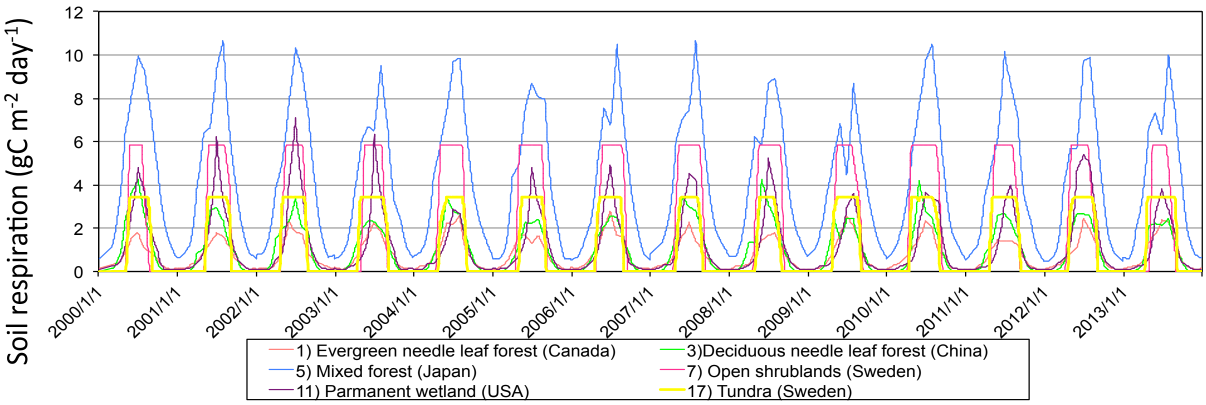

Figure 2. Seasonal variation in SR at 6 ecosystems which were estimated using LST from 2000 to 2013.

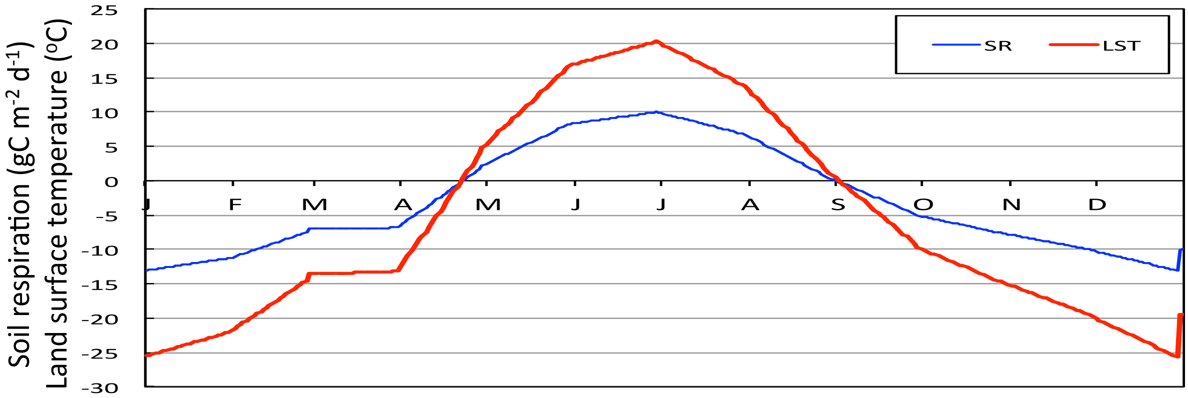

Figure 3. Seasonal variation in land surface temperature (LST) by MODIS and estimated soil respiration in open shrub land, Sweden in 2002.

SR was estimated by LST and KBDI at 8 ecosystems (Figure 4), and very small differences were found among No.8 woody savanna and No.9 savanna, and No.12 cropland and No.14 cropland/natural vegetation mosaic. SR in evergreen broadleaf forest in Brazil and savanna in Australia did not have clear seasonal variation. Gaumont-Guay et al. (2006) reported that maximum SR was about 9.5 gC m^{-2} d^{-1} during summer in deciduous broadleaf forest, Canada. The maximum SR of our result in deciduous broadleaf forest were varied from 7.3 to 12.5 gC m^{-2} d^{-1}, average of maximum SR was 10.0 gC m^{-2} d^{-1} for 13 years. The estimation of SR in this study performed well in deciduous broadleaf forest.

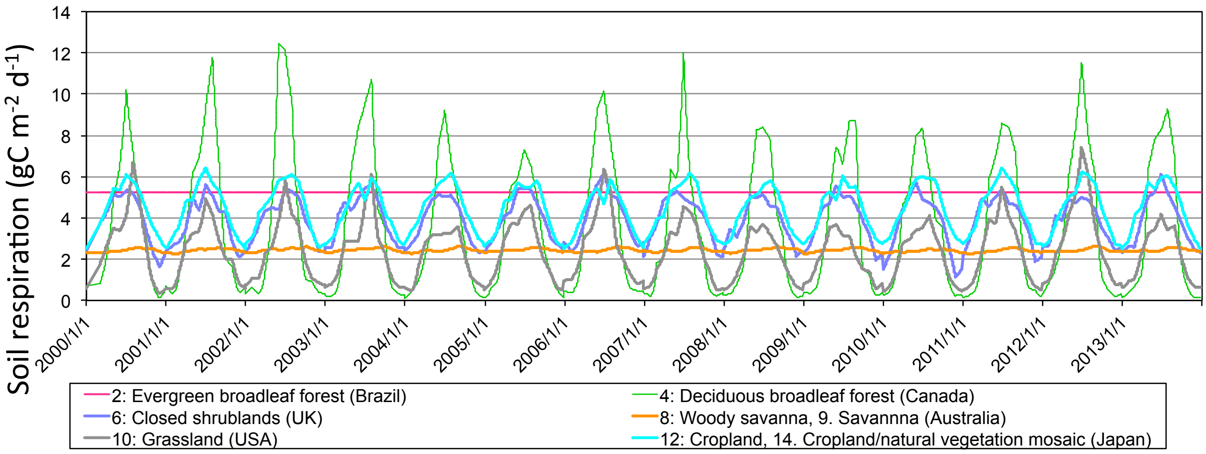

Figure 4. Seasonal variation in SR at 8 ecosystems estimated using LST and KBDI from 2000 to 2013.

The annual variations in SR at 6 ecosystems were estimated using LST for 13 years as shown in Figure 5. Mean annual SR at 14 ecosystems had large spatial variation from 291 to 1883 gC m^{-2} y^{-1}. The ecosystems of lowest and largest annual carbon emission from soil were evergreen needle leaf forest and evergreen broadleaf forest, respectively. These results were conducted estimation at a point scale, and we extrapolate the models to calculate SR on a global scale. In the future work, we will compare the result of biogeochemical model (VISIT) and previous studies (Bond-Lamberty and Thomson, 2010; Hashimoto, 2012) with the result of the present estimation.

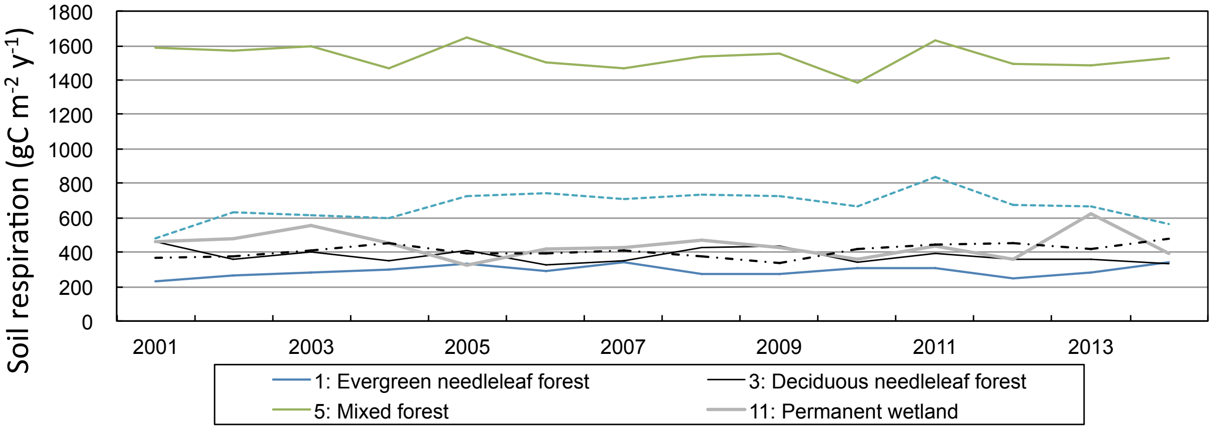

Figure 5. The annual variation in SR at 6 ecosystems which were estimated using LST for 13 years

5.CONCLUSION

The objectives of this study are to estimate soil respiration based on experimental equation at 14 ecosystems using MODIS product (LST and KBDI) to evaluate the global soil respiration for 13 years. SR was estimated by soil temperature at 6 ecosystems, but LST data in high arctic region need to correct because seasonal variation in LST was larger than the actual soil temperature data. SR was estimated by LST and KBDI at 8 ecosystems, but it was difficult to distinguish between woody savanna and savanna, and cropland and cropland/natural vegetation mosaic. Mean annual SR at 14 ecosystems had a high spatial variation from 291 gC m^{-2} y^{-1} in the evergreen needle leaf forest to 1883 gC m^{-2} y^{-1} in the evergreen broadleaf forest. However, these results were conducted estimation at a point scale, therefore we have to calculate. In the future work, we will estimate SR on a global scale, and compare it with the result of biogeochemical model (VISIT) and previous studies (Bond-Lamberty and Thomson, 2010; Hashimoto, 2012).

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