Soil Water Depletion and Soil Erosion In the Coarse Soil Region of the Loess Plateau

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outlines

- Background
- Results
- Conclusion
- Future plans
Location of the Loess Plateau

640,000 km²

BeiJing

Yangling
China initiated its "Grain for Green" program in 1999 as a large conservation program designed to prevent soil erosion. It is an example of payment for ecosystem services.

Does soil erosion reduce by the program? What happened on slope land?
"Grain to Green" program

- Food shortage in some area
- Plant growth limited by soil water content because of high ET of introduced vegetation
- Water resource problem - Yellow River

Nature geoscience (2015) doi:10.1038/NGEO2602

\[ NPP = 383-528 \text{ g C m}^{-2} \text{ yr}^{-1} \]

Nature Climate Change (2016) doi:10.1038/nclimate3092

- Groundwater shortage?
Field observation

Shenmu

Yangling

Xian
Liudaogou watershed

<table>
<thead>
<tr>
<th>Land use type</th>
<th>%</th>
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<tbody>
<tr>
<td>Grass land</td>
<td>56%</td>
</tr>
<tr>
<td>Shurbland</td>
<td>22%</td>
</tr>
<tr>
<td>forest</td>
<td>5%</td>
</tr>
<tr>
<td>farm land</td>
<td>6%</td>
</tr>
<tr>
<td>others</td>
<td>11%</td>
</tr>
</tbody>
</table>
Mean Precipitation is 400 mm, mainly occurs in Jul, Aug, Sep, lead to water erosion.

High temperature during rainfall seasons, but wind erosion in winter and spring with heavy wind speed.
Field experiments

- Slope runoff plots: 15*4m, 15° three treatments: farmland, alfalfa and abandoned land.

- Terraced plots: 20*10m, five plots: bareland, farmland, alfalfa, shrubland (Caragana) and abandoned land.
Artificial rainfall test

Rainfall intensity: 20mm/h, 40mm/h, 60mm/h

Rainfall events: 1-5 times
Greater differences were observed in October 2013 where it was clear that shrubs and grasses had used more soil water than either the food crops or the weeds in the abandoned land. Furthermore, soil water was significantly recharged in the soil profiles under bare land and farmland.
## Soil water depletion under land use types

Soil water recharge and root uptake depth from 2008 to 2013 under different land use types at Shenmu, Shaanxi, China.

<table>
<thead>
<tr>
<th>Land use</th>
<th>Maximum Recharge depth (cm)</th>
<th>Maximum water uptake depth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare land</td>
<td>below 500</td>
<td>100</td>
</tr>
<tr>
<td>Farmland</td>
<td>below 500</td>
<td>160</td>
</tr>
<tr>
<td>Forage land</td>
<td>120</td>
<td>below 600</td>
</tr>
<tr>
<td>Shrubland</td>
<td>120</td>
<td>below 600</td>
</tr>
<tr>
<td>Abandoned land</td>
<td>260</td>
<td>300</td>
</tr>
</tbody>
</table>

Soil water recharge depths extended deeper than 5 m under bare land and farmland, but introduced forage (alfalfa) and shrub (caragana) species depleted the soil water stores in the 0-6 m layers within a few years, prevented deep soil water recharge.
The soil water balances were notably different among the land use types, and the introduced forage land and shrubland exhibited higher water consumption than either the local crops or the native plants growing on the abandoned land.
Soil water in bare land

Soil water was recharged to about 5 m on average since the recharge depth was deeper than 5 m in 2010 and 2013 but was less than 3 m in the other study years. The greater recharge depth occurred in 2010 and 2013 due to the higher antecedent water contents and wet years.
Soil water in crop land

Soil water under farmland had very similar distributions in the soil profile to those in the soils under bare land, which indicated that seasonal rainfall could meet the local food crop water demands.
Soil water in alfalfa land

Distinct decreases in the soil water contents in the 1-3.5 m layer of the soil profile were evident in the second year after alfalfa was planted and the affected layer increased to a depth of 4.5 m in the third year. It is possible that root uptake of water may also have occurred from layers deeper than 6 m, which exceeded our measuring depths. The water recharging depth was generally less than 1 m, and only exceeded this depth in 2013 due to the higher rainfall (665 mm).
Soil water in shrubland

Caragana consumed deep soil water in 2010 and 2011, and the maximum uptake depth tended to increase from 2009 to 2012, exceeding 6 m. However, rainwater infiltrated to a depth of about 1.2 m during each of the 6 study years.
Soil water in abandoned land

Under the abandoned land, the water uptake and recharge depths were observed between those found under farmland and the two restored vegetation. The maximum infiltration depth was 1.6, 3.0 and 2.6 m in 2009, 2010 and 2013 respectively, but the water uptake depth was 0-1 m for five of the study years, but extended down to 3.4 m in 2011.
Soil erosion under different land use

Runoff and sediments were significantly reduced by “Grain to Green” (2007-2012 years)

Yearly runoff from farm land was 23 mm but alfalfa land only 2.3 mm, sediment was 5%.
Soil water depletion
from slope field plots

Although non-native vegetation (Alfalfa) can reduce soil erosion, these can also lead to deep soil desiccation.

Under water stress, alfalfa can extract water from deep soil layers. The top figure shows alfalfa extracting soil water down to 260 cm. But crop land has more water in soil profile, which may recharge groundwater.
Tips

✓ Vegetation restoration significantly reduced the runoff and sediments on slope scales.

✓ Soil water can be recharged deeper than 5 m under bare land and farmland, but introduced grass (alfalfa) and shrub (Caragana), species can deplete soil water within a few years (<6 years) and stop deep soil water recharge as exhibited by the negative water balances.
Runoff controlling factors

Natural rainfall results

Runoff in farmland plots

Runoff was directly affected by the rainfall amount and intensity.

How about the relationship between Antecedent soil water content (ASWC) and runoff?
Daily VWC of the soil shallow layer was simulated by HYDRUS-1D.
there were three rainfall events that generated very high runoff when the ASWCs were relatively low. The measured meteorological data showed that the rainfall intensities of these three events were greater than 24 mm h$^{-1}$ and the amounts of rainfall were greater than 54 mm.

Runoff was typically increased with increases in ASWC
Runoff was affected significantly by the ASWC of shallow soils in the artificial field rainfall tests.
The subsequent rainfall events could also have significant effects on hydrographic characteristics including time to runoff, runoff volume, soil loss, sediment concentration.
Summary

✓ Vegetation restoration significantly reduced the runoff and sediments. Because the coarse soil has high initial infiltration and Ks, soil become drier and initial infiltration get higher. ASWC is very important factor to affect runoff.

✓ If shallow ground water could only be supplied by soil water percolation, plants with high biomass (such as alfalfa and caragana) would cut this supply path by completely stopping deep soil recharge.
Future work

- Pasture short roots, low ET, runoff but low sediment
  Animal (goat, cattle) -- high quality meat
Thanks!!

The field station