Increasing cropland soil carbon sequestration, China is in action

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In this talk

- Agricultural production and challenge
- Carbon stock of Chinese cropland
- Action: Application of organic material
- Action: Land use rights transfer
China provides food and meat for 1/5 of the world population
Grain yield increased 122% since 1980. Rice, wheat, and maize increased 49%, 136% and 259%, respectively. It continuously increased in recent 12 years. Meat, milk and egg production have increased 88%, 426% and 53% from 1996 to 2015.
Agricultural production

Composition of GDP

Composition of agricultural

Agriculture: ¥6.55 Trillion in 2018, account for 7.92%

Source: China statistic yearbook 2018
Climate change

Most vulnerable agriculture !!!

Higher temperature

Decreased precipitation

Source: Third National Climate Change Assessment Report, 2017
Challenge

- Limited arable land
- Unbalanced water resources
- High input for food security
- High GHG emission, pollution
- Climate change
- Negative impacts on food security
- Low input, high productivity
- Affordable and applicable tech
## SOC stock in Chinese cropland

<table>
<thead>
<tr>
<th>Method</th>
<th>Target year</th>
<th>Area (Mha)</th>
<th>Soil depth (cm)</th>
<th>SOC change rate (Tg C a⁻¹)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNDC model</td>
<td>1990</td>
<td>130</td>
<td>30</td>
<td>-95</td>
<td>Li et al., 2003</td>
</tr>
<tr>
<td>DNDC model</td>
<td>1998</td>
<td>96.8</td>
<td>30</td>
<td>-78.89</td>
<td>Tang et al., 2006</td>
</tr>
<tr>
<td>Meta analysis</td>
<td>1980~2000</td>
<td>118</td>
<td>20</td>
<td>15.6~20.1</td>
<td>Huang et al., 2006</td>
</tr>
<tr>
<td>Meta analysis</td>
<td>1980s~2000s</td>
<td>155.76</td>
<td>Soil profile</td>
<td>23.61</td>
<td>Xie et al., 2007</td>
</tr>
<tr>
<td>Meta analysis</td>
<td>1980~2000</td>
<td>130</td>
<td>30</td>
<td>21.9 (16.6~27.8)</td>
<td>Sun et al., 2010</td>
</tr>
<tr>
<td>Meta analysis</td>
<td>1985~2007</td>
<td>138.7</td>
<td>20</td>
<td>25.5</td>
<td>Pan et al., 2010</td>
</tr>
<tr>
<td>National soil census</td>
<td>1980~2007</td>
<td>130</td>
<td>20</td>
<td>9.6</td>
<td>Yan et al., 2011</td>
</tr>
<tr>
<td>Agro-C model</td>
<td>1980~2009</td>
<td>130</td>
<td>30</td>
<td>24.3 (11~36.5)</td>
<td>Yu et al., 2012</td>
</tr>
<tr>
<td>DNDC + Century</td>
<td>1980~2008</td>
<td>130</td>
<td>20</td>
<td>17.8</td>
<td>Zhao et al., 2015</td>
</tr>
</tbody>
</table>

**SOC change rate (1980 ~ 2010): -78.89 ~ 36.5 Tg C a⁻¹**
### SOC stock in Chinese cropland

<table>
<thead>
<tr>
<th>Method</th>
<th>Process</th>
<th>Area (Mha)</th>
<th>Soil depth (cm)</th>
<th>Carbon sequestration potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deduced from long-term field monitor</td>
<td>Statistical model + scenarios of fertilization, straw residue return and no till (Qin et al., 2013)</td>
<td>60.7</td>
<td>-</td>
<td>5.96~34.4 Tg a⁻¹</td>
</tr>
<tr>
<td></td>
<td>Saturation level statistical model (Sun et al., 2010)</td>
<td>140</td>
<td>30</td>
<td>2.7 Pg</td>
</tr>
<tr>
<td>Empirical formulation</td>
<td>Empirical model + NPP acceleration/straw return/scenarios of no till (Yu et al., 2018)</td>
<td>130</td>
<td>30</td>
<td>2<del>2.5 Pg (2000</del>2005)</td>
</tr>
<tr>
<td>Process based ecological models</td>
<td>Agro-C + yield/straw return/scenarios of no till (Yu et al., 2013)</td>
<td>130</td>
<td>30</td>
<td>20.3~88.4 Tg a⁻¹ (~2050)</td>
</tr>
<tr>
<td></td>
<td>Century + DNDC + no till/straw return/scenarios of organic manure (Zhao et al., 2015)</td>
<td>130</td>
<td>30</td>
<td>0.12<del>0.71 Pg (2009</del>2028)</td>
</tr>
</tbody>
</table>
National policies & action plans

- **State Council**

- **Ministry of Agriculture and Rural Affairs**
  - 2015, launched the Non-profit project “crop and straw returning to the field”
  - 2019, “Expanding demonstration of organic fertilizer to replace fertilizer”
  - 2019, “Accelerate the resource utilization of livestock and poultry breeding waste”
  - 2019, “Accelerate the green development of agriculture and rural areas”

- **NDRC, MOF, MARA & MOEE**
  - 2015, “Further accelerate the comprehensive utilization of crop straws and the ban on burning”
Straw return rate of stable food crop of China in the recent 30 years

Actions: straw residue return return
**Actions: straw residue return**

- **Household survey 2016~2017**
- More than 71% of crop straw was returned to field in different forms
- Among them, mechanical turned down is the most popular one, followed by crush return

(Qin et al., 2018, unpublished)
Actions: organic fertilizer

- to quantify change in **SOC stocks** under various fertilizer treatments and **straw return**, in different climatic zones, soil types, and land uses

- to identify **strategies** for enhancing C sequestration to mitigate climate change and ensure food security

- 33 long-term fertilization experiment (>20 years)
CF, OF, CFOF, and SR significantly enhanced SOC concentration by 27, 66, 47, and 26% (p < 0.05), respectively.

OF, CFOF, and SR significantly decreased soil bulk density by 11, 5, and 9% (p < 0.05), respectively.
Actions: organic fertilizer

- Effect of long-term organic fertilization on SOC stock
- The IPCC default factors often overestimated the SOC gain in the cool temperate zone with moist climate and underestimated the soil C gain in other zones
Black soils had the highest initial SOC stock in cropland soils.

Significant effects ($p < 0.01$) of initial SOC stocks were observed on the response ratio of SOC stocks under different fertilization regimes.

Using the linear relationship between the SOC stock response ratio and initial SOC content based on data from long-term organic fertilization (OF and CFOF) experiments, we extrapolated the maximum SOC retention in the top 30 cm of cropland soils in China to be 35.9 Mg C ha$^{-1}$ for upland soils under dry climate, 60.5 Mg C ha$^{-1}$ for upland soils under moist climate and 74.3 Mg C ha$^{-1}$ for paddy soils under moist climate.
Long-term fertilization experiment

Wangcheng, Hunan province, 36-year long-term fertilization
- No fertilization: -3.12%
- NPK + STRAW: +20.33%
Guide the **orderly transfer** of rural land contractual management **rights**, encourage and support the **transfer of contracted land to large professional households, family farms, farmer cooperatives**, and develop various forms of moderate scale management.
Actions: Land use rights transfer

- Life cycle assessment – farm survey
- GHG
- SOC
- Carbon footprints
- Input use efficiency
- Grain production

Large-scale farming operations are win-win for grain production, soil carbon storage and mitigation of greenhouse gases

Yongchang Zhu, Muhammad Ahmed Waqas, Yu'ee Li, Xiaoxia Zou, Defeng Jiang, Andreas Wilkes, Xiaobo Qin, Qingzhu Gao, Yunfan Wan, Gajjtraj Hasbagan

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- Shandong province, major grain producing area of north China
- Wheat-maze and wheat-rice
## Actions: Land use rights transfer

<table>
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<tr>
<th>Item</th>
<th>Abbreviation</th>
<th>Emission factor</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter wheat seed</td>
<td>EF$_{\text{winter wheat seed}}$</td>
<td>0.40 kg CO$_2$ e kg$^{-1}$</td>
<td>West and Marland, 2002</td>
</tr>
<tr>
<td>Maize seed</td>
<td>EF$_{\text{maize seed}}$</td>
<td>3.85 kg CO$_2$ e kg$^{-1}$</td>
<td>West and Marland, 2002</td>
</tr>
<tr>
<td>Rice seed</td>
<td>EF$_{\text{rice seed}}$</td>
<td>1.99 kg CO$_2$ e kg$^{-1}$</td>
<td>This study$^a$</td>
</tr>
<tr>
<td>N fertilizer</td>
<td>EF$_N$ fertilizer</td>
<td>8.30 kg CO$_2$ e kg$^{-1}$</td>
<td>Zhang et al., 2013</td>
</tr>
<tr>
<td>P fertilizer</td>
<td>EF$_P$ fertilizer</td>
<td>0.61 kg CO$_2$ e kg$^{-1}$</td>
<td>West and Marland, 2002</td>
</tr>
<tr>
<td>K fertilizer</td>
<td>EF$_K$ fertilizer</td>
<td>0.44 kg CO$_2$ e kg$^{-1}$</td>
<td>West and Marland, 2002</td>
</tr>
<tr>
<td>Herbicide</td>
<td>EF$_{\text{herbicide}}$</td>
<td>17.24 kg CO$_2$ e kg$^{-1}$</td>
<td>West and Marland, 2002</td>
</tr>
<tr>
<td>Pesticide</td>
<td>EF$_{\text{pesticide}}$</td>
<td>18.08 kg CO$_2$ e kg$^{-1}$</td>
<td>West and Marland, 2002</td>
</tr>
<tr>
<td>Fungicide</td>
<td>EF$_{\text{fungicide}}$</td>
<td>18.98 kg CO$_2$ e kg$^{-1}$</td>
<td>West and Marland, 2002</td>
</tr>
<tr>
<td>Diesel oil</td>
<td>EF$_{\text{diesel oil}}$</td>
<td>3.10 kg CO$_2$ e kg$^{-1}$</td>
<td>NDRC, 2011</td>
</tr>
<tr>
<td>Electricity</td>
<td>EF$_{\text{electricity}}$</td>
<td>0.80 kg CO$_2$ e kW h$^{-1}$</td>
<td>NDRC, 2011</td>
</tr>
<tr>
<td>Direct N$_2$O emission from N fertilizer on upland crops</td>
<td>EF$_1$</td>
<td>0.01 kg N$_2$O-N kg$^{-1}$ N</td>
<td>IPCC, 2006</td>
</tr>
<tr>
<td>Direct N$_2$O emission from N fertilizer on flooded rice</td>
<td>EF$_{1FR}$</td>
<td>0.003 kg N$_2$O-N kg$^{-1}$ N</td>
<td>IPCC, 2006</td>
</tr>
<tr>
<td>Indirect N$_2$O emission from synthetic N fertilizer volatilization</td>
<td>EF$_{2S\text{N}}$</td>
<td>0.01 kg N$_2$O-N kg$^{-1}$ N</td>
<td>IPCC, 2006</td>
</tr>
<tr>
<td>Indirect N$_2$O emission from N content volatilization of organic fertilizer</td>
<td>EF$_{2O\text{N}}$</td>
<td>0.01 kg N$_2$O-N kg$^{-1}$ N</td>
<td>IPCC, 2006</td>
</tr>
<tr>
<td>Indirect N$_2$O emission from N fertilizer leaching</td>
<td>EF$_3$</td>
<td>0.0075 kg N$_2$O-N kg$^{-1}$ N</td>
<td>IPCC, 2006</td>
</tr>
<tr>
<td>CH$_4$ emission from rice paddy</td>
<td>EF$_4$</td>
<td>215.5 kg CH$_4$ ha$^{-1}$</td>
<td>NDRC, 2011</td>
</tr>
<tr>
<td>Changes in soil organic carbon stocks</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Combined chemical and organic fertilizer</td>
<td></td>
<td></td>
<td>Li et al., 2017</td>
</tr>
<tr>
<td>Straw incorporation</td>
<td></td>
<td></td>
<td>Li et al., 2017</td>
</tr>
<tr>
<td>Application of chemical fertilizer</td>
<td></td>
<td></td>
<td>Li et al., 2017</td>
</tr>
<tr>
<td>Application of organic fertilizer</td>
<td></td>
<td>667 kg C ha$^{-1}$year$^{-1}$</td>
<td>Li et al., 2017</td>
</tr>
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<td></td>
<td></td>
<td>440 kg C ha$^{-1}$year$^{-1}$</td>
<td>Li et al., 2017</td>
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<td></td>
<td></td>
<td>136 kg C ha$^{-1}$year$^{-1}$</td>
<td>Li et al., 2017</td>
</tr>
<tr>
<td></td>
<td></td>
<td>483 kg C ha$^{-1}$year$^{-1}$</td>
<td>Li et al., 2017</td>
</tr>
</tbody>
</table>

**GHG emission and SOC stock change factors**
Actions: Land use rights transfer

Input efficiency increase percentage

LSFO

SOC
Actions: Land use rights transfer

(a) SHFO
(b) SHFO
(c) SHFO
(d) SHFO

Farm type

CF interm of area (kg CO₂-eq ha⁻¹)

LSFO

LSFO

LSFO
Actions: Land use rights transfer

- Organic fertilizer & straw incorporation: 16~28%
- Grain yield: 1~6%
- SOC stock: 6~9% (531~603 kg C ha\(^{-1}\) a\(^{-1}\))
- N input: 7~25%
- Pesticides, herbicides, fungicides: 25~53%
- Carbon footprints: 7~21%
In conclusion

- China is actively promoting the utilization of farmland waste resources and strengthening the research and promotion of soil carbon increase measures.
- Long-term (≥20 years) application of fertilizers and straw return enhances soil carbon storage.
- Large-scale farming operations are win-win for grain production, soil carbon storage and mitigation of greenhouse gases.
Thanks!