Manage temperate forest for soil carbon-lessons from natural forests

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Background

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1. Background

- Soil store huge amount of carbon (1550 PgC), 3 times of the atmosphere C pool, and 2~4 times of the vegetation carbon pool.
- A minus change could potentially change the CO$_2$ concentration of the atmosphere.
Soil carbon under threaten

Deforestation

Afforestation

Fire

Environmental change

Amazon forest, Brazil

Gros Morne National Park, Canada
Research area

- Warm temperate area in middle China
- Oak forests (Secondary forest, *Quercus aliena* var. *acuteserrata*)
- Terrestrial monsoon climate
- MAT 15.1°C, MAP 885.6mm
More than half of natural forest in China is young regenerated forests (65%), they are in different stage of succession, how forest succession affect soil carbon through changes in vegetation and soil worth to answer.

Succession positively affect soil respiration by affecting biomass and labile organic carbon, also, forest succession benefit soil physical characteristic (capillary porosity) promote soil CO₂ emission.

Luan et al., Plant and Soil (2011)
Luan et al., Soil Biology & Biochemistry (2011)
Succession effects on soil respiration of biotic and abiotic components

- Succession positively affect soil labile carbon and consequent soil heterotrophic respiration (HR), but nonlinearly affect autotrophic respiration (AR), lead the late stage of succession has higher proportion of HR;
- Due to the time lag of AR to temperature, the temperature sensitivity ($Q_{10}$) of HR is higher, lead a higher risk of carbon loss at the background of global warming.

**Time-lag**

**$Q_{10}$ of AR lower than that of HR**

Luan et al., Soil Biology & Biochemistry (2011)
A recent work

- How succession affect soil carbon through different biotic components, and what are the roles that symbiotic fungi play
- Microcosm + $^{13}$C labeling

(modified Moore et al., 2015)
Warming and cooling have differential effects on SOM decomposition;
- Warming increase $Q_{10}$, and labile carbon;
- The increased $Q_{10}$ due to warming is related with increase of microbial metabolic quotient.

$qCO_2$ explains increased $Q_{10}$ due to warming

Luan et al., 2014, Biogeochemistry
50% throughfall reduction normally do not have significant effect on soil CO$_2$ emission,

but increase RS during wet year, decrease RS during drought year.

Warm temperate region, soil moisture threshold is ~ 10 vol%.

Lu et al., 2017, Scientific Reports
In response to both drought and warming

**Warming + Drought**

- Warming triggered SR, drought alleviated the warming induced C loss;
- The increment of SR is mainly attributable to AR under warming and drought.
- But there is attenuation of soil respiration in response to soil warming, which is Microbe-mediated (Wang et al., accepted).

(Liu et al., 2016, Agricultural and Forest Meteorology)

Wang et al., Science of the Total Environment (accepted)

IUFRO 2019, E8q, Yi Wang, Microbe-mediated attenuation of soil respiration in response to soil warming in a temperate oak forest
Recent works

- Drought effects on carbon allocation, $^{13}\text{CO}_2$ Pulse labeling
- Role of Mycorrhizal fungi on C under drought stress
- Microcosm, $^{13}\text{C}$ addition labeling
• China has the largest area of plantations in the world (80 million ha), account 36% of forest area.
• These plantations mainly are monocultures (81%).
Stand structure explain spatial variation of SR

*Pinus armandii* F.

*Quercus aliena* var. *acutiserrata*

**Coniferous-broad-leaf mixed stand**

**Broadleaf mixed stand**

Luan et al., *Soil Biology & Biochemistry* (2012) 44:143-150
Stand structure parameter well explains the spatial variations of RS;
- Basal area (BA), max. DBH, and mean DBH within various distances (from 2 m to 10 m) and $R_S$;
- Soil properties also contributed to the spatial variations of SR;
- Stepwise regression models, including both stand structure parameters and soil properties, explained 50-70% of the variation.

<table>
<thead>
<tr>
<th>Forest type</th>
<th>Parameters</th>
<th>$R_S$ (μmol CO₂ m⁻² s⁻¹)</th>
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<tbody>
<tr>
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<td>df</td>
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<tr>
<td>Pine plantation</td>
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<tr>
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<td>BD</td>
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<td></td>
<td>$R_S = 0.009$ LFOC - 1.249</td>
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<tr>
<td></td>
<td>$BD + 2.611$</td>
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<td>Oak forest</td>
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<tr>
<td></td>
<td>WHC</td>
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<td></td>
<td>Max. DBH₄</td>
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<td>$R_S = 3.265$ WHC + 0.014 max. 1.21</td>
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</tbody>
</table>

Luan et al., Soil Biology & Biochemistry (2012)
Tree species diversity promotes soil carbon stability

- Subplots with higher tree species diversity showed lower $Q_{10}$;
- Different mechanisms underline coniferous and broadleaf-mixed, and broadleaf-mixed forests;
- **Coniferous and broadleaf-mixed**: lower underground competition strength;
- **Broadleaf-mixed**: likely be more closely related to the quality of the substrate that is affected by tree species.

Luan et al., Science of the Total Environment (2018)
Summary

- Succession promote C storage of labile fraction, which is vulnerable to disturbance. Also, succession alters soil property that facilitate C loss;
- Warming may lead irreversible change of soil carbon, which is attributable to microbial change;
- Moderate drought may not threat soil carbon of warm-temperate area within a short term;
- Tree species diversity benefit soil carbon stability but via differential mechanisms between forest types.
Call for submissions to

- **Special issue**: Soil Biology & Biochemistry
- **Topic**: Plant-soil interactions in forests, under management practices and climate change
- **Anticipated open time**: At the end of 2019

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5-Year Impact Factor: **6.065**
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Thanks for your attention!