Overview of Hydrological Studies over Dry Regions in China.

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NEESPI/LCLUC Science Team International Regional Meeting on Dryland Processes in Central Asia
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Introduction
Northern Eurasia Science Partnership Initiative (NEESPI) Area

Northern Eurasian Area
Where are dry land area in China?
Water Cycle in China

- Precipitation: 9,000 km³
- Evaporation: 9,000 km³
- Glaciers
- Underground runoff: 2200 km³
- Juvenile water inflow: 700 km³
- Precipitation on land surface: 110,000 km³
- Evaporation from land: 65,200 km³
- Precipitation on surface ocean: 458,000 km³
- Evaporation from ocean: 502,800 km³
- River runoff: 42,600 km³
- Water expenses for hydration: 2712
- Area of closed regions runoff: 30,000 km³
- Area of exorheic runoff: 119,000 km³
- Ocean area: 361,000 km³
Why Dry? Relationship between Annual Precipitation and Distance From Sea

After Wang Jian
Mountain glaciers much recession

Melting water makes up \( \frac{1}{4} \) (streamflow)

Mt glacier ice/snow storage = 5600 km\(^3\) (two times of China’s total annual flow);

60.5 Km\(^3\) of annual melting water, including 25.6 km\(^3\) to China’s dry land area

Mt. glaciers

来源：施雅风，2005
Development and eco-environment issues in China’s Dry Land Area
We are just here **in developing area of China’s dry land regions**

Urumqi City in Remote West Desert of China Has Expanded as the Largest City in the Central Asia

- **Location in the Northwestern, Northern and Northeastern China**;
- **Dry land area in China amounts to above 3.5 million km², including semi-arid lands**;
- **Urumqi south is just the center of whole Asia**.
Socio-economy development in China’s dry lands

- Population growth: increase of 2.8 times;
- Farmland expansion: increase of 22;
- Irrigation: expansion 3.8;
- Grain output: increase of 4;
Water-related Eco-environment Issues
西北沙漠与沙漠化
地下水枯胡杨林死亡
植被破坏水土流失
牧场退化草原沙化
Lespedeza (Huyang)
西北生态退化问题影响东部的环境
超载放牧

草场退化
上游民勤大水农灌，下游湖干（青土湖）

河水污染到处可见
超采地下水，地下水位下降，井干枯

绿了农田，黄了树林
Hydrologic Regime Features
Regional differentiation of Water Balance in China: According to about 100 Watersheds
Regional differentiation

- Climatically deterministic - Zoning
- Main indicator is Aridity (A)
  - $A = \frac{Rn}{LP}$
  - $A = \frac{ET}{P}$
  - $A = \frac{Eo}{P}$
  - $A = 0.16 \Sigma T / P$ (Zhang Baokun 1950s)
- Other formula…
Aridity Indexes (A):

\[ A = 1923.8605/P - 0.56048536 \]

\( C_r = 1 \)相当于 \( P = 1200 \text{mm/a} \)
# Aridity Indexes

<table>
<thead>
<tr>
<th>干湿状况</th>
<th>指标</th>
<th>年干燥指数</th>
<th>天然植被</th>
<th>其它</th>
</tr>
</thead>
<tbody>
<tr>
<td>湿润</td>
<td></td>
<td>≤1.00</td>
<td>森林</td>
<td></td>
</tr>
<tr>
<td>半湿润</td>
<td></td>
<td>1.00~1.50</td>
<td>森林草原/（草甸）</td>
<td>次生盐渍化</td>
</tr>
<tr>
<td>半干旱</td>
<td></td>
<td>1.50~4.00</td>
<td>（草甸草原）草原</td>
<td>可旱作</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.50~5.00（青藏高原）</td>
<td>（荒漠草原）</td>
<td></td>
</tr>
<tr>
<td>干旱</td>
<td></td>
<td>≥4.00</td>
<td>荒漠</td>
<td>需灌溉</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥5.00（青藏高原）</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Falkenmark Index
Cv Comparison between the dry and the wet rivers basins
Table: A comparison of the variation coefficient (Cv) of water cycle components in dry and wet watersheds.

<table>
<thead>
<tr>
<th>Watersheds</th>
<th>Coefficient of variation of annual water cycle components (Cv)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Precipitation (P)</td>
</tr>
<tr>
<td>Dry (P &lt; 500 mm)</td>
<td>0.40</td>
</tr>
<tr>
<td>Wet (P &gt; 1200 mm)</td>
<td>0.19</td>
</tr>
</tbody>
</table>
Critical features of water cycle

- Transformation of hydrologic states is dominant in vertical direction;
- Main water exchanges are in between precipitation and evapotranspiration;
- Runoff formation is mainly in mountains and dominant of melting water from snow pack and glaciers;
- Runoff is diminishing in downstream basins in process of frequent water interactions;
- Groundwater is main source for exploitation in the basins.
Major Research Issues
1. Research on hydrological cycle & water changes
Water is coming from mts and intensively interacted in downstream bains

Runoff zone  Water interaction zone  Water depleting zone

precipitation  evapotranspiration
2. Eco-environmental flow
To better understand river flows interacting with the eco-environment

- **P** precipitation
- **E** evapotranspiration
- **W_n** (In-stream / Inside channels)
- **W_i** (Linked / Interacted)
- **W_E** (Uplands Outside of channels)
- **W_{(d)}** domestic sector
- **W_{(p)}** production sector

RS: surface runoff
RG: subsurface runoff

(Eco-environment Flows)
3. To further determine relations between water and ecosystems
Lespedeza dying under water stress

Chinese call “Huyang tree”
Ecosystem and buried groundwater table

Chinese call "Hongliu tree"

Buried g.w. table $< 3$ m is good enough for Jarrah

Buried g.w. table $> 7$ m is inadequate for Jarrah

来源：工程院西北水项目, after Y. Chen,
“HUYANG” growth & buried g.w. tables

来源：工程院西北水项目, after Y.Chen,
Figures show that it is good to control buried g.w. table in around 6 m.
4、Research on dynamics of subsurface balance
A model for regulating / balancing recharge & evaporation by controlling groundwater table:

Max recharge

FS-ET
\[ FS(h) = m + nh + jh^2 + kh^3 + \ldots \]  
\[ FS(h) - ET(h) > 0 \]  
\[ d[FS(h) - ET(h)]/dh = 0 \]

As figure shown, we get:

\[ dFS/dh = 0 , \ h = Hm , \]

\[ Dg = 10000 \mu (Hc - h) , \]
\[ (h < Hc) \]
5、Salinity control on basis of water-salinity relation
水循环中的水分与盐分运动的关系
\[ RSB = C_1 P + C_2 R_i - C_3 R_o - S_i + S_r + S_f + S_w \]

where

- \( RSB \) = regional salinity balance in tons;
- \( C_1 \) = salinity content of precipitation (\( P \));
- \( C_2 \) = salt content of surface runoff (\( R_i \)) inflowing into salinity balance region (given region);
- \( C_3 \) = salt content of surface runoff (\( R_o \)) outflowing from the given region;
- \( S_i \) = salts used by crops/plants;
- \( S_r \) = salts remained by crops/plants;
- \( S_f \) = salts brought by fertilizing.
- \( S_w \) = salts from mother rock weathering
\[ P - RS + CN + EG = E + T + FG + \Delta W_1 \quad \text{土壤水量平衡} \]
\[ FG + FR + FS + FI = EG + RG = \Delta W_2 \quad \text{地下水量平衡} \]
\[ \Delta WG = \Delta W_1 + \Delta W_2 = P - R + CN - E - T + FR + FS + FI \]
\[ SB = C_1 P + C_2 R_i - C_3 R_O - S_i + S_r + S_w \quad \text{水量盐分平衡} \]
\[ SB = 728.46 + 291.02 - 545.34 = 474.17 (in \times 10^4 \text{ton}) \]

\[ q = \int K / (K + q) d \psi \]

\[ q / ET_0 \propto (1 - h / H_d) \]
\[ q / ET_0 = F (1 - h / H_d) \quad (h > 0) \quad \text{潜水上升排泄} \]

\[ q(h) = a + bh + ch^2 + dh^3 + \cdots \]
\[ FS(h) = P - RS - [\theta_f(h) - \theta_i(h)] \quad \text{潜水补给} \]
\[ FS(h) = P - [\theta_f(h) - \theta_i(h)] \]
6、Determine ecological water allocation necessary for sustaining ecosystems
Water Competition estimation: A case of Xinjiang Uigur Auto. region

Water exploitation rate: \( u = 70\% \)
Water returning rate: \( r = 30\% \)

\[ E_a = 1 - (u - ur) = 1 - u(1 - r) \]

\( E_a \) = part rate of streamflow remaining for the ecosystems, \( E_a = 51\% \)
Quality of environmental flow & ratio between sewerage & runoff (bw)
7、Research on “green water” and “blue water
Green & Blue Water

After Malin Falkenmark
GWSP SSC

降水--实际水资源

用水的耗散

陆地宏观估计——绿水与蓝水的估算

Precipitation
True Water Resource
100%

Consumptive Water Use

Forests
Grasslands
Wetlands
Crops

Green Water
65%

Blue Water 35%

Return Flow

90%
Green Water & Blue Water

- **Blue water** \( W_B = W_S + W_g - \Delta SG \)
- **Green water** \( W_G = P - W_B \)
- \( W_{Blue} \), \( W_S = \) surface water ; \( W_g = \) groundwater ;
- \( \Delta SG \) exchanges between \( W_S \) & \( W_g \)
- \( P = \) total precipitation
Dominant GREEN WATER in the north &
Dominant BLUE WATER in the south
8. Water resources & climate change
Temperature rising impact
(from 1960s to 1990s)

In the dry land areas

- Gansu 甘肃: 0.87°C
- Inner Mongolia 内蒙古: 1.07°C
- Ningxia 宁夏: 0.85°C
- Qinghai 青海: 0.93 °C
- Shaaxi 陕西: 0.46°C
- Xinjiang Uigur Auto region 新疆: 0.85°C
- Precipitation has increased in Xinjiang since end of last century;
- In Xinjiang it’s likely to be a warm-wet scenario, but eastern part is still warm-dry;
- The Mt. glaciers are recessive obviously
Brief remarks
1. Water shortage is the most crucial issue in development of dry land regions

2. The ecosystem degradation is common challenge for sustainable development in the dry land areas

3. Rational water allocation is urgent need for high competition in the water supply shared by various sectors
4. Hydrological responses to climate change impact are characterized by non-linearity and geographical differentiation in large extent of North Eurasia.

5. It’s necessary to distinguish climate change influence from human activities impact and to let decision makers to take countermeasures accordingly.

6. Hydrological cycle can provide a base for rational water management
生态水文的微观研究：实验研究—原创性

中科院生态站网

Distribution of CERN's Field Stations

中科院生态站网
Thanks for attention!
仅供参考，谢谢！
降水量1990s (mm/year)

- < 200
- 200 - 400
- 400 - 800
- > 800