Carbon budgets and trends in China

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Content

Where China carbon study is?

1. What kinds of terrestrial carbon data we have
2. What we have done in evaluating carbon budget
3. What the situation of carbon budget is: uncertainty
4. What is essential to Chinese carbon study
1. What kinds of terrestrial carbon data we have

1.1 Ecosystem research data
1.2 IGBP-transect research data
1.3 Forest inventory data
1.4 Eddy flux data
1.1 Ecosystem research data

- **Time**: May, 1998 – Present
- **Typical ecosystems**
  - Changbai Mountain Forest Ecosystem Research Station
    - Quercus mongolica forest ecosystem
    - Pinus Koraiensis forest ecosystem
  - Changling Grassland Station
  - Inner Mongolia Grassland Ecosystem Research Station
    - meadow steppe & meadow steppe farmland
    - Fenced & grazing Leymus chinensis grassland
    - Fenced & grazing Stipa gradis grassland
    - Dry steppe
Contents

- Daily and seasonal soil CO₂ fluxes
- Plant community photosynthesis
- Leaf ecophysiology
- Dynamical biomass and NPP
- C、N、P、S of dominant species
- Soil property
- Microclimate gradient observation
1.2 IGBP-transect research data

Investigation time:
- 1994
- 1997
- 1998
- 2001

mid-latitude semi-arid areas
Lat. 42°∼46° N
Long. 112°∼130.5° E
Length: 1,600 km
Width: 300 km
• **Land use database**
  - **Time:** 1997 & 2001
  - Sampling plots: 81 (every 25 kilometers one spot)
  - Contents: location, land use types

• **Soil carbon database**
  - **Time:** 1997 & 2001
  - Sampling plots: 30
  - Contents: Bulk density, C, N, P, K and effective C, N, P, S, K, Na, Ca, Mg, Cu, Zn, Fe, Mn and effective K, Cu, Zn, Fe, Mn, Cation exchange capacity, pH, Electronic conductivity, Soil water-holding capacity, Soil texture (International system)

• **Soil CO₂ flux**
  - **Time:** 2001
  - Sampling plots: 30
  - Contents: Soil CO₂ emission, Soil temperature: 0, 5, 15, 20cm
• **Plant community Photosynthesis**
  – **Time:** 2001
  – Sampling plots: 30
  – contents: Photosynthesis of plant community

• **Plant leaf physiological database**
  – **Time:** 1997
  – Sampling plots: 100 plots, 252 species
  – contents: location, leaf photosynthesis, leaf conductance, leaf transpiration, air temperature, air relative humidity, etc

• **Plant community investigation**
  – **Time:** 1997 & 2001
  – Contents:
    – tree: LAI, number and DBH of every species
    – Shrub: LAI, number, coverage and height of every species
    – grass in forest sampling: number, coverage and height of each species
    – grass in grass sampling: coverage, height and frequency
1.3 Forest inventory data

- Up to now, national level forest inventory survey in China has been executed five consecutive times from 1973 to 1998
  - 1973-1976
  - 1977-1981
  - 1984-1988
  - 1989-1993
  - 1994-1998
1.4 Eddy flux data

<table>
<thead>
<tr>
<th>Type</th>
<th>CA</th>
<th>CM</th>
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</thead>
<tbody>
<tr>
<td>Forest</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Grassland</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Agriculture</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Wetland</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Distribution of EC tower in China**

- **TECT**
  - Agricultural station, Hebei (Maize)
  - Agricultural station, Gansu (highland barley)
  - Managed Korean pine Forest Station, Helongjiang
  - Wetland station, Liaoning (Paddy rice, phragmites communis)
  - Agricultural station (Maize), Liaoning
  - Agricultural station (Paddy rice), Anhui

- **Boreal Forest Station, Helongjiang**

- **DESERT STEPPE STATION, XINJIANG**

- **AGRICULTURAL STATION, BEIJING**

**Examples:**
- **Agricultural station, Liaoning**
- **Wetland station, Liaoning**
- **Agricultural station (Maize), Liaoning**
- **Agricultural station (Paddy rice), Anhui**

**Typical steppe, Inn Mongolia (Stipa krylovii)**
2. What we have done in evaluating carbon budget

2.1 FID-based NPP model

2.2 Terrestrial ecosystem dynamic model
### 2.1 FID-based NPP model

B = aV \ (Brown \ & \ Lugo, \ 1984) \ or \ B = aV + b \ (Fang \ et \ al., \ 1996)

\[ B = \frac{V}{1.2728 + 0.0011V} \]
\[ R^2 = 0.92, n = 17 \]

\[ B = \frac{V}{0.9365 + 0.0018V} \]
\[ R^2 = 0.96, n = 17 \]

\[ NPP = \frac{B}{0.2017A + 0.0224B} \]
\[ R^2 = 0.64, n = 17 \]

\[ NPP = \frac{B}{0.1747A + 0.0662B} \]
\[ R^2 = 0.51, n = 17 \]
Regarding the difference between natural and planting *larix* forest

$y = 0.91x + 0.67, \ R^2 = 0.82$

Disregarding the difference between natural and planting *larix* forest

$y = 0.70x + 2.34, \ R^2 = 0.65$
Application of FID-based model in forest of China

\[ B = \frac{V}{a + bV} \]

(\( B \) and \( V \) are biomass(Mg/ha) and volume(m³/ha), \( a, b \) are constants)

<table>
<thead>
<tr>
<th>Type of forest stands</th>
<th>Parameters in Eq.2</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>( a )</td>
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<tr>
<td><em>Cunninghamia Lanceolata</em></td>
<td>0.808</td>
</tr>
<tr>
<td><em>Pinus Massoniana, Pyunamensis</em></td>
<td>1.428</td>
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<tr>
<td><em>Larix spp.</em></td>
<td>0.94</td>
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<tr>
<td><em>Picea, Abies</em></td>
<td>0.56</td>
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<tr>
<td><em>P.tabulaeformis</em></td>
<td>0.32</td>
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<tr>
<td><em>P.armandii</em></td>
<td>0.542</td>
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<tr>
<td>Other pines and conifer forests</td>
<td>1.393</td>
</tr>
<tr>
<td><em>Cypress</em></td>
<td>1.125</td>
</tr>
<tr>
<td>Mixed conifer and deciduous forests</td>
<td>2.558</td>
</tr>
<tr>
<td><em>Populus</em></td>
<td>0.587</td>
</tr>
<tr>
<td><em>Betula</em></td>
<td>0.975</td>
</tr>
<tr>
<td><em>Quercus</em></td>
<td>0.824</td>
</tr>
<tr>
<td><em>Cinnamomum, Phoebe</em></td>
<td>0.76</td>
</tr>
<tr>
<td><em>Casuarina</em></td>
<td>0.807</td>
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<tr>
<td><em>Sassafras</em></td>
<td>0.727</td>
</tr>
<tr>
<td><em>Eucalyptus</em> and mixed broad-leaf forests</td>
<td>0.98</td>
</tr>
<tr>
<td>Nonmerchantable woods</td>
<td>0.98</td>
</tr>
</tbody>
</table>
### Terrestrial Ecosystem Dynamic Model (TEDM)

#### Atmosphere (Land surface model of GCMs)
- Water, heat, and CO₂ exchanges

#### Vegetation
- Multi-scale NEP model based on photosynthetic mechanism
- Photosynthetic allocation (based on BIOME-BGC)
- Human activities (based on CENTURY)
- Water and heat exchanges

#### Soil (based on GCMs)
- Validation

#### Past climate and Past vegetation
- Experiments of simulating water stress on representative plant species in northern China

#### Long-term ecosystem research observation
- Changbai Forest Station
- Changling Meadow Station
- Inner Mongolia grassland station

#### Carbon balance

#### Ecosystem services

#### Evaluating the effects

#### Adapting and mitigating strategy

**Application**
- Scaling up
- Feedback
- GCM
- PFTs
ATMOSPHERE
(prescribed atmospheric datasets)

Weather Generator (sub daily) or Hourly Meteorological Data

Land Surface Module
Canopy Physics: energy & water balance, aerodynamics
Soil Physics: energy and water balance
Plant Physiology: photos. & leaf respiration, stomatal conductance
leaf nitrogen content

GPP, foliage respiration
Vegetation structure & biomass

Aboveground Carbon Cycling
Biomass Production: GPP, total respiration, NPP

Belowground Carbon & Nitrogen Cycling Module
Carbon cycling: decomposition of litter & soil organic matter, soil respiration
Nitrogen cycling: nitrogen mineralization, deposition, fixation, fertilizer, plant uptake, leaching

Vegetation Phenology Module: budburst & senescence

Daily LAI

temperature, photosynthesis

Vegetation Phenology Module: budburst & senescence

Land Surface Module

t ~ minutes to hours

Vegetation Dynamics Module

t ~ days to weeks

t ~ years
Effects of soil nutrient (Sc, Sn, g/m²) on An

Biochemical model: \( \text{An} = \min\{W_c, W_j, W_p\} - \text{Rd} = f(C_i, T_l, \text{PPFD}) \)

\[
W_c = \frac{V_{c_{\text{max}}}(C_i - \Gamma)}{C_i + K_c(1 + O/K_o)}; \quad W_j = \frac{J(C_i - \Gamma)}{4.5(C_i + 2.33\Gamma)}; \quad W_p = \frac{V_{c_{\text{max}}}}{2}
\]

\[V_{c_{\text{max}}} = V_{c_{\text{max}15}} \cdot \exp\left\{ 3000 \cdot \left[ \frac{1}{288 \cdot 1.16} - \frac{1}{T_r + 273 \cdot 1.16} \right]\right\} \]

\[V_{c_{\text{max}15}} = \frac{(A_{\text{max}} + \text{Rd}[C_i + K_c \cdot (1 + O/K_o)])}{C_i - \Gamma} \]

\[A_{\text{max}} = \frac{190 \cdot N}{360 + N} \quad N = N_T \cdot \frac{1}{I_0} \]

\[N_T = \frac{\exp[u_1 - u_3(0.00831T_r)]}{1 + \exp[(u_2 \cdot T_r - 205.9)/(0.00831T_r)]} \cdot K_T(T_r) \]

\[\mu \pm S_c \begin{cases} > 13000 & g / m^2 \text{ ÇÔ } T_r < 288 \cdot 1.16 \quad K \hat{=} \pm \hat{=} \hat{=} \\ = \{1 + [15 - (T_r - 273 \cdot 1.16)] / 30\} \cdot (1 + S_r - 13000 / 10000) \end{cases} \]

\[K_T(T_r) = 1 \]

\[u_1 = 40.8 + 0.01 \cdot (T_r - 273 \cdot 1.16) - 0.002 (T_r - 273 \cdot 1.16)^2 \]

\[u_2 = 0.738 - 0.002 (T_r - 273 \cdot 1.16) \]

\[u_3 = 97.412 - 2.504 \ln(N_p) \]

\[N_p = 120 \cdot \min\{Sn / 600, 1\} \cdot \exp(-8 \cdot 10^{-5} \cdot Sc) \]
Without soil nutrient effect

With soil nutrient effect

\[ y = 1.1082x - 9.0204 \]

\[ R^2 = 0.7254 \]
Scaling from leaf to canopy

Environment

Surface

Leaf

Boundary Layer

Radiation

Stomate

Net photosynthesis

Simulated net primary productivity rate

$y = 0.9753x$

$R^2 = 0.5234$

$\frac{\% g}{m^2} = \frac{\% g}{m^2}$

Simulated net primary productivity rate

Gc = (LAI_sunny/LAI) $\times$ gs(PAR_sunny) + (LAI_shady/LAI) $\times$ gs(PAR_shady)

$R = 0.568$ (n=14)
3. What the situation of carbon budget is: uncertainty

F: Changbai Forest Ecosystem Research Station
M: Changling Grassland Station
T: Inner Mongolia Grassland Ecosystem Research Station
P: precipitation (cm)
NPP: 10gC m⁻² yr⁻¹
SC: total soil carbon (10gC m⁻²)

CENTURY model
Parameters
FILE100
EVENT100
Climate data

Grassland
Forest
Grassland/Forest

File
EVENT100
Climate data

Grassland
Forest
Grassland/Forest

Mean monthly P
Monthly Min. T
Monthly Max. T

Grazing
TREM
OMAD
FIRE
SITE
FIX
GRAZ
CROP

Mixed coniferous-broadleaved forest
Meadow steppe ecosystem
Typical steppe ecosystem

Annual NEP: 4.03tC/hm² a⁻¹
Annual soil emission: 1.91tC/hm² a⁻¹
Carbon budget: 2.12tC/hm² a⁻¹

Boreal Forest is a carbon sink
Case study — Carbon budget of the *Stipa Grandis* steppe (estimating area: 400m × 400m) in Inner Mongolia

### Carbon Flow and Storage

- **Atmosphere**: 24.9tC
- **Soil organ carbon**: 820.4tC
- **Plant**: 45.8tC
  - From A-biomass: 2.9tC/a
  - From B-biomass: 7.2tC/a
- **Litter**: 10.1tC/a
- **Soil and Litter respiration**: 14.1tC/a
- **Above-biomass**: 7.4tC
- **Below-biomass**: 38.4tC
- **Carbon sink**: 13.0tC/a or 81.2gC/m²•a
NEE of Typical steppe ecosystem in Inner Mongolia by TEDM model

- NEE = 0.175, CENTURY model
- NEE = 0.114, Mean, TEDM
- NEE = 0.081, Observed estimation
- NEE = 0.077, Flux observation
4. What is essential to Chinese carbon study

- How to obtain properly carbon flux? E.g. sampling time, data calibration, and EC in mountain region
- How to evaluate regional carbon flux by EC? IGBP-transects, remote sensing method
- Data fusion: how to integrate different carbon data?
- How to mitigate carbon emission and enhance carbon sequestration? Wind energy, bio-fuel

Thanks!