Assessment of afforestation strategy with respect to hydrological effects in a semi-arid region of NW China

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Background

1. In China, afforestation in large scale

2. But restoring vegetation is a dilemma
   - Necessary to improve environment
   - Increasing worries, such as:
     Reduce water yield
     No enough water for forests

3. Limited ecological conditions
   - Big variation of precipitation
   - Strong potential of evapotranspiration
   - Water shortage
The location of research site

Diediegou small watershed:

- Liupan Mountain
- The ecotone between the semi-humid and semi-arid region
- On the north slope, semi-arid climate
Water-limited area, the annual precipitation:

- 428mm/yr
- Mainly in the summer (Jul., Aug., Sep.)
- Big variation among years, in growing season:
  2003: 666 mm; 2004:435mm; 2005:390.6mm; 2006: 465mm
The variation of rainfall intensity

Growing season of 2004

<table>
<thead>
<tr>
<th>Scale of rainfall</th>
<th>Rainfall Events</th>
<th>Accumulation of Precipitation</th>
<th>The percentage of growing season precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10 mm</td>
<td>36</td>
<td>135 mm</td>
<td>31%</td>
</tr>
<tr>
<td>10-20 mm</td>
<td>4</td>
<td>70 mm</td>
<td>16%</td>
</tr>
<tr>
<td>20-30 mm</td>
<td>2</td>
<td>48 mm</td>
<td>11%</td>
</tr>
<tr>
<td>&gt; 30 mm</td>
<td>3</td>
<td>172 mm</td>
<td>40%</td>
</tr>
<tr>
<td>sum</td>
<td>45</td>
<td>435 mm</td>
<td>100%</td>
</tr>
</tbody>
</table>
### Three research plots

<table>
<thead>
<tr>
<th>Plot</th>
<th>Vegetation</th>
<th>Slope /°</th>
<th>Slope aspect</th>
<th>Slope location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot1</td>
<td>Grassland</td>
<td>30</td>
<td>South west</td>
<td>Middle</td>
</tr>
<tr>
<td>plot2</td>
<td><em>Larix principi-rupprechtii</em> plantation</td>
<td>29</td>
<td>North west</td>
<td>Bottom</td>
</tr>
<tr>
<td>plot3</td>
<td><em>Larix principi-rupprechtii</em> plantation</td>
<td>11</td>
<td>North west</td>
<td>Bottom</td>
</tr>
</tbody>
</table>
Location of plots on the slope

North

plot1

plot2

plot3

River
Hydrological Processes:
• Interception
• ET
• Soil water moving
• Runoff
Calibration and Validation of BROOK90

- Running model on **plot scale**
- **Monitor data**: growing season of 2004, 2005 and 2006
- **Measured and simulated soil moisture** to be compared
- **8 soil layers**: 0-10cm, 10-20cm, 20-30cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm
Plot 1

Soil moisture (v%) measured vs. simulated for 10 cm, 20 cm, and 50 cm depths from 2004 to 2006.
## The list of absolute and relative errors

<table>
<thead>
<tr>
<th>Soil layer (cm)</th>
<th>Plot1 (Grassland)</th>
<th>Plot2 (Larch plantation)</th>
<th>Plot3 (Larch plantation)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>10</td>
<td>1.9</td>
<td>8</td>
<td>1.9</td>
</tr>
<tr>
<td>20</td>
<td>2.0</td>
<td>9</td>
<td>2.3</td>
</tr>
<tr>
<td>30</td>
<td>2.1</td>
<td>11</td>
<td>1.9</td>
</tr>
<tr>
<td>40</td>
<td>2.6</td>
<td>12</td>
<td>1.5</td>
</tr>
<tr>
<td>50</td>
<td>0.9</td>
<td>4</td>
<td>2.4</td>
</tr>
<tr>
<td>60</td>
<td>1.8</td>
<td>9</td>
<td>2.7</td>
</tr>
<tr>
<td>70</td>
<td>2.3</td>
<td>12</td>
<td>3.4</td>
</tr>
<tr>
<td>80</td>
<td>1.9</td>
<td>9</td>
<td>2.6</td>
</tr>
</tbody>
</table>

A: absolute error (volume, %); B: Relative error (%)
The water balance component

The water balance under grassland in growing seasons

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>I</th>
<th>T</th>
<th>SE</th>
<th>SRFL</th>
<th>SEEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>435.0</td>
<td>26.1</td>
<td>271.7</td>
<td>35.6</td>
<td>28.0</td>
<td>9.5</td>
</tr>
<tr>
<td>2005</td>
<td>390.6</td>
<td>26.1</td>
<td>261.8</td>
<td>55.8</td>
<td>1.6</td>
<td>3.6</td>
</tr>
<tr>
<td>2006</td>
<td>465.0</td>
<td>28.4</td>
<td>240.9</td>
<td>77.0</td>
<td>1.1</td>
<td>13.2</td>
</tr>
<tr>
<td>Average</td>
<td>430.2</td>
<td>26.9</td>
<td>258.1</td>
<td>56.1</td>
<td>10.2</td>
<td>8.8</td>
</tr>
</tbody>
</table>

- The biggest: transpiration, >60% of precipitation
- The second biggest: soil evaporation, >10% of precipitation
- Interception: stable
- Surface runoff: lowest, big variation depending on rainfall intensity
The change after afforestation

Transpiration increase in growing season

• The increasing value: 61mm for plot2
  111mm for plot3

• It depends the rainfall characters
Soil evaporation decrease

- Soil evaporation reduction: ~50mm
- The reason: the shady of forest canopy
Interception: a little increase

Interception increase: ~10mm
Surface runoff reduce to 1~2 mm

In dry year, it will be lower
Summary of water balance change after afforestation

<table>
<thead>
<tr>
<th></th>
<th>Trend</th>
<th>Change value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transpiration</td>
<td>+</td>
<td>61-110mm</td>
</tr>
<tr>
<td>Soil evaporation</td>
<td>-</td>
<td>~50mm</td>
</tr>
<tr>
<td>Interception</td>
<td>+</td>
<td>~10mm</td>
</tr>
<tr>
<td>Surface runoff</td>
<td>-</td>
<td>~8mm</td>
</tr>
</tbody>
</table>

Afforestation:

• More water consumed by transpiration and interception
• Low surface runoff reduce less
Water limitation for transpiration

Plant available water in 0-80cm soil layer:
- Grassland is bigger than larch forest
- Sometime in larch forest PAW is zero
Conclusions

1. The water budget of ecosystems in dry area has a strong character of water-limitation
   - Runoff is the smallest part of water budget with lower than 10mm/yr;
   - Transpiration is the biggest part of water budget with more than 60% of the precipitation of growing season.
2. After afforestation:

- Transpiration strong increase with the value of 61-110 mm per growing season.
- Soil evaporation will decrease about 50 mm.
- The surface runoff reduces to lower than 2mm.
- Thus, more water will be consume by vegetation after afforestation although the water limitation is existed.
Thank you for your attention