Davaa, G. 2002 Human influences on hydrological systems in Mongolia, *Proceedins of IMH*, No. 24, 171-181, UB, 2002.
Davaa, G., Mijiddorj, R., Khudulmur, S., Erdenetuya, M., Kadota, and T., Baatarbileg, N. 2005 Responces of the Uvs lake regime to the air temperature fluctuations and the environment changes, *Proceedings of the First International Symposium on Terrestrial and Climate Changes in Mongolia,* Institute of Meteorology and Hydrology, Mongolia, 130-133.
Jadambaa, N. 2002 *Ground Water of Mongolia,* White Book of Mongolia, Ulaanbaatar, 199-214.
Kadota, T. and. Davaa, G. 2004 A preliminary study on Glaciers in Mongolia, *Proceedings of the 2nd International Workshop on Terrestrial Change in Mongolia*, Institute of Meteorology and Hydrology, Mongolia, 100-102.
Myagmarjav, D.B. and Davaa, G. 1999 *Surface Water of Mongolia,* Interpress, Ulaanbaatar, 345 p.
National Standard Agency, 1998 *National Water Quality Standard,* National Standard Agency, Ulaanbaatar, MNS-458698, 5 p.
Sellers, P.J., Meeson, B.W., Closs, J., Collatz, J., Corprew, F., Hall, F.G., Kerr, Y., Koster, R., Kos, S., Mitchell, K., McManus, J., Myers,D., Sun, K.-J., and Try, P. 1995 An overview of the ISLSCP Initiative I Global Data Sets, ISLSCP Initiative I Global Data Sets for Land-Atmosphere Models, CD-ROM, Volumes 1-5, NASA.
Tserensodnom, J. 2000 *Catalog of Lakes,* "*Shuvuun saaral*", 141 p. Ulaanbaatar,
Tuvdendorzh, D. and Myagmarzhav, B. 1986 *Atlas of the Climate and Water Resources in the Mongolian People's Republic*, Ulaanbaatar.
Yatagai, A and Yasunari, T. 1995 Trends and decadal-scale fluxtuations of surface air temperature and precipitation over China and Mongolia during the recent 40 year period (1951-1990), *J. Meteorol. Soc. Japan*, 72, 937-957.

Surface Water of Mongolia

Монгол орны гадаргын ус

Gombo Davaa (Hydrology Section, Institute of Meteorology and Hydrology)
Dambaravjaa Oyunbaatar (Hydrology Section, Institute of Meteorology and Hydrology)
Michiaki Sugita (Graduate School of Life and Environmental Sciences, University of Tsukuba)

Abstract

Mongolia receives very limited precipitation with an annual mean value ranging from <50 mm in the southern part to 400 mm in the northern area, and some 70-90% of the precipitated water evaporates back into the atmosphere. As a result, a low discharge of the order of 0.1-1 mm/day is common in most rivers. Also flow regime is not very stable and changes a lot depending on location, season, and year. Seasonal variability is more predominant in rivers in Asian Internal Basin, while those in Pacific Ocean and Arctic Ocean Basins show somewhat more stable regime. Three types of long-term trend of river flows—(i) decrease, (ii) increase and (iii) no change—can be found in Mongolian rivers. The exact cause(s) of these trends is (are) not yet clear, but human activities and recovery from the past human activities in combination with global climatic change are suspected as possible reasons. The water quality of rivers has been classified with the water quality index. Most rivers are still very clear, although some rivers near cities, larger villages and mines are with polluted water.

Keywords: aridity, river, water resources

1. Precipitation and Evaporation

Mongolia receives annual precipitation of P=250-400 mm/year (Fig. 1), with more than 60% concentrated during summer time. In general, the amount of precipitation is largest in the northern part and decreases toward south. In Gobi area, P is as low as 50 mm/year, while in the northern part, area with $P>350$ mm/year can be found. This distinctive horizontal variation of precipitation has created an ecotone of forest-steppe-desert from the north toward south in Mongolia. Water balance studies with river discharge and precipitation data (e.g., Batima and Dagvadorj, 2000; Sugita, 2003) have revealed that on average, 70-90% of the precipitation evaporates from the land surfaces into the atmosphere, and remaining parts recharge groundwater and rivers. This is because the atmospheric demands for evaporation as expressed by the potential evaporation are so large that most of the rainfall end up with evaporation as soon as they fall onto the land surfaces. As such, horizontal distribution of the mean evaporation is similar to that of precipitation. This can be seen with the distribution of the aridity index, defined as the ratio of precipitation over potential evaporation (Fig.2), which indicates the general dryness of Mongolia particularly in southern parts.

2. Water Resources

The total surface water resource of Mongolia is estimated as 599 km^3/year, and is composed

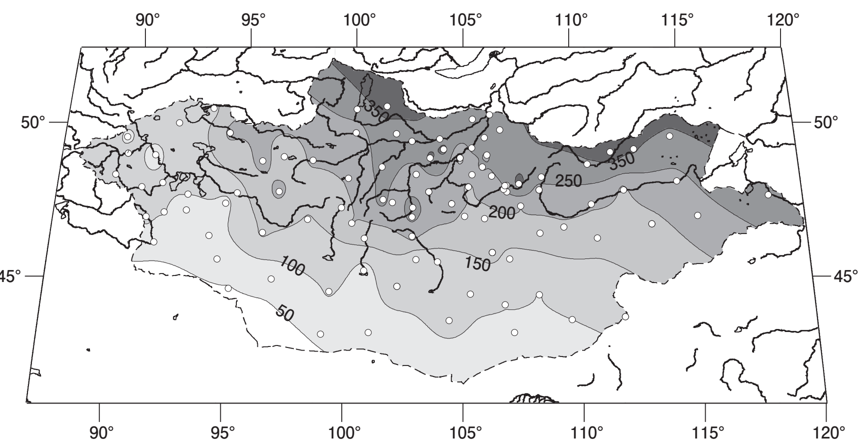

Fig. 1 Annual Precipitation (averages for 1993-2001), mm/year

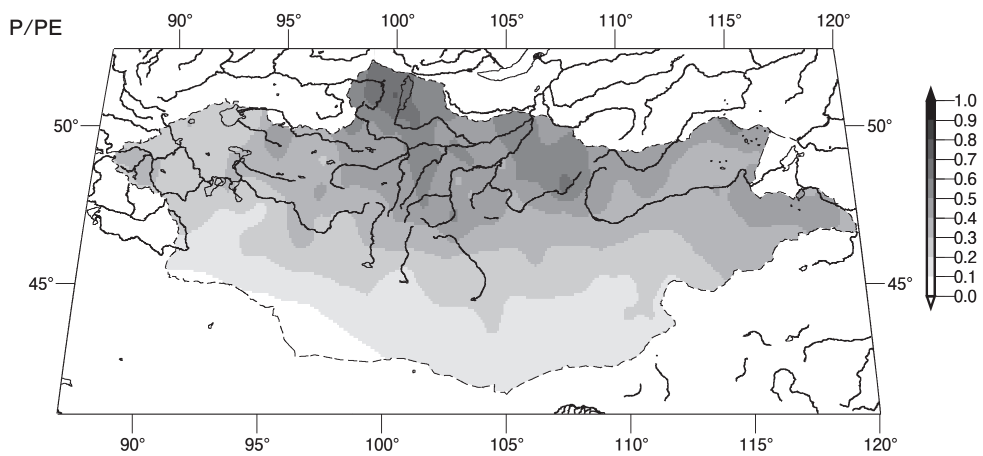

Fig. 2 Aridity index (Precipitation/Potential Evaporation). Precipitation is the average for 1993 to 2001, while potential evaporation was calculated with the Penman method for 1988 (Sugita, 2003) with ISLSCP Initiative I data set (Sellers et al., 1995).

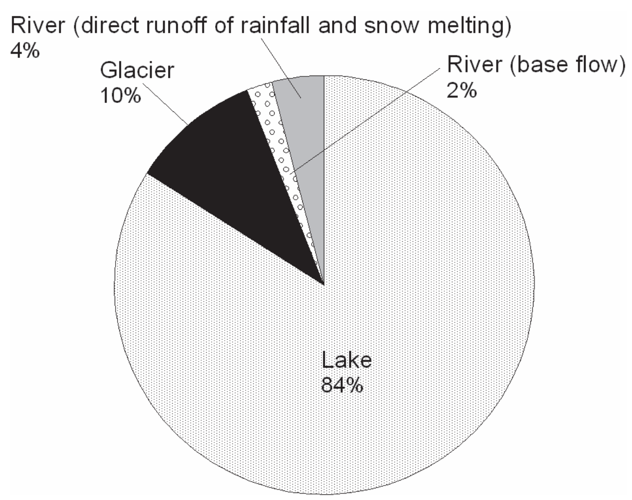

Fig. 3 Surface water resources components of Mongolia

mainly from water stored in lakes (500 km^3/year) and glaciers (62.9 km^3/year) (Fig.3). Only 5.8% of the total surface water resources, *i.e.*, 34.6 km^3/year, are in rivers, with 2.1% in base flow and 3.7% in direct runoff of rainfall and from snow melting as determined from a flow separation analysis. Note that the amount of 34.6 km^3/year consists of the river runoff formed within Mongolia (30.6 km^3) and water inflow from adjacent countries of Russia and China (4 km^3/year). The amount of water resources in the renewable ground water (*i.e.*, groundwater with smaller residence time that can be replenished relatively quickly) has been estimated as 10.8 km^3/year (Jadambaa, 2002). Despite their small size, the surface and groundwater resources play vital roles in the country's economy, especially in agriculture, livestock production, industry and domestic water supply. For example, 31% and 25% of the total population of Mongolia receive water as tap water or as tank distribution, which mostly come from groundwater; 36% directly from groundwater well and 10% from rivers (Batima and Dagvadorj, 2000). The total water withdrawals from the groundwater (80%) and surface water (20%) in 1996 were equal to 0.40 km^3, 25.2% of which were used for municipal needs, 25.8% for industry, 34.6% for livestock, 7.9% for irrigated arable land, and 6.5% for other needs (Myagmarjav and Davaa, 1999).

3. River Water Monitoring

Monitoring of the water regime of rivers and lakes began in early 1900s and at present days 120 gauging stations are operating in main 75 rivers and 12 lakes in Mongolia. Also 142 stations periodically take samples for chemical analysis (Fig. 4). River basin ecosystems extending from Siberian taiga till the Gobi desert are known to be among the richest in terms of bio-diversity. The taiga forests are mainly distributed in Khangai, Khuvsugul mountain ranges. Also, 64 stations take

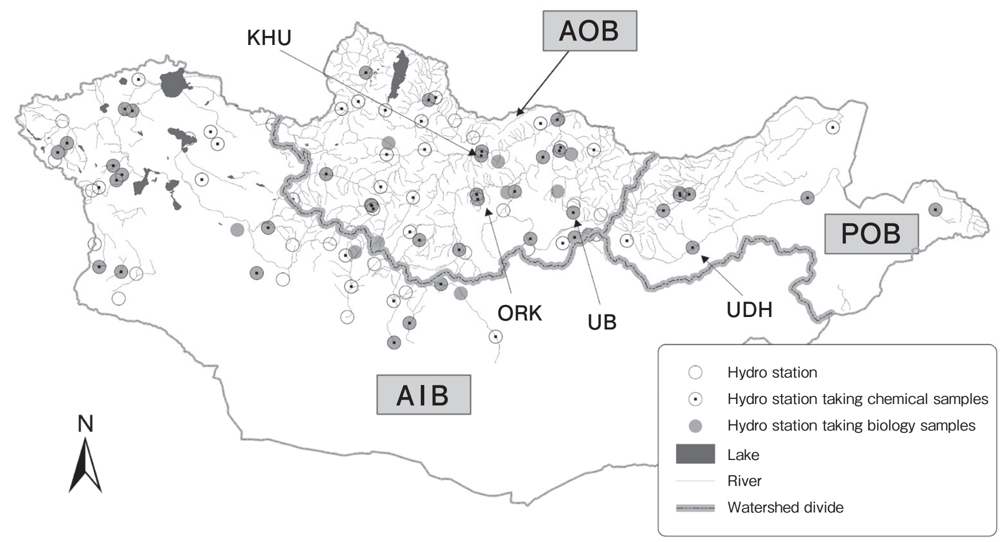

Fig. 4 Three main basins and hydrological monitoring network in Mongolia. The Basin AOB represents the Arctic Ocean Basin, POB the Pacific Ocean Basin, and AIB the Asian Internal Basin. UDH, UB, ORK, and KHU represent Underhaan, Ulaanbaatar, Orkhon, and Khutag shown in Figs. 6 and 9.

samples of plankton and benthos organisms for bio-monitoring and qualitative analysis (Fig. 4).

4. River Flow Characteristics

Mongolia has around 4113 rivers with the total length of 67,000 km and average channel density of 0.05 km/km^2. These rivers originate in Central Asian high mountains ranges and drain into three main river basins of the Arctic Ocean Basin (AOB), the Pacific Ocean Basin (POB) and the Asian Internal Basin (AIB) (Figs. 4 and 5). In another word, 60% of the river runoff formed in the Mongolian territory drains into Russia and China. Only 40% flows into lakes of Gobi, partially recharging groundwater aquifers.

The runoff in the rivers draining from the Khuvsugul, the Khangai and the Khentei Mountains is formed mainly from rainfall (56-75% of annual runoff), that in the rivers taking their origin from the Altai Mountain is from snow and ice melting waters (50-70%), and that in other rivers is from snow

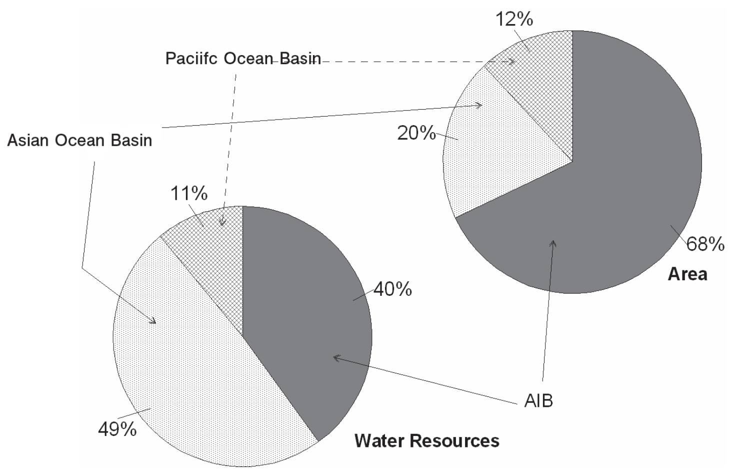

Fig. 5 Percentages of water resources (km^3/year) and the area of the three main river basins of Mongolia. The divides of the three basins are shown in Fig. 4

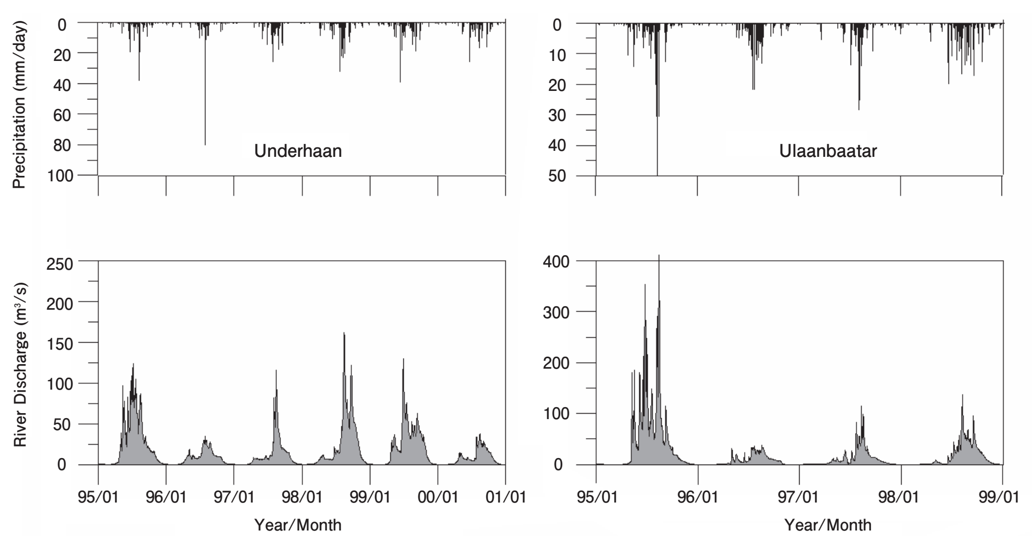

Fig. 6 Examples of annual flow regime of Mongolian rivers with daily precipitation data at Underhaan on Kherlen river and at Ulaanbaatar station of Tuul river (Locations are indicated in Fig.4). As the figures indicate, most of the precipitation and runoff take place during warm period of the year.

melting or rainfall and ground water (Myagmarjav and Davaa, 1999). This indicates that the specific proportion of runoff components varies in time and space. Two examples of seasonal changes of river discharge with precipitation are graphically shown in Fig.6. The base flow component fed by groundwater has been estimated as 15-40% with an average of 36.1% within the country of the total annual runoff (Myagmarjav and Davaa, 1999).

With the long-term river flow data collected at 130 hydrological stations for various periods, the specific discharge q of each station was derived. Based on its horizontal distribution, Mongolia has been classified into 4 regions (Fig.7): (i) high flow region with $2<q<16$ ℓ/sec/km^2, (ii) medium flow region with $0.5<q<2$, (iii) low flow region with $0.02<q<0.5$, and (iv) very low flow region with $q<0.01$. As expected, northern and western regions are with higher flow while the flow decreases toward south and east. This can also be found with the flow duration curves of Mongolian rivers (Fig.8).

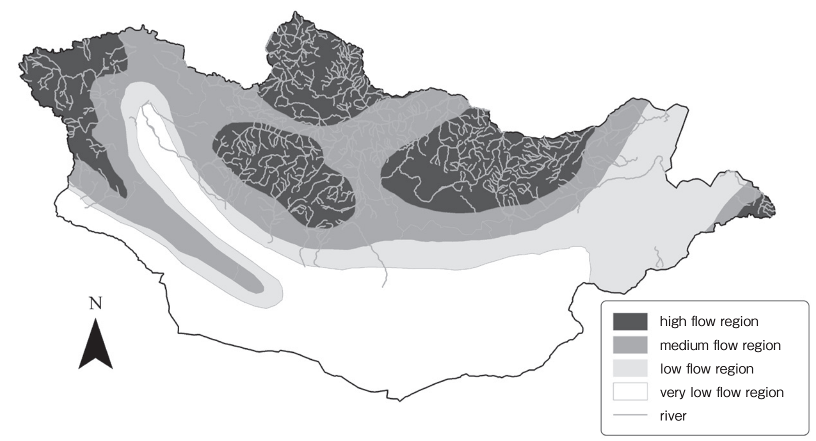

Fig. 7 Spatial distribution of surface runoff in Mongolia. River networks are also shown.

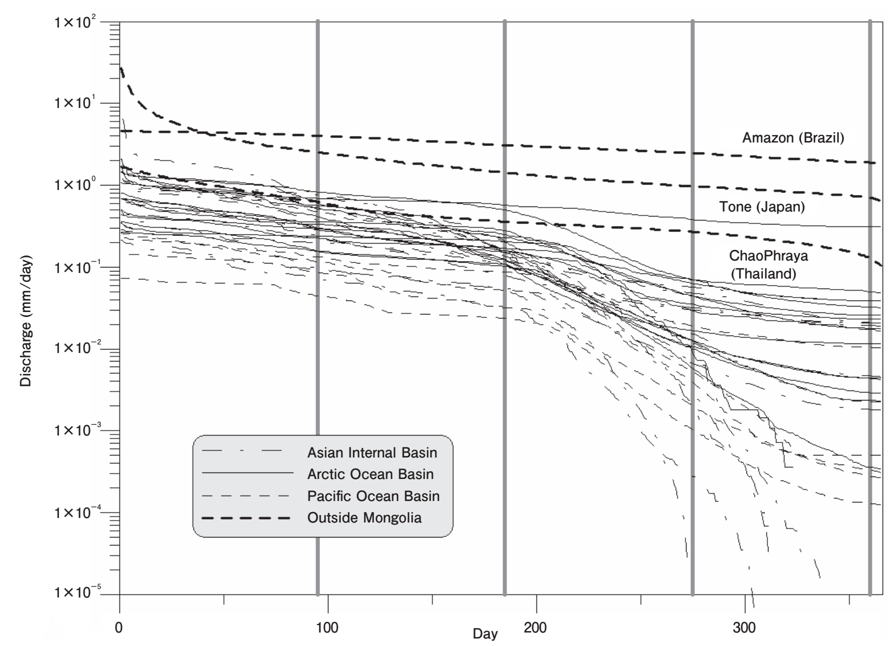

Fig. 8 Flow duration curve of selected rivers in three river basins in Mongolia. Curves of three rivers in different climatic zones are also shown for comparison.

The curves are designed to indicate the flow characteristics of river basin and the daily runoff value of a year is ordered and shown from the largest amount at left to the smallest to the right in the graph. A flat curve tends to indicate a steady and stable river flow all year round. An example is the Amazon river in Brazil or the Chao Phraya river in Thailand. Mongolian rivers are, in contrast, much less stable, and experience very limited flow approximately half of the year. This is because most of Mongolia is in arid region, and river water is easily lost through evaporation and infiltration into the ground while river flows. Also during winter period, rivers get frozen so that there is no or only small amount of flows. Also noticeable in Fig.8 is that there are some differences among rivers in three major watersheds shown in Fig.4. Those rivers in AOB and POB are more stable than those in AIB. This is another indication of the severe aridity in southern part of Mongolia. Finally, it should be noted that the flow amount is given in the unit of mm/day, discharge per unit watershed area per day; therefore a direct comparison between river basins of different size is possible. The higher flow of larger Mongolian rivers is comparable with that of the Chao Phraya river, but their low flow is much smaller than that of the other rivers in humid regions.

The Mongolian rivers also have characteristics of large year-to-year variation (Fig. 9). These changes could have taken place from global and local origins. As a global origin, an analysis has

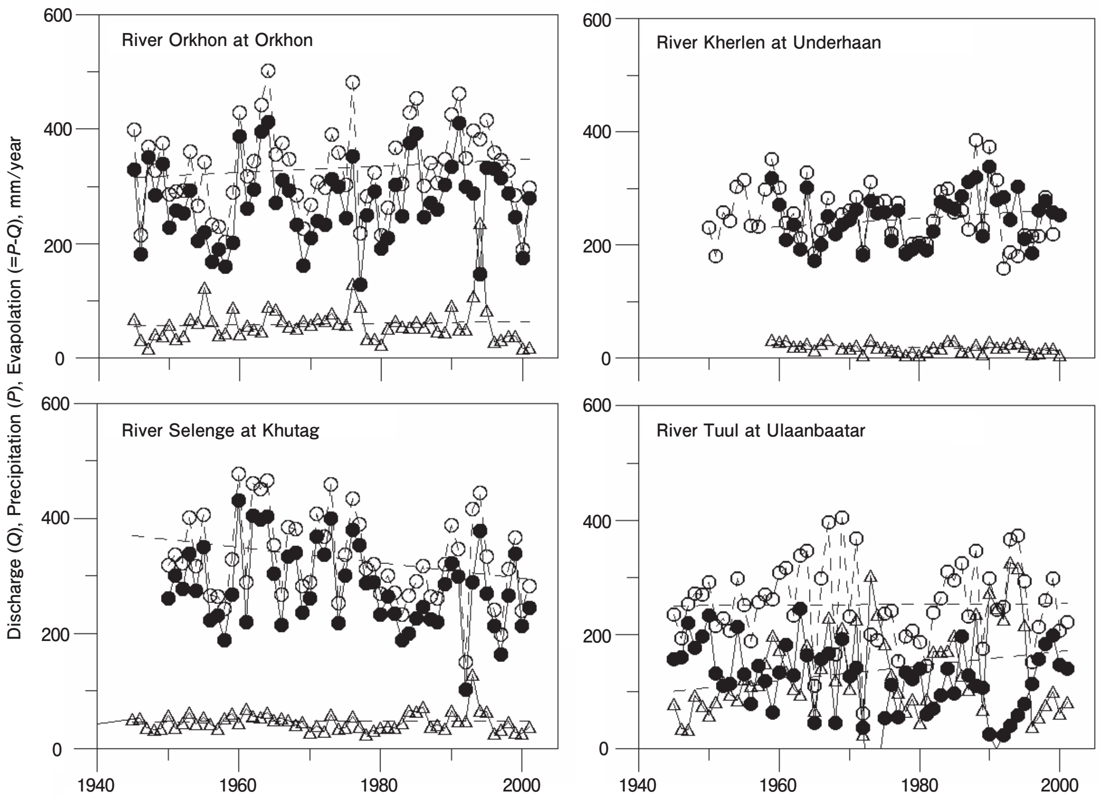

Fig. 9 Long-term flow variation of major rivers in Mongolia. Location of river is shown in Fig.4. Open circles denote precipitation *P* (mm/year) measured at the same location where discharge was measured except for Kherlen river where basin mean precipitation was derived by the Thiessen method. Open triangles denote annual total river discharge *Q* (mm/year) and closed circles are *P-Q* which is an estimation of annual basin evaporation (mm/year). Regression lines are also shown for *P* and *Q* values to indicate long-term trend.

indicated that precipitation has been decreasing and temperature increasing on average in this region (*e.g.*, Yatagai and Yasunari, 1995). However, the trends differ depending on area and season, as shown by Batima and Dagvadorj (2000). Fig. 9 also gives both increasing and decreasing trends depending on the location and depending on the target years. The local origins include human activities. In order to assess this type of influences to the Mongolian rivers, the runoff coefficient *C*, defined by the ratio of the annual runoff depth measured at a hydrological station and the basin average precipitation evaluated as the mean of observed precipitation at the meteorological stations within the watershed, was calculated at 17 selected stations. Then the calculated value of *C* was classified into two phases according to flow record: (1) early periods with undisturbed natural regime and (2) recent period with increasing human influences. Basin evapotranspiration was then calculated as the differences between the mean precipitation and the runoff for (1) and (2), separately.

Change of river runoff can be classified into three groups according to the derived trend of the runoff coefficients (Table 1):

1. River basins where the value of *C* has increased.
2. River basins where the value of *C* has remained the same. In another word, river basins remain with natural flow regime and water resources without human influences.
3. River basins where the value of *C* has decreased and evapotranspiration increased.

The result is graphically shown in Fig.10. Also shown in this graph are the locations of lakes,

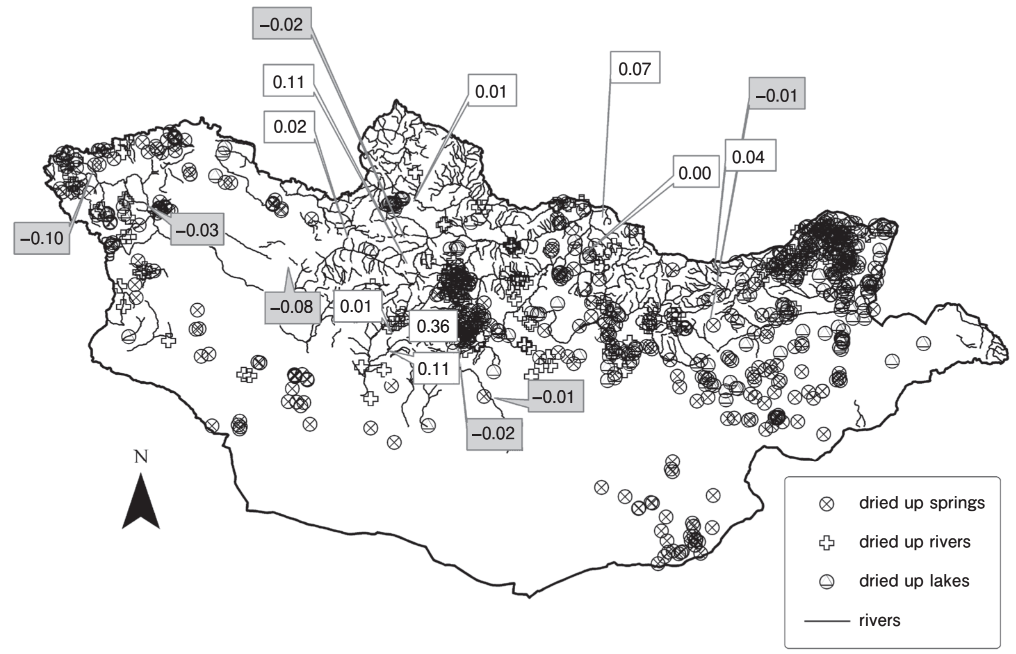

Fig. 10 Change in runoff coefficient and distribution of dried up rivers, springs and last years. Numbers indicate the change of runoff coefficient with increase in an open box and decrease in an closed box.

Table 1　Changes in discharge characteristics in selected rivers

No.	River - Station	C	Period	precipitation P mm/year	Discharge R, mm/year	dR, mm	Evapotranspiration, (P-R) mm/year	Change in evapotranspiration %
				Rivers with increasing C				
1	Tuul - Ulaanbaatar	0.49	1945 - 1974	255.0	126		129.0	- 21.7
		0.57	1975 - 2000	250.0	149	26.5	101.0	
2	Delgermuren - Moron	0.21	1950 - 1980	231.8	58.4		173.4	- 3.41
		0.22	1981 - 1997	238.0	70.5	20.5	167.5	
3	Onon - Binder	0.29	1971 - 1986	314.2	91		223.2	9.68
		0.33	1987 - 1997	364.1	119.3	13.7	244.8	
4	Tui - Bayankhongor	0.22	1971 - 1984	228.6	50.1		178.5	- 16.53
		0.23	1985 - 1997	191.7	42.7	0.5	149.0	
5	Chuluut - Undur - Ulaan	0.26	1977 - 1987	346.7	90.3		256.4	- 16.54
		0.37	1988 - 1997	347.3	133.3	43.1	214.0	
6	Eroo - Eroo	0.61	1959 - 1978	310.5	187.6		122.9	- 31.1
		0.68	1979 - 2000	265.6	180.9	19.2	84.7	
7	Kharaa - Baruunharaa	0.117	1951 - 1970	287.4	34.0		253.4	2.0
		0.121	1971 - 2000	293.1	34.6	0.3	258.6	
8	Tsagaanchuluut - Galuut	0.42	1983 - 1991	216.2	92.3		123.8	-19.8
		0.53	1992 - 2000	221.4	122.1	30.1	99.3	
9	Ider - Tosontsengel	0.29	1971 - 1984	214.5	61.6		152.8	8.1
		0.31	1985 - 2000	241.0	75.8	5.9	165.2	
				Rivers with decreasing C				
10	Ongi - Uyanga	0.30	1973 - 1985	236.2	69.5		166.7	7.7
		0.28	1986 - 1997	250.65	71.0	-4.3	179.6	
11	Ongi - Saikhan - Ovoo	0.03	1970 - 1980	230.7	6.7		224.0	6.6
		0.02	1981 - 1997	243.2	4.4	-2.2	238.8	
12	Orkhon - Kharkhorin	0.27	1973 - 1985	296.5	81.1		215.4	2.6
		0.24	1986 - 1997	291.5	70.6	-7.6	220.9	
13	Kherlen - Undurkhaan	0.08	1959 - 1980	269.3	19.36		249.9	- 8.6
		0.07	1981 - 1997	247.0	18.5	-0.3	228.5	
14	Ider - Zurkh	0.24	1960 - 1982	211.6	50.0		161.5	25.0
		0.22	1983 - 2000	256.8	54.8	-6.8	202.0	
15	Chigestei - Uliastai	0.71	1952 - 1970	219.6	155.6		64.0	44.1
		0.63	1971 - 1997	229.7	137.5	-24.7	92.2	
16	Khovd - Ulgii	0.79	1961 - 1981	113.6	83.4		30.3	74.4
		0.69	1982 - 1997	140.5	87.7	-22.7	52.8	
17	Khovd - Myangad	0.47	1966 - 1979	118.7	54.0		64.8	26.1
		0.44	1980 - 1997	139.8	58.1	-7.7	81.7	

dR is the difference between the actual discharge R in later period and the simulated discharge for natural condition (=[C in earlier period] × [P in later period])

rivers and springs that had been dried up in the recent three years of 2000-2002. It appears that there are no clear regional difference in terms of characteristics of these changes, and this tends to suggest that the cause of the change is of local nature possibly with combination of global changes. In the first group the following river basins are included: upstream basins, above some towns and villages such as Ulaanbaatar, Bayangol, Eroo, Binder etc., of the Tuul, the Kharaa, the Eroo, the Onon, the Ider, the Chuluut, the Tsagaanchuluut and the Tui rivers. Increase of the runoff is suspected to have been caused by the decrease of the surface roughness and evapotranspiration by deforestation and land degradation in the basins. However, so far adequate data and studies which prove this hypothesis do not exist. The Tuul and the Eroo river basins have observed the highest decrease in evapotranspiration; quite high decrease in the Tui and the Chuluut rivers and less decrease in evapotranspiration in the Delgermuren river. But in the Onon and the Ider river basins, a slight increase of evapotranspiration was found, which can be an indication of some forest recovery processes in the basins.

Upstreams of the Orkhon river above Kharkhorin town, the Ongi, the Khovd, the Chigestei river basins, mid reaches of the Kherlen river and downstream of the Ider river are included in the third group. In these river basins the evapotranspiration has increased. These changes may indicate recovering of land and vegetation coverage in the basins. However some human activities such as use of hydropower, water intake for irrigation, construction of reservoirs, mining activities in the basins and along the river channel certainly affect evaporation and relief of ground surface. For example, the construction of reservoirs in the upstream of the Ongi river, use of the Orkhon river water for hydropower generation and irrigation, intensive open gold mining activities at the upstream of the Orkhon river all have seriously influenced regime and resources of rivers and river water losses have increased significantly in recent years.

5. Water Quality

The water quality index W_{qi} has been estimated by the following formulae:

$$W_{qi} = \frac{\sum_i \left(\frac{C_i}{Pl_i}\right)}{n} \qquad (1)$$

where C_i is concentration of i-th pollutant, Pl_i is the maximum permissible level of i-th pollutant which has been determined for each type of pollutant by National Standard Agency (1998), and n is the total number of pollutants. As pollutants, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, and other pollutants such as ammonium, nitrate, nitrite etc. have been included. Water quality of rivers has been classified based on Table 2, and

Table 2　Assessment of water quality

Water quality classification	Water quality index
Very clean	< 0.3
Clean	0.3-0.9
Slightly polluted	0.9-2.5
Polluted	2.5-4.0
Very polluted	4.0-6.0
Dirty	6.0-10.0
Very dirty	>10.0

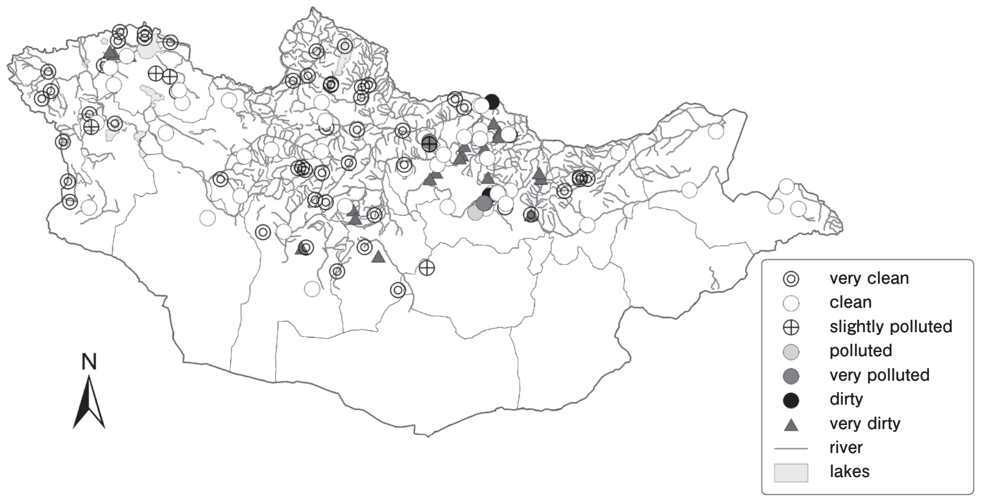

Fig. 11 Water quality classified by water quality index defined by (1) and Table 2.

is graphically shown in Fig.11.

6. Flood Damage

Since the systematic observation period (1940-), serious floods have been observed at Mongolia rivers and they caused severe property damages and loss of life. The total damage resulting from those floods has been estimated as 56 billion Tugrig (Tg). About 18 flood events were observed from 1996 to 1999 and resulted in 54 lives lost and a lot of property damages. The total damage is estimated as 531.8 million Tg. (Note that 1 US $ was equal to 7.1 Tg in 1991, 40 Tg in 1994, and 1000 Tg in 1999.)

7. Lake Environment

As mentioned, 84% of the total water resources are in lakes (Fig.1). Therefore, Mongolia may be called as the country of lake-water resources. This in turn calls for the adaptation of a proper lake management. There are some 3060 lakes with surface area A>0.1 km^2. The biggest lake in terms of surface area is Lake Uvs (A= 3518.3 km^2). By the volume and depth, Lake Khuvsugul is the biggest and contains 74.0 % of the total fresh water resources of Mongolia (Tables 3 and 4). 83.7% of the total lakes are small lakes with A <1.0 km^2 but surface area of these small lakes composes only 5.6% of the total lake area of 16003 km^2 (Tserensodnom, 2000).

Bigger lakes are concentrated in the area known as Great Lakes' Hollow and the Valley of Lakes located in western and southwestern Mongolia (see Fig. 12). However, clear climatic and lake morphological differences exist between the Hollow and the Valley. In the Great Lakes' Hollow, when we go down from Mountain area to the desert area, the average depth h of the lakes increases and surface area per unit depth (=A/h) decreases (Table 3). Since the potential evaporation exceeds annual precipitation in all areas except in higher mountainous regions (Fig.2), these lakes never dry up and persist against drought period. In contrast, this ratio of A/h increases

Table 3 Mean values of morphologic elements of some lakes

Lake	Water level, m	Surface area A, km^2	Volume km^3	Average depth, h, m	A/h km^2 /m	Location
Khuvsugul	1647.60	2770.0	383.7	138.5	20.0	Khuvsugul
Uvs	759.94	3518.3	35.7	10.1	98.6	Great Lakes' Hollow
Khyargas	1035.29	1481.1	75.2	50.7	19.7	Great Lakes' Hollow
Khar-Us	1160.08	1495.6	3.12	2.1	479.4	Great Lakes' Hollow
Khar	1134.08	565.2	2.34	4.1	137.8	Great Lakes' Hollow
Terkhiin Tsagaan	2059.21	54.9	0.333	6.1	9.0	Khangai Mountain
Buir	583.02	615.0	3.75	6.1	100.8	Eastern Mongolian Plain land
Boon Tsagaan	1312.0	252	2.355	10	25.2	Valley of Lakes
Adgiin Tsagaan	1285	11.5	0.009	0.8	14.4	Valley of Lakes
Orog	1217	140	0.42	3	46.7	Valley of Lakes
Ulaan	1008	(175)	Dried up	–	–	Valley of Lakes

Table 4 Water balance of some lakes

Lake	Surface input		Surface output		Groundwater Inflow - Outflow	Retention time, years
	Precipitation	Inflow	Evaporation	Outflow		
Khuvsugul	269.0	408.1	665.0	187.0	+175.0	162.6
Uvs	96.6	395.4	689	0	+197.0	14.7
Khyargas	55.9	652.4	937.1	0	+228.8	54.2
Khar-Us	56.4	1979.2	942.7	675.3	−417.6	1.1
Khar	54.0	1786.9	1117.8	1287.9	+564.8	1.7
Terkhiin Tsagaan	237.2	7574.3	504.2	7307.8	0.0	0.8
Buir	250.0	1394.7	860.0	1472.7	+687.7	2.6

Unit of water balance: mm/year

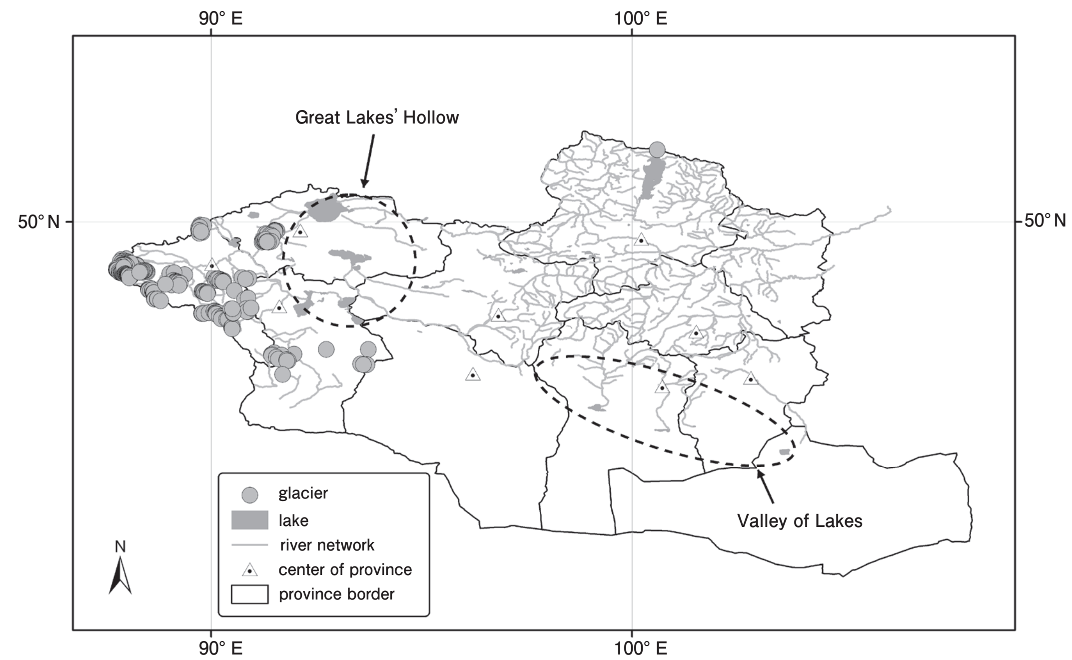

Fig. 12 Glaciers in Mongolia. General location of Great Lakes' Hollow and the Valley of Lakes are also shown.

with increasing evaporation rate for the lakes located in the Valley of Lakes. Therefore, these lakes become quite shallow in very dry areas and most of medium lakes such as Orog, Taatsyin Tsagaan, Adgiin Tsagaan and Ulaan in the Valley of Lakes dry up 1-2 times per 11-12 years. This is very tragic period of ecological crisis when millions of fishes, aquatic plants and animals die in isolated spots of concentrated saline mud left by drying lake.

The geographical characteristics have created a wide variety of lake ecological conditions within the country. The lakes located in high mountain regions contain a cold water of small mineralization rate, supersaturated with oxygen. Here, the main limiting factor of the growth of aquatic plants and overall lake population is the shortage of nutrients and coldness of water. In the transition zone from high mountainous region to forest, forest steppe, and dry steppe, the nutrient concentration of lakes increases due to the increase of heat energy. It results in the increase of biodiversity in lakes. In the Gobi desert region, the biodiversity reduces due to excess of heat energy supply which causes high evaporation and metamorphosis of lake water constituents with the oxygen deficit. Such specific ecological condition of lakes requires locally optimized conservation measures and a proper lake resource management.

8. Glacier

Glacier forms at elevation above 2750 m with mean annual air temperature of –8°C and annual precipitation about 380 mm/year (Baast, 1999). In Mongolia, glaciers are distributed in area of between 46°25' - 50°50' N, 87°40' - 100°50' E, at altitude of 2750 - 4374 m (Fig.12). Spatial distribution is sporadic and decreases from north-west to south-east. In total, 262 glaciers exist with the total

area of 659 km^2 (Dashdeleg *et al*., 1983). Surface area of the biggest glacial valley, Potanin's glacier in Altai Tavan Bogd, is 53.5 km^2. Mean depth of Mongolian glacier has been estimated as 55.8 m, and the total water resources accumulated in glacier is estimated as 62.6 km^3 (Dashdeleg *et al*., 1983). Over the last 40 years from 1945 to 1985, the area of glacier had decreased by 6 % (Baast, 1999).

Retreat of glaciers has been intensified in the last decades. For example, Kharkhiraa, Turgen, Tsambagarav and Tavanbogd glacier areas were estimated as 50.13, 43.02, 105.09 and 88.88 km^2 from the topographic map compiled in 1940s with a scale of 1:100 000 (Kadota and Davaa, 2003). Among them, the areas of the Kharkhiraa, Turgen and Tsambagarav glaciers decreased by 27.3, 32.5 and 31.9% since 1940s till 2002, respectively (Davaa *et al*., 2005).

Acknowledgements

The data used in this paper have been obtained from Institute of Meteorology and Hydrology of Mongolia and from Global Runoff Data Centre. We would like to thank them all for making available those data.

■ References:

Baast P. (1999): *Catalog of Mongolian Glaciers*, Ulaanbaatar, Unpublished report of Institute of Meteorology and Hydrology of Mongolia, 162 p. (Монгол орны орчин үеийн мөстөл, каталог), УЦУХ, Эрдэм шинижлгээний ажлын тайлан, Улаанбаатар, 1999, 162 х.)

Batima, P. and D. agvadorj, D. (2000): *Climate Change and Its Impacts in Mongolia*, National Agency for Meteorology, Hydrology and Environmental Monitoring and JEMR Publishing, Ulaanbaatar, Mongolia, 227 p.

Dashdeleg, N., Evilkhaan, R., and Khishigsuren, P. (1983): Modern glaciers in Altai mountain, *Proceedings of IMH*, No. 8, Institute of Meteorology and Hydrology, Ulaanbaatar, 121-126. (Дашдэлэг Н., Эвилхаан Р., Хишигсүрэн П. Монгол Алтайн орчин үеийн мөсдөл, УЦУХ-гийн бүтээл, No. 8, Улаанбаатар, 1983, хх. 121-126)

Davaa, G. (2002): Human influences on hydrological systems in Mongolia, *Proceedins of IMH*, No. 24, 171-181, UB, 2002. (Г. Даваа "Хүний үйл ажиллагааны нөлөөлөл ба усны экосистем", УЦУХ-гийн бүтээл, № 24, 2002, Улаанбаатар, хх. 171-181)

Davaa, G., Mijiddorj, R., Khudulmur, S., Erdenetuya, M., Kadota, T., Baatarbileg, N. (2005): Responces of the Uvs lake regime to the air temperature fluctuations and the environment changes, *Proceedings of the First International Symposium on Terrestrial and Climate Changes in Mongolia*, Institute of Meteorology and Hydrology, Mongolia, 130-133.

Jadambaa, N. (2002): Ground Water of Mongolia, *White Book of Mongolia*, Ulaanbaatar, 199-214. (Жадамбаа Н. Монгол орны газрын доорх ус, Монголын цагаан ном, Улаанбаатар, 2002 он, хх. 199-214)

Kadota, T. and. Davaa, G. (2004): A preliminary study on Glaciers in Mongolia, *Proceedings of the 2nd International Workshop on Terrestrial Change in Mongolia*, Institute of Meteorology and Hydrology, Mongolia, 100-102.

Myagmarjav, D.B. and Davaa, G. (1999): *Surface Water of Mongolia*, Interpress, Ulaanbaatar, 345 p. (Монгол орны гадаргын ус, Улаанбаатар, 1999, Интерпресс компани, хянан тохиолдуулсан Б. Мягмаржав, Г. Даваа)

National Standard Agency (1998): *National Water Quality Standard*, National Standard Agency, Ulaanbaatar, MNS-458698, 5 p. (Монгол Улсын Стандарт, Усны чанарын стандарт, MNS-458698, Улаанбаатар, 1998, 5 х.)

Sellers, P.J., Meeson, B.W., Closs, J., Collatz, J., Corprew, F., Hall, F.G., Kerr, Y., Koster, R., Kos, S., Mitchell, K., McManus, J., Myers,D., Sun, K.-J., and Try, P. (1995): An overview of the ISLSCP Initiative I Global Data

Sets, ISLSCP Initiative I Global Data Sets for Land-Atmosphere Models, CD-ROM, Volumes 1-5, NASA.
Sugita, M. (2003): Interaction between hydrologic processes and ecological system, *Science J. Kagaku*. 73, 559-562.
Tserensodnom, J. (2000): *Catalog of Lakes*, "Shuvuun saaral", 141 p. Ulaanbaatar. (Монгол орны нуурын каталог), Шувуун саарал, Улаанбаатар, 2000, 141 х.
Tuvdendorzh, D. and Myagmarzhav, B. (1986): *Atlas of the Climate and Water Resources in the Mongolian People's Republic*, Ulaanbaatar.
Yatagai, A and Yasunari, T (1995): Trends and decadal-scale fluctuations of surface air temperature and precipitation over China and Mongolia during the recent 40 year period (1951-1990), *J. Meteorol. Soc. Japan*, 72, 937-957.

Монгол орны гадаргын ус

SURFACE WATER OF MONGOLIA

Гомбын Даваа（Ус цаг уурын хүрээлэн, Ус судлалын сектор）
Дамбаравжаагийн Оюунбаатар（Ус цаг уурын хүрээлэн, Ус судлалын сектор）
Мичиаки Сүгита（Цукүбагийн Их Сургууль, Амьдрал ба Орчны Шинжлэх ухааны сургууль）

Оршил

Монгол оронд хур тунадас харьцангуй бага, жилд нутгийн өмнөд хэсэгт 50 мм, хойт хэсэгт 400 мм хүрэх ба түүний 70-90 хувь эргэж ууршина. Иймээс гол мөрний урсац бага, ерөнхийдөө 0.1-1.0 мм/хоног байна. Голын урсац тогтворгүй жил, улирлаар болон орон зайн хэлбэлзэл ихтэй. Тухайлбал, Төв Азийн гадагш урсацгүй ай савын голуудын урсац улирлаар ихээхэн хэлбэлзэх ба Номхон далай болон Хойт мөсөн далайн ай савын голуудын урсац харьцангуй тогтвортой байна. Гол мөрний сав газар, түүний урсацын өөрчлөлтийг илэрхийлэгч болох урсацын итгэлцүүрийн өөрчлөлтийн хандлагаар Монгол орны гол мөрний сав газруудыг урсацын итгэлцүүр нь 1) багасаж буй, 2) ихсэж буй, 3) өөрчлөлтгүй гэсэн гурван төрөлд хуваав. Гол мөрний урсацын өөрчлөлтийн шалтгаан нь төдийлөн тодорхой бус боловч хүний үйл ажиллагааны болон уур амьсгалын дулааралтын хам нөлөө нь үндсэн шалтгаан болно. Гол мөрний усны чанар, бохирдлын түвшинг усны чанарын индексээр үнэлэв. Ихэнх гол мөрний ус цэвэр байгаа боловч зарим томоохон хот, суурин газар, уул уурхай орчимд голуудын ус бохирдож байна.

Түлхүүр үг: хуурайшил, гол мөрөн, усны нөөц

1. Хур тунадас ба ууршил

Монгол оронд жилдээ 250-400 мм хур тунадас унах /1 дүгээр зураг/ ба түүний 60 гаруй хувь нь зуны саруудад орно. Хур тунадас ерөнхийдөө нутгийн хойноос өмнө тийш багасах ба Говийн зарим хэсэгт жилд 50 мм ба түүнээс бага, харин хойт хэсэгт 350 мм ба түүнээс их байна. Хур тунадасны энэхүү бүслэг хуваарилалт нь ой, хээр, цөлийн бүс, тэдгээр хоорондын шилжилтийн бүсийг /экотон/ тодорхойлно. Гол мөрний урсац, хур тунадасны мэдээнд тулгуурлаж хийсэн усны тэнцлийн судалгааны үр дүнгээс үзвэл жилийн хур тунадасны 70-90 хувь нь агаарт ууршиж, үлдэх хувь нь газрын доорх ус ба гол мөрний урсацыг сэлбэнэ /П.Батима, Д.Дагвадорж, 2000; М.Сүгита, 2003/. Агаарын хуурайшил ба ууршиц үлэмж их учраас хур тунадас газарт унамагц эргэж ууршиx нөхцөлтэй. Олон жилийн дундаж ууршлын орон зайн хуваарилалт нь хур тунадасныхтай төсөөтэй байна. Үүнийг хур тунадас ба ууршцын харьцаагаар илэрхийлсэн хуурайшлын индексийн тархацын зургаас харж болно /2 дугаар зураг/. Хуурайшил Монгол оронд, ялангуяа нутгийн өмнө хэсэгт их байна.

2. Усны нөөц

Монгол орны гадаргын усны нийт нөөц 599 км^3/жил бөгөөд үүний ихэнх нь нуур /500 км^3/жил/, мөстөл, мөсөн голуудад /62.9 км^3/жил/ агуулагдана /3 дугаар зураг/. Гол мөрний урсац гадаргын усны нийт нөөцийн дөнгөж 5.8% буюу 34.6 км^3/жил байна.