The Impact of Climate Change and Human Activity on Mongolian Water Resources

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Abstract
Problems of water resources are becoming important factors restricting social and economic development of our country. Water resources of Mongolia are dramatically sensitive to climate change that a small alternation in the precipitation might bring about severe water shortage. In the recent 50 years, it is obviously warmer in southern of Mongolia than before. The particularly obvious warming in winter had not only resulted in a greater evaporation and reduction of runoff volume, but also intensified the conflicting of water supply and demand. The impacts of climate change on water resources are displayed in every sector of water system. In this paper, we will pay attention to develop integrated water recourse management plan.

Keywords: water, water supply, climate change, evaporation, precipitation, wastewater.

Climate
The Mongolian climate is extremely continental with a short, hot summer and a long, cold winter, high temperature fluctuation (both daily and seasonal) and a relatively high number of cloudless days. The average annual temperature is between -7.8°C and +8.5°C (Figure 1, Table 1)

Source: “Assessment of the water sector in Mongolia” Report, 2007

Figure 1. The geographical distribution of average temperature, °C
### Table 1. Average air temperature for different regions

<table>
<thead>
<tr>
<th>Region</th>
<th>Average air temperature of coldest month (January) (°C)</th>
<th>Region</th>
<th>Average air temperature of warmest month (July) (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valleys between mountain ranges Altai, Khangai, Khentii and Khuvsgul</td>
<td>-30 to -34</td>
<td>Great lake valley, Orkhon and Selenge basin and region between Altai, Khangai, Khentii, and Khuvsgul mountain ranges</td>
<td>+15 to +20</td>
</tr>
<tr>
<td>High mountains</td>
<td>-25 to -30</td>
<td>Altai, Khangai, Khentii and Khuvsgul mountain ranges</td>
<td>+15</td>
</tr>
<tr>
<td>Steppe</td>
<td>-20 to -25</td>
<td>Dornod steppe and other steppe zones</td>
<td>+20 to +25</td>
</tr>
<tr>
<td>Gobi Desert</td>
<td>-15 to -20</td>
<td>Southern part of Dornod steppe and Gobi Desert</td>
<td>+25 to +30</td>
</tr>
</tbody>
</table>

The annual average precipitation is low in Mongolia; it is about 300-350 mm in Khangai, Khentii, and Khuvsgul mountain ranges; 250-300 mm in Mongol Altai and forested areas; and 50-150 mm in Gobi Desert area (Figure 2).

![Geographical distribution of annual precipitation, mm](image)

Source: “Assessment of the water sector in Mongolia” Report, 2007

Figure 2. Geographical distribution of annual precipitation, mm

Mongolia is situated in more sensible region with climate change than in many other regions in the world. The main cause for this fact is that the country is located in a narrow inland
transition zone between the great Siberian taiga and the Central Asian desert, highly elevated above sea level.

Figure 3. Spatial average of normalized annual temperature over Mongolia

In the past 60 years, the annual average temperature has increased by 1.9 °C; more specifically, for the winter period by 3.6°C, the spring and fall period by 1.3-1.8 °C, and in summer time by 0.5°C (Figure 3). During this time, the annual average precipitation has decreased by 10% within the country (Figure 4).

Figure 4. Spatial average of normalized annual precipitation over Mongolia

Surface water resources

Surface water resources of Mongolia are composed of rivers (34.6 km$^3$), lakes (500 km$^3$) and glaciers (62.9 km$^3$). The 36.5% of the total lakes are distributed in the Gobi region and 410 km$^3$ of total lake water resource 500 km$^3$, is fresh water. The 75.2% of the total glaciers are the mountainside glaciers, the 21% are valley glaciers and the 3.8% are denudation surface glaciers. The 50-70 percent of annual runoff of rivers in Altai mountain area forms from snow and glaciers contribution, while 5-10 percent from rainfall. In case of rivers originating from Khuvsgul, Khangai and Khentei mountain ranges, the 56-76 percent of annual runoff forms from rainfall. Highest runoff is observed at Selenge-Sukhbaatar site. The variation of rivers water resources is presented in Figure 5.
The main elements of surface water balance, such as the total inflow, evaporation from water surface and total evaporation, are varied due to climate condition, soil and vegetation cover and land surface of the country. The main elements of the surface water balance of Mongolia are presented in the Figures 9, 10, 11.

It is very important to determine climate impacts on the river regime and balance, and tendency according to the time and the space.
Climate change impact on surface water volume
Scenarios generated by the Hadley model (England) show that by 2040-2070 runoff will increase in the Pacific Ocean basin and to a less extent in the Arctic Ocean basin. For the Central Asian Closed basin it is expected that until 2040 runoff will increase a little and then by 2070 runoff will decrease.

In 2004, meteorologist L. Natsagdorj determined that potential evaporation had been increased by 3.2-10.3 % in steppe and Gobi region in last 60 years and 10.2-15.0 % in mountain and forest-steppe regions and in the first half of 21st century the total evaporation will increase by 6-10 times than precipitation based on summarizing the total surface evaporation studies estimated by other researchers.

Groundwater resources
The groundwater resources are formed differently depending on geological formation, climate, geomorphologic and hydrological conditions. In 1958, groundwater resources was estimated for the first time in Mongolia by the Russian scientist A.T. Ivanov and later, the Institute of Water Exploratory Research (IWER) in 1973, Russian scientist N.A. Marinov (1977), scientists G. Davaa, M. Myagmarjav (1999) and scientists Sh. Jadambaa, G. Tserenjav (2003) estimated the groundwater resources using different methods. These estimations are summarized in the following table.

In 2003, Dr. N. Jadambaa and G. Tserenjav estimated the groundwater resources that could be used for economic use of pastureland, shown in the table 2. Their estimation was based on a proposed distance between four water points in the whole territory of the country and it took into consideration different types of water bearing rock formations and possible rates of discharge when calculating the groundwater resources.
Table 2. Potential groundwater resources per unit area (1 km$^2$) and whole territory of Mongolia

<table>
<thead>
<tr>
<th>Classification of exploitation resource per unit area</th>
<th>Water for unit area</th>
<th>Area of distribution</th>
<th>Groundwater resources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10^3$ m$^3$/year</td>
<td>$10^3$ km$^2$</td>
<td>$10^3$ m$^3$/year</td>
</tr>
<tr>
<td>1 Area with small resources</td>
<td>&lt; 3</td>
<td>770225</td>
<td>1032.9</td>
</tr>
<tr>
<td>2 Area with from small to moderate resources</td>
<td>3-10</td>
<td>571780</td>
<td>3032.7</td>
</tr>
<tr>
<td>3 Area with moderate resources</td>
<td>10-30</td>
<td>139825</td>
<td>2182.8</td>
</tr>
<tr>
<td>4 Area with large resources</td>
<td>&gt; 30</td>
<td>65790</td>
<td>4538.0</td>
</tr>
<tr>
<td>Total</td>
<td>1547620</td>
<td>10786.4</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: N. Jadambaa and G. Tserenjav’s estimation in 2003

Potential groundwater resources for pasture by Mongolian economic regions is $2548.39 \times 10^6$ m$^3$/year (80.90 m$^3$/s) in Dornod region (including Hentii, Dornod and Sukhbaatar provinces), $2600.0 \times 10^6$ m$^3$/year (82.5 m$^3$/s) in Central region (including Selenge, Tuv, Darkhan-Uul, Dundgobi, Dornogobi, Gobisumber and Umnugobi provinces), $3005.1 \times 10^6$ m$^3$/year (95.4 m$^3$/s) in Khangai region (including Khuvsgul, Bulgan, Orkhon, Arkhangai, Uvurkhangai and Bayankhongor provinces) and $2633.7 \times 10^6$ m$^3$/year (83.6 m$^3$/s) in west region (including Gobi Altai, Zavkhan, Khovd, Uvs and Bayan-Ulgii province).

Water quality

**Surface water quality per basin**

In terms of the assessment of surface water quality per basin, the surface water in the mountainous region of Mongolia is fresh and soft, and it is included in the hydrocarbon calcium classification. In the *Arctic Ocean Basin* which occupies 19.5% of the territory of Mongolia, the Selenge River and its tributaries, the Sishged and Huremtei Rivers’ mineralization is at maximum 320.0 mg/l in winter. In summer, when it is fed by spring snow melting and rainfall floods, the mineralization becomes at minimum 53.3 mg/l, pH = 7.40-8.30 (low alkali) and average hardness is 2.30 mg-ekv/l. At the all sample sites along Selenge river, water is fresh (mineralization is 200-320 mg/l), soft (hardness is 2.30 mg-ekv/l), with pH = 7.40-8.30 (low alkali), and belongs to 1-2$^{nd}$ types of Hydrocarbon Calcium classification. Near to upstream of Orkhon river, Ulaan, Tsagaan rivers and Tsenkher, Tsetserleg, North Tamir, South Tamir, Khoshigt, Jargalant and Mогоi tributaries are very clear, soft and not affected by human influences. The mineralization of Eroo river which is the biggest tributary of Orkhon river is not more than 70 mg/l and the hardness is 0.30 mg-ekv/l. Therefore, this river is very clear, soft and its chemical composition resembles with rain water. The Kharaa river belonging to 2$^{nd}$ type of Hydrocarbon sodium and calcium classification is clear and soft. All tributaries near to upstream of Tuul, are mountain clear, soft and not affected by human influences.

In the *Pacific Ocean Basin*, the average mineralization for the Onon, Ulz, Kherlen and Khalkh rivers is at maximum 120-300 mg/l and the average hardness is 2.0 mg-ekv/l. They have considerable fresh and soft water.
In the *Central Asian Internal Drainage Basin*, the average concentration level of mineralization of the Bulgan, Uyench, Bodonch, Buyant, Khovd, Tsenkher, Tsagaan, Sagsai, and Sogoot rivers with their tributaries which are Bokhmoron, Turgen, Ongi, Taats, Tui and Baidrag etc. is about 60-450 mg/l, which is very fresh. Their hardness is 0.80-3.80 mg-ekv/l. By research materials of surface water chemical composition, mineralization of most rivers is mainly determined as 300-500 mg/l so that it is almost suitable for any economic sectors uses. On the other hand, mineralization of the main lakes is different from each other. For example, mineralization of Uvs, Khyargas, Khar, Boontsagaan, Sangiin dalai, Khukh and Oigon Lakes is 2’000-15’000 mg/l, but mineralization of Khar Us, Khuvsgul, Buir, Tolbo, Terkhiin tsagaan and Khoton Lakes is 50-300 mg/l.

**Groundwater quality**

Mongolian ground water quality and chemical composition can be defined by 4 physical-geographical zones.

The *Khangai- Khenti mountainous region* involves most of the forest steppe area (30% of Mongolia) and covers the northern part of the country. The mineralization of the samples taken from this region range between 100-800 mg/l, with rare exceptions of having >1000 mg/l. Average mineralization equals to 450 mg/l. Hardness of water in the region equals to 4.5 mg-eqv/l.

The *Altai mountainous region* involves Mongol Altai, Siilhem, Kharhiraa, Turgen and Gobi-Altai mountains of western Mongolia. Average mineralization for the region is 640 mg/l and hardness is 4.8 mg-eqv/l which is higher than the previous region. The water for the region is salty and fluorinated.

The *Mongolian Dornod steppe region’s* average mineralization is 950 mg/l, average hardness is 5.6 mg-eqv/l and it is characterized by a high concentration of iron.

The average mineralization for the *Gobi region* is 1120 mg/l and hardness is 5.4 mg-eqv/l which exceeds the standard for drinking water. Water quality in more than 100 soums does not meet the drinking water quality standard since 60% of the soums have water rich in mineralization, 40% have high hardness and over 80% of them have a high magnesium-hardness degree.

The groundwater mineralization and chemical composition of the Mongolian territory are changed from north to south by principle that the chemical composition is altering from hydrocarbon into sulphate, then chloride but cation altering from calcium into magnesium and sodium.

**Water pollution**

The regime and quality of water resources become more and more affected by human influences, global climate warming and changing soil and vegetation cover to. A state inventory for surface water conducted in 2003 showed that although most of the rivers still contain mountain fresh water, for at least 28 rivers in 8 provinces riverbeds have changed and/or are polluted due to mining activities. For example, the large Orkhon, Tuul, Kharaa and Eroo rivers in the Selenge river basin have been polluted from the impacts of gold mining industries, urbanization and industrial activities within the basin.
As impacts of mining activities, the aquatic ecosystem with insect and fish populations have been changing. Fresh water fishes cannot survive in heavily polluted blurry rivers and the amount of fishes which get infected by diseases is increasing. Groundwater sources which are close to Ulaanbaatar city and other bigger cities are polluted by urban waste and garbage since the regulations for protected zones are not obeyed.

**Water resource scarcity**

In recent years, water resource scarcity is appearing in some regions from reason of climate change and human impacts.

A state inventory for surface water conducted in 2003 shows that the total number of rivers in Mongolia is 5565 and from them 683 dried out in the last few years. Also 1484 springs of total 9600 springs and 760 lakes of total 4193 lakes dried out.

According to the LANDSAT7 satellite information of the glacier study in Kharkhiraa, Turgen, Tsambagarav and Tavanbodg mountains, the glacier area decreased by 30% from 1940 to 2002.

A state inventory for surface water was conducted again in 2007. As the preliminary result, the abovementioned situation has become worse that the total number of rivers in Mongolia is 4290 and from them 887 dried out. Also 2096 springs of total 7244 springs and 1164 lakes of total of 2569 lakes have dried out. These results show that the water resources are rapidly becoming scarce. Water resource scarcity raises trouble for state, public and water user and needs to be well concerned on account of life base. A comparison of the state inventories for surface water conducted in 2003 and in 2007 is presented in the following figure.

**Conclusions**

Because of its geographical location and rugged topography, Mongolia is highly vulnerable to anticipated impacts of climate change on water resources. Due to the cross cutting nature of water resources, increased mean temperature, recurrent drought and floods, retreating glaciers and permafrost, and more intense and infrequent rainfall patterns will have a wide ranging set of impacts on water resources.

Water is most likely source of conflict, with different sectors for resources that will in many places become scarcer. These increased vulnerabilities to climate hazards will compound current water governance problems in Mongolia. Therefore, governance structures and water use practices will need to adapt to climate change. Good examples of Integrated Water Basin Management should be developed.
References
17. State surface water registration preliminary results executed in 2007
18. Guidelines and standards of water in Mongolia