Effects, Present Problems and Countermeasures of Conservation Tillage in the Loess Plateau of China

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OUTLINE

- Background of the Loess Plateau of China
- Integrated effects of conservation tillage in the Loess Plateau of China
- Present problems in the development of conservation tillage in the Loess Plateau of China
- Countermeasures and proposals in the development of conservation tillage in the Loess Plateau of China
Background

Soil erosion and limited water available are two major constraints.
A typical hilly and gully area of the Loess Plateau
Background

- **Erodible topsoil and severe soil erosion**
  - Annual erosion soil add up to 2.1 billion ton
  - Erosion area reach to $3.4 \times 10^5 \text{km}^2$
  - Erosion intensity even over 20000t/km²·a

- **Poor vegetation**
  - Forest cover rate only 6.5%
  - Vegetation cover rate of grassland 25%~65%
  - Grassland with medium and the worst degradation make up to 68.8%
Background

- Lack of water resource
  - Water resource 440m³ per capita and 2800m³/ha
- High rainfall variability
- Mono-agricultural structure and poor management
- Low and unstable yield
- Low income of farmers
Previous research

- 1960s, mainly focused on gravel mulch
- 1970s, started minimum tillage
- 1980s, focused on plastic and straw mulch
- 1990s, combined minimum tillage with straw mulch
- 2001, conducted conservation tillage
Background

- Many reports have shown that conservation tillage positively affects soil quality and crop yield.
- However, contradictory results were also reported:
  - Lower temperature may slow germination of crop.
  - Increased weeds, insect and rodent pest.
  - Reduce yield in early stage.
Therefore, The Australian Centre for International Agricultural Research (ACIAR) project “improving the productivity and sustainability of rain-fed farming systems for the western Loess Plateau of Gansu province” has been implemented in Dingxi, Gansu since 2001.

The aim of the research is to identify a suitable conservation agriculture practice for the western loess plateau.
The details of the treatments designed in the long-term conservation tillage experiment in Dingxi, Gansu

<table>
<thead>
<tr>
<th>Code</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Conventional tillage with no straw</td>
</tr>
<tr>
<td>TS</td>
<td>Conventional tillage with straw incorporated</td>
</tr>
<tr>
<td>NT</td>
<td>No-till with no straw cover</td>
</tr>
<tr>
<td>NTS</td>
<td>No-till with straw cover</td>
</tr>
<tr>
<td>TP</td>
<td>Conventional tillage with plastic mulch</td>
</tr>
<tr>
<td>NTP</td>
<td>No-till with plastic mulch</td>
</tr>
</tbody>
</table>
Impacts of different tillage and stubble management on grain yield _ Spring wheat
Impacts of different tillage and stubble management on grain yield _ Field pea
Summary

**Grain yield**

- Overall, NTS produced the highest average yield for both wheat and field peas over five seasons.
- Although both plastic mulch treatments had similar yields as NTS for spring wheat, these two treatments are unsustainable.
- Grain yield from no-till without straw was unsatisfactory.
Soil moisture dynamics

DXCT_Soil water_0-200cm_wheat-pea

Soil moisture dynamics

Soil water (mm)

Rainfall (mm)

Fallow Wheat Fallow Pea

DUL:554
CLL_P: 235
CLL_W: 179
Soil moisture dynamics

**DXCT_Soil water_0-200cm_pea-wheat**

- **Soil water (mm)**
- **Rainfall (mm)**

- T
- TS
- NT
- NTS
- TP
- NTP
- Rain

- Fallo
- Pea
- Fallow
- Wheat

*Legend for events:
- Fallo: Fallow
- Pea: Pea
- Wheat: Wheat*
Soil water at sowing (wheat)
Soil water at sowing (pea)
Summary

- **Soil water**
  - Seasonal variation was large and treatment differences were small
  - NTS treatment had more water available to crops probably due to greater infiltration and less evaporation
  - Soil moisture profiles never being filled up during the past 5 years
Water stable macro-aggregation
measured in Aug, 2003 after harvest

0-5cm

5-10cm
Soil bulk density measured in Mar. 2004, before sowing
## TOC and $C_{WB10}$ - modified Walky-Black using 12N $H_2SO_4$

<table>
<thead>
<tr>
<th>treatment</th>
<th>TOC g kg$^{-1}$</th>
<th>$C_{WB10}$ g kg$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-5cm</td>
<td>5-10cm</td>
</tr>
<tr>
<td><strong>W/P</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>8.30C (100)</td>
<td>7.91B (100)</td>
</tr>
<tr>
<td>NTS</td>
<td>9.86A (119)</td>
<td>8.98A (114)</td>
</tr>
<tr>
<td>NT</td>
<td>8.83BC (109)</td>
<td>8.27B (104)</td>
</tr>
<tr>
<td>TS</td>
<td>9.04B (106)</td>
<td>8.93A (113)</td>
</tr>
<tr>
<td><strong>P/W</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>8.64A (100)</td>
<td>8.46A (100)</td>
</tr>
<tr>
<td>NTS</td>
<td>9.00A (104)</td>
<td>8.73A (103)</td>
</tr>
<tr>
<td>NT</td>
<td>8.58A (99)</td>
<td>8.44A (100)</td>
</tr>
<tr>
<td>TS</td>
<td>8.91A (103)</td>
<td>8.58A (101)</td>
</tr>
</tbody>
</table>
Saturated hydraulic conductivity measured in Mar. 2004, using disc permeameter
Summary

- Soil quality
  - NTS increased soil organic carbon and had greater proportion of water stable macro-aggregation
  - This indicates that the soil structure became more stable in NTS
Summary

- Soil quality
  - Saturated hydraulic conductivity on NTS was significantly higher than other treatments in both phases
  - This confirmed that NTS had the greatest infiltration rate
Effects of conservation tillage on Soil Antierodibility

Rainfall intensity is 85 mm/hr

- No Cover
- 60% Cover
- 100% Cover

Runoff Rate (mm/hr) vs. Time (s)
## Effects of conservation tillage on Soil Antierodibility

<table>
<thead>
<tr>
<th>Rotation Sequence</th>
<th>Treatment</th>
<th>Ponding start time(min)</th>
<th>Runoff start time(min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P→W→P→W→P</td>
<td>NT</td>
<td>7.33b</td>
<td>8.04c</td>
</tr>
<tr>
<td></td>
<td>NTS</td>
<td>8.75a</td>
<td>9.21a</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>5.30c</td>
<td>5.38d</td>
</tr>
<tr>
<td></td>
<td>TS</td>
<td>7.79b</td>
<td>8.38b</td>
</tr>
<tr>
<td>W→P→W→P→W</td>
<td>NT</td>
<td>6.84b</td>
<td>7.5ab</td>
</tr>
<tr>
<td></td>
<td>NTS</td>
<td>8.67a</td>
<td>9.17a</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>6.12b</td>
<td>7.01b</td>
</tr>
<tr>
<td></td>
<td>TS</td>
<td>7.13b</td>
<td>7.79ab</td>
</tr>
</tbody>
</table>
## Effects of conservation tillage on Soil Antierodibility

<table>
<thead>
<tr>
<th>Rotation Sequence</th>
<th>Treatment</th>
<th>Sum Runoff (mm)</th>
<th>Sum infiltration (mm)</th>
<th>Sum erosion (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P→W→P→P→W→P</td>
<td>NT</td>
<td>45.89b</td>
<td>39.11a</td>
<td>28.02b</td>
</tr>
<tr>
<td></td>
<td>NTS</td>
<td>44.78b</td>
<td>40.22a</td>
<td>26.57b</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>60.32a</td>
<td>24.68b</td>
<td>70.8a</td>
</tr>
<tr>
<td></td>
<td>TS</td>
<td>50.23b</td>
<td>34.77a</td>
<td>32.11b</td>
</tr>
<tr>
<td></td>
<td>NT</td>
<td>62.90a</td>
<td>22.10b</td>
<td>32.73a</td>
</tr>
<tr>
<td>W→P→W→P→W→W</td>
<td>NTS</td>
<td>44.85c</td>
<td>40.15a</td>
<td>14.89c</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>53.10b</td>
<td>31.90b</td>
<td>27.77ab</td>
</tr>
<tr>
<td></td>
<td>TS</td>
<td>66.26a</td>
<td>18.74c</td>
<td>23.79b</td>
</tr>
</tbody>
</table>
Summary

✓ slow down runoff start time by 2.16~3.83min
✓ reduce runoff by 18.4%~34.7%
✓ increase infiltration by 20.5%~38.6%
✓ reduce soil erosion by 86.5%~166%
## Effects of conservation tillage on economic benefit

<table>
<thead>
<tr>
<th>Crop</th>
<th>Target variable</th>
<th>Treatment¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>T</td>
</tr>
<tr>
<td><strong>Spring wheat</strong></td>
<td>output (¥/hm²)</td>
<td>2912</td>
</tr>
<tr>
<td></td>
<td>input (¥/hm²)</td>
<td>2360</td>
</tr>
<tr>
<td></td>
<td>ratio of output and input</td>
<td>1.234</td>
</tr>
<tr>
<td></td>
<td>Net return (¥/hm²)</td>
<td>552</td>
</tr>
<tr>
<td></td>
<td>Economic profit rate (%)</td>
<td>23.4</td>
</tr>
<tr>
<td><strong>Field pea</strong></td>
<td>output (¥/hm²)</td>
<td>2519</td>
</tr>
<tr>
<td></td>
<td>input (¥/hm²)</td>
<td>2179</td>
</tr>
<tr>
<td></td>
<td>ratio of output and input</td>
<td>1.156</td>
</tr>
<tr>
<td></td>
<td>Net return (¥/hm²)</td>
<td>340</td>
</tr>
<tr>
<td></td>
<td>Economic profit rate (%)</td>
<td>15.6</td>
</tr>
</tbody>
</table>
Summary

- Improve the ratio of output and input by 39.47%
- increase net return by 900 ¥/hm²
Harmonious management of organism mulching and stubble covering on bare field in an area supposed to be poor in straw

- Lower temperature of covered soil slow germination
- Stubble allelochemicals inhibit weeds as well as crops
- Increase perennial weeds, diseases, insect and pest
- Not conducive to manure application
Development in combining legume-cereal-potato crop rotations with zero tillage and stubble retention

- Potato stubble is too less to meet requirements of conservation tillage that maintains at least 30% crop residue on the soil surface.
- Soil environment of no-till is unfavorable to potato growth.
Improvement of mechanization and semi-mechanization technologies to match with sloping land

It is difficult to adopt large conservation tillage machine in the loess plateau, because:

- sloping farmland with a degree above 5 in western Loess Plateau account for 80% of total farmland
- Farmland is dominated by a number of small-scale productions and decentralized management of households in western Loess Plateau
Small and Medium-sized equipments for zone tillage need to be developed

- Not only to achieve five functions at one operation, including
  - Opening a furrow
  - No-till planting
  - Fertilizing
  - Covering soil
  - Pressing

- But also to accommodate other farm system issues, such as
  - Breaking up compacted layers
  - Fertilizing and seeding separately
  - Preventing the residue from blocking
  - Profile modeling for sloping land
  - Incorporation of animal manures
Ingrained traditional ideas of farmers

- Certain perennial weeds and certain diseases can become problematic
- Crop residues on the soil surface were considered a barrier to good seed germination
- Regardless of eco-environment, tillage systems need to be selected that will contribute to sustain farm profitability
Acquiring aid in the form of policies and capital from government

Policies:

- Work out feasible plans, and form a popularization system
- Teach theories and experiences to farmers by technical training
- Organize agricultural extension events
- Provides the necessary guidance
Acquiring aid in the form of policies and capital from government

**Capital:**

- Earmark large amounts of funds to research and develop supporting agricultural machinery
- Implement policy of fiscal subsidies, to encourage farmers to apply conservation tillage
Developing conservation tillage into conservation agriculture by system designing

- Altering tillage practices is only part of soil conservation management. Erosion can also be reduced by changing cropping systems.
- For example, including forage crops in rotations reduces tillage requirements and also contributes to rebuilding soil structure and organic matter levels.
Speeding the progress of research and development of supporting agricultural machinery

- Large machine practiced by large-scale, commercial farmers worldwide is not suitable for small-scale and decentralized household.

- Scientific research personnel create appropriate set of machinery easily operated with high efficiency, satisfying the diverse requirements of sloping land.
Intensifying publicity and training for farmers

Setups for popularizing agricultural techniques and units of agricultural scientific research should popularize conservation tillage technology by conducting several activities.

- Open days
- Technical training
- Theme exhibitions
- On-farm research
- Hand out leaflets
- Return visit
Establishing conservation tillage technology demonstration zones

- These zones play their role in demonstration projects and driving force

- So as to bring along and promote the development of other areas, inducing the close combination and coordinated development of ecological improvement, economic construction and social development.
Thank You