Changes in the Hydrological Environment and Land Degradation in the Tarim Basin

Hiroki TAKAMURA* and Muhtar QONG

*Department of Geography, Faculty of Letters, Rissho University. 4-2-16 Osaki, Shinagawa-ku, Tokyo 141, Japan. Fax: +03-5487-3353, E-mail: hiroki@ris.ac.jp

I Introduction

The Tarim Basin is located in the central part of Eurasian Continent and is a typical inland basin, with an area of 530,000 km^2 in the extreme arid zone. Around the basin there are huge mountains such as the Kunlun mountains to the south; the Tianshan Mountains to the north and the Pamir Plateau to the west. The central part of the Tarim Basin is occupied by the Taklimakan Desert, extending ca. 1,500 km from west to east and ca. 600 km north to south with an area of 338,000 km^2.

Several large rivers and groundwater were formed due to the development of alluvial fans at the foots of surrounding mountains in the Tarim Basin. The Tarim River system is a main river system in the Tarim Basin. The Yarkant River in the west and the Khotan River in the southwest and the Keriya River in the south once reached the Tarim River in ancient times, but now only the flood water can flowed into the Tarim River. At present, the length of rivers in the desert changes greatly year by year with the fluctuation in the amount of discharge. For example, in 1991, the Keriya River reached as far as 200 km from the Keriya oasis to the lower reaches in Daryaboyi, but in 1992, the river discharge disappeared at the point ca. 130 km away from the Keriya oasis.

In fact, the hydrological environment is changing continuously in the Tarim Basin, precipitation, river water and ground water were not equivalent to evaporation loss from the land surface, lower reaches of rivers and some lake surface.

The present study is intending to:
To synthesize patterns, processes and the relationship between the changes in hydrological environment and land degradation currently taken place in the Tarim Basin.

II Hydrological Environment

1. Air temperature

The average air temperature in the surrounding areas of the Taklimakan Desert ranges from -9℃ in January to 25℃ in July. It is extremely hot in summer, generally in July and ground surface temperature sometimes exceed 60℃. In contrast, it is extremely cold in winter. Therefore, the annual range of air temperature in the Taklimakan Desert is very large. For instance, at Khotan station the annual mean air temperature is 12.2℃、 and the mean air temperature is 25.6℃ in July, and that is -5.4℃ in January. The daily range of air temperature is very apparent and generally 12.5℃ at Khotan. Especially during autumn, the daily range of air temperature is largest. Recently, air temperatures in and around the Taklimakan Desert has been rising obviously in all stations in winter. The mean surface air temperature has risen about 3.0° C with a range from 2.0 to 9.0℃ since 1951 and the risen rate reaches 0.05-0.21℃/year in winter(Fig. 1)

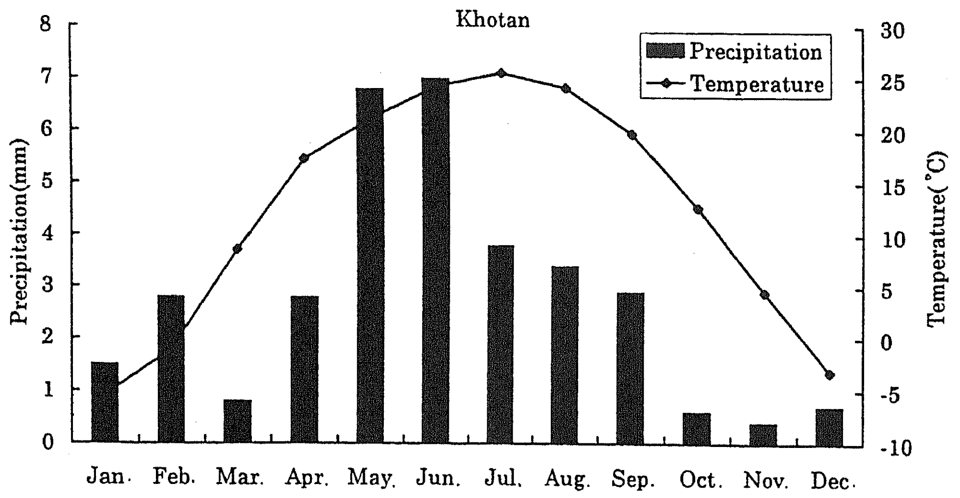


Fig. 1 Monthly average precipitation and temperature at Khotan(1959-1979)

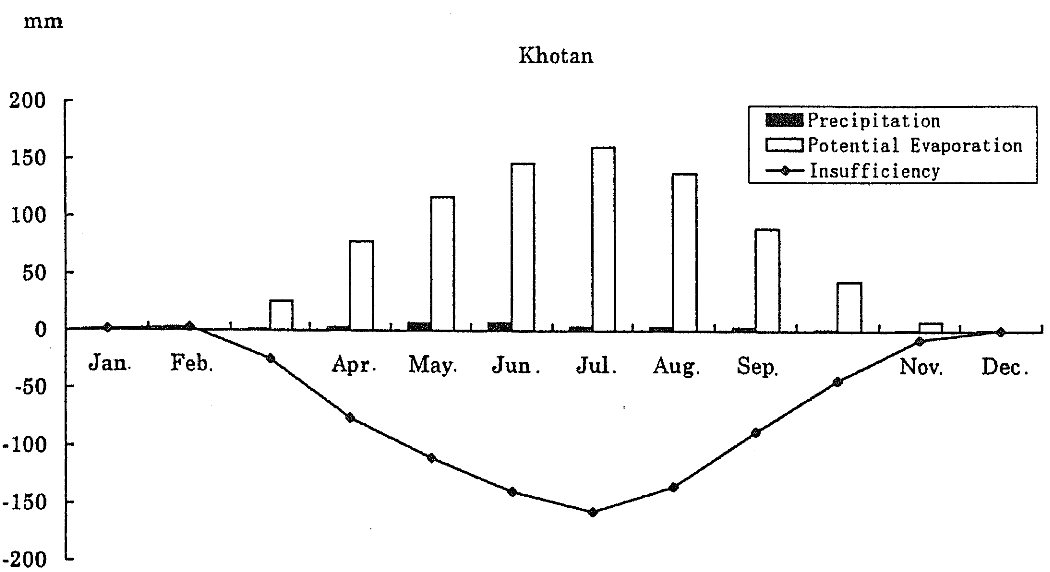


Fig.2 Monthly average precipitation, potential evaporation and water deficit at Khotan(1959-1979)

2. Precipitation

In the Tarim Basin the annual mean precipitation, which is concentrated from June to September is reduced gradually from the west to the east. The southern and the eastern areas are extremely arid, the annual mean precipitation is only 0 to 50 mm (Cheng, 1992). The precipitation of central part of desert is unknown, because of there is no meteorological station. The mean annual precipitation of Turpan is 17 mm, and the other oases located in the marginal region of the Taklimakan Desert are ranging from 20 to 70 mm.

Recently, there are some changes in the amount of precipitation in the Tarim Basin. For example, summer precipitation seems to be increasing at Qarkilik in the southeastern part of the Tarim Basin since 1950s. The annual precipitation's were 16.2 mm in the 1950s, 18.0 mm in the 1970s and 40.0 mm in the 1980s, respectively (Yin *et al.*, 1992).

3. Evapotranspiration

Because of the existence of the Tianshan Mountains the air with water vapor cannot reach the Tarim Basin, which located in the leeside of the Tianshan Mountain Ranges. However, there is a track of moisture transportation from the Indian Ocean along some river valleys and the moisture can arrive at the south edge of the Tarim Basin sometimes in summer.

However moisture holding air flows in and around the Tarim Basin are weaker in summer and stronger in winter. Accordingly, in the desert area not only precipitation is largely limited, but also annual evaporation (potential evaporation) is very high. It is over 2000 mm most of the stations in the Tarim Basin. For example, the annual potential evapotranspiration is 2602 mm (recorded in the local meteorological station) at Khotan.

But, according to our calculations by using Thornthwaite method the potential evapotranspiration from the surface are very large and strong in and around Taklimakan Desert. Data of the five meteorological stations (located around Taklimakan Desert) for the years 1959-1979 are shown in OHP. The annual potential evapotranspiration is 787.8mm and the water deficit is –735.7mm (the annual precipitation is 52.1mm) at Kashgar. In the southern part of the Taklimakan Desert, the potential evapotranspiration is higher than the other places. For example, The annual potential evapotranspiration is 804.3mm and the water deficit is –770.8mm(the annual precipitation is 33.5mm, 1250-1300m a.s.l) at Khotan(Fig. 2).

4. Humidity

The annual mean relative air humidity is lower in summer and higher in autumn and winter. For example, the mean annual relative air humidity is 42% at Khotan, but the seasonal variation of relative humidity is very large, and it changes with the change of temperature between day and night. The relative air humidity is higher when the temperature falls down; it is ca. 50% from November to February.

5. Water Resources

The discharge of rivers entering into the Tarim Basin depends mostly on the melting of snow and ice of surrounding high mountains .The river discharge is mainly concentrated to the spring and summer seasons, and it accounts for 60-70% of annual discharge. Sometimes floods occurs during the snow-melt season. But, the annual discharge is relatively stable and it makes up the main part of the water resources and plays an important role in maintaining the ecological environment in the Basin. The Aksu, Yarkant and Khotan Rivers join at near Aral and formed the Tarim River. The Tarim River is located at the foreland plain of the Tianshan Mountains. The annual discharge of the river is composed of 72.0% from the Aksu River, 22.5% from the Khotan River and 5.5% from the Yarkant River, respectively (Wang, 1991).

There are many lakes, in and around the Basin. In the plain area, there are Bagrash Lake, Ayding Lake and Shekar Lake. These lakes are the important surface water resources, especially fresh water lakes can be used as irrigation water for agriculture.

There are a large amount of groundwater resources in the aquifer of the Basin(available groundwater resources ca. $1.3616*10^{10}m^3$). In the piedmont fan areas, where shallow groundwater is rich and many springs are concentrated. Water leakage plays an adjustment and supply role in abstracting groundwater along the rivers. For example, the annual discharge of the Keriya River is $7.06\times10^8m^3$, and 56% of discharge $4.0\times10^8m^3$, water is used as irrigation water for agriculture and the remained $3.0\times10^8m^3$ water still leaking into the ground and recharge the groundwater per year (Soil and Land Resources in the Taklimakan Desert, 1994).

III Land Degradation

The Tarim Basin is one of the regions affected by land degradation: degradation of its lands resulting from the changes of hydrological environment and human activities.

1. Sandy Desertification

In the Tarim Basin, ca. 857,000 ha (Wang, 1996) of lands have been desertified by wind erosion during the last century (Zhu, 1987). Especially, in the bank region of the Tarim River 38,000 ha of land have been desertified because the water supply from river runoff had been cut off. This occupies 61% of the total area of alluvial plain of Tarim River.

Along the lower reaches of the Tarim and the Konqi Rivers desertified lands account for ca. 66% of the total area, including 49% of latent and weakly desertified lands and 51% of severely decertified lands (Xi and Zhou, 1983).

2. Vegetation Degradation

At least 285,000 ha of *Populus euphratica* woodlands were destroyed since 1958 not only in the lower reaches but also in the middle reaches of the Tarim River (Fan, 1984). The result was that 32% of woodland disappeared and 10% of woodland was devaluated in the Tarim Basin (Wang, 1996).

3. Soil Salinization

In the Taklimakan Desert, salt accumulation is very conspicuous along the river course because of intensive evaporation (2,000-2,500 mm/year) and low precipitation (0-80 mm/year). The area affected by salinization 5,857,100 ha (Li, 1984), mainly distributed in the Tarim Basin.

4. Land Aridization

In addition to the above major desertified land types, there is another important environmental degradation resulting from careless management of water resources. This is a common problem in many canal irrigation areas in the Tarim Basin.

1) Due to the agricultural development on a large scale many reservoirs were constructed. As the result the some changes of distribution pattern in water system occurred.

2) There was enough runoff so that a large lake, the Lop Nur Lake with more than 535,000 ha, was formed at the end of the Tarim River system. In 1921, the Tarim River changed its river course and flowed to the old Lop Nur Lake, and the lake area with more than 200,000 ha was formed. But, in 1970s water supply to the lower reaches has decreased. As the result the famous Lop Nur Lake was disappeared in 1972, and groundwater level in the lower reaches of the Tarim River, lowered from 3-5 m in the 1950s to 8-10 in the 1980s (Zhu *et al.*, 1988; Zhu and Wang, 1996).

3) River water was fresh with the mineral concentration of lower than 1 g/l (Okada *et al.*, 1995) in the past. But now, the river water is fresh (the mineral concentration lower than 1 g/l) only in 3 months, and brackish (1-3g/l) in 3 months and salt water (more than 3g/l) in 6 months (Zhu *et al.*, 1988). In addition, the mineral concentration of the lake water increased continuously.

IV Discussion and Conclusion

According to our investigation, environmental changes due to the changes of hydrological environment have resulted from following reasons:

1. Evapotranspiration

Evapotranspiration is used for vegetated surface. The annual evapotranspiration is different in and around oases in the Tarim Basin. According to our calculations the annual precipitation is about 25-100mm, annual evapotranspiration is about 100mm at Khotan station. So that, in situations where this annual precipitation is completely evaporate and to create intense water deficit. Thus the potential evapotranspiration will reached to above 500mm in the oases, in some desert area the potential evapotranspiration will reached 1000mm. The oases, which located in the southern part of the Tarim Basin, located between 25mm and 100mm isohyet. Many oases in the northern part of the Tarim Basin are located between 25mm-200mm isohyet and 100mm-200mm isogram of annual evapotranspiration, therefore, higher temperatures may still lead to a general increase in evapotranspiration. As the result the precipitation will evaporate completely, especially in the warmer seasons. In general this will lead to insufficiency of water in the areas. For example, many oases located between 1mm and 5mm isogram of mean annual river runoff, and the oases, which located in the west and north part of the Tarim Basin, located between 1mm and 5mm isogram of mean annual river runoff. Because of there is no enough rainfall in the central part of the desert, the deficit of river water (runoff) reached to about 1000mm per year. River runoff and runoff coefficients trend to be higher in the surrounding mountain areas(Fig. 3).

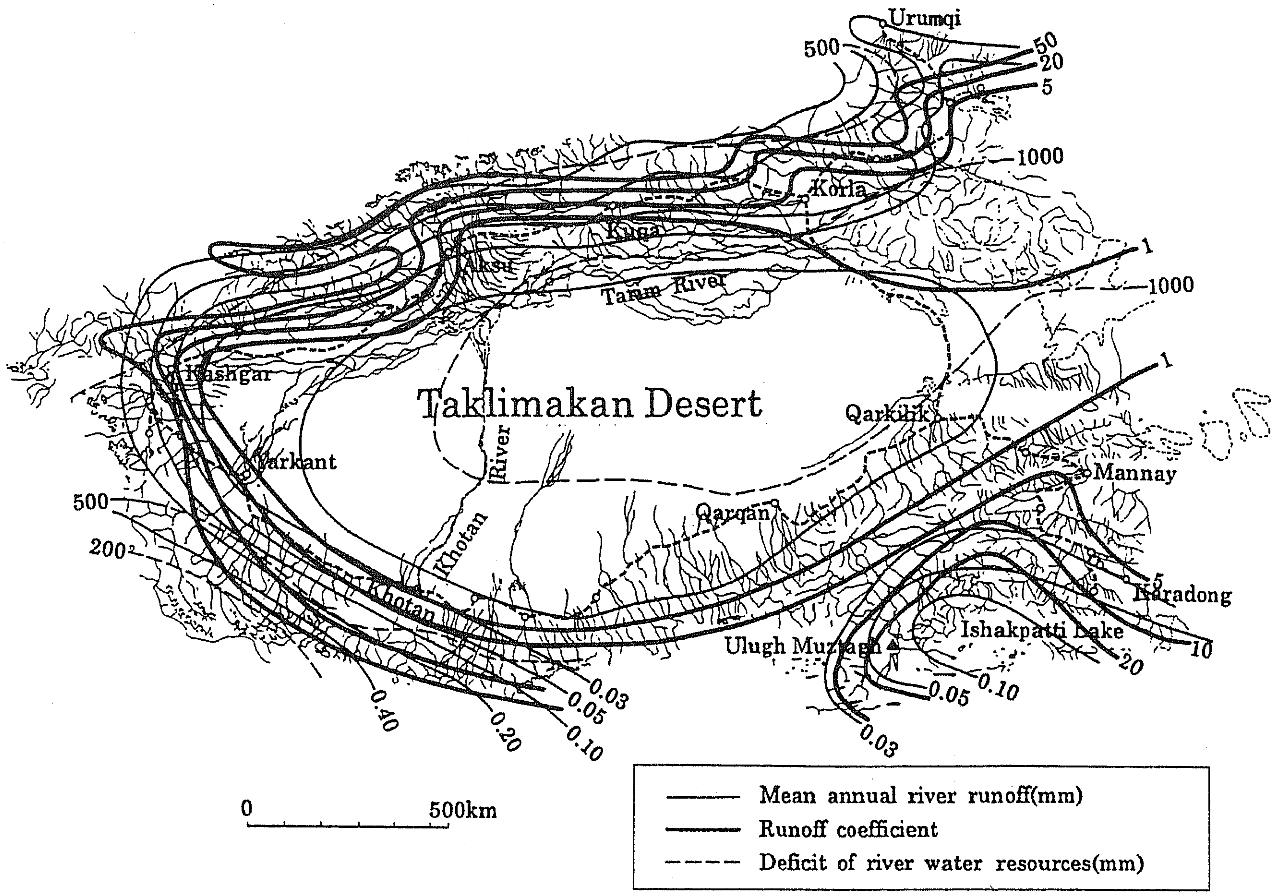


Fig. 3 Distribution of the mean annual river runoff, runoff coefficient and deficit of river water resources in the Tarim Basin

2. Water Resources Management

1) The river water which flowed to the lower reaches reduced sharply. The irrigated farmland, which was distributed on the lower reaches of the many inland rivers, was abandoned because of shortage of water supply. So that, the land degradation in the lower reaches of river is caused by the misuse of inland river water in the upper and middle reaches in the Tarim Basin.

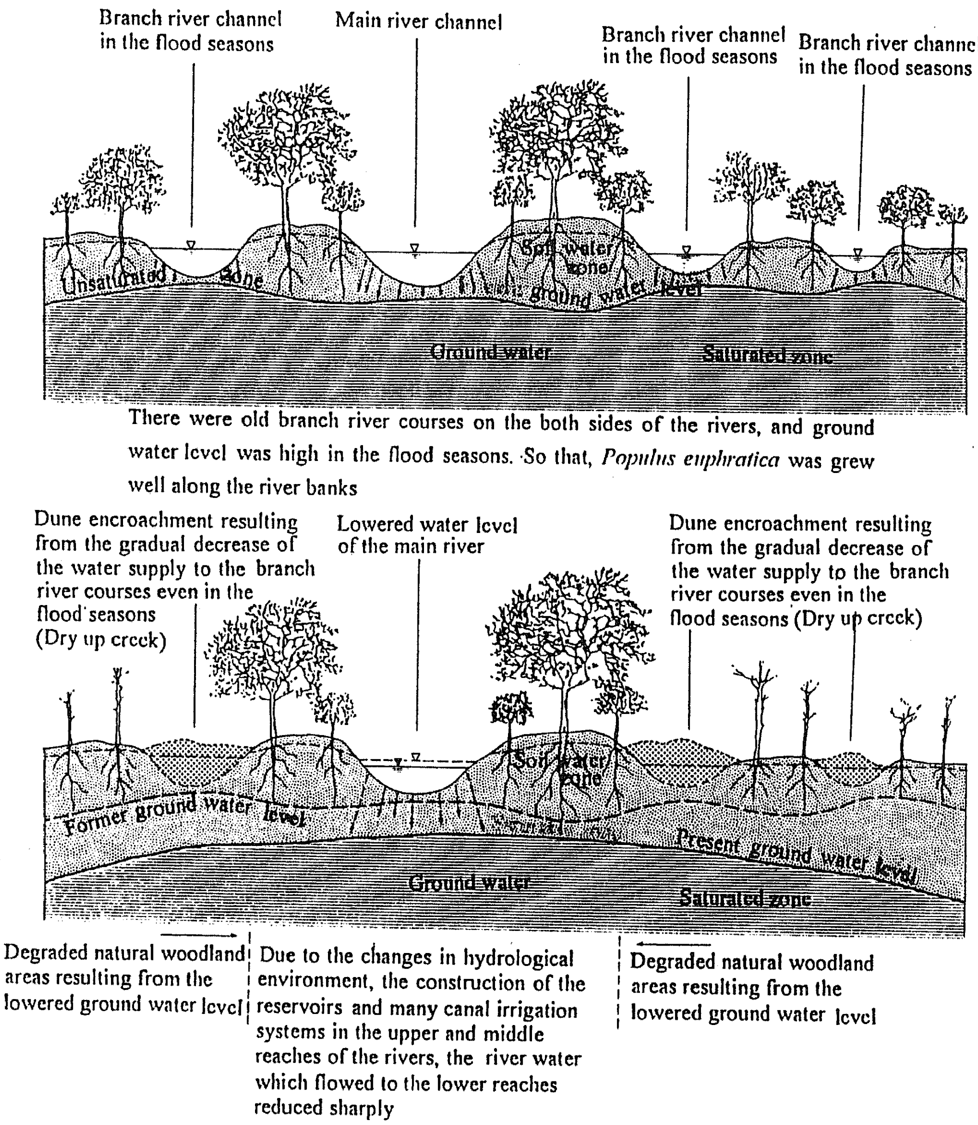
2) The groundwater level lowered 4-6m between 1959 and 1979 in the Argan District located in the lower reaches of the Tarim River. All of those prove the land degradation in the form of land aridization. From the results of the field investigation from 1993 to 1995, in the middle reaches of the Tarim River there are many old dried river courses on the both sides of the present river courses with 80-100 km width.

Due to the changes in water supply, especially lowering of the groundwater level, *Populus euphratica* woodlands were greatly degenerated and former landscape of natural woodlands was turned into the landscape of withered woodlands or bare sandy surface(Fig. 4).

3. Soil Salinization

1) In the Tarim Basin, land salinization is a result of the large amount of water infiltration from the rivers and irrigation canals to the surrounding areas. Especially, the water seepage from the canals are so serious and 2,565 million m^3 of river water have been recharged to groundwater per year (Lei, 1995). The utilization coefficient of canals is only from 0.4 to 0.45 on the average, although a great amount of irrigation water supplied to the farmlands.

2) It is very clear that, especially in an arid area, water leakage around a dam has brought about disadvantageous influence on surrounding areas due to the rising of groundwater level, resulting in severe soil salinization.



Due to the changes in water supply, especially lowering of the ground water table *Populus euphratica* woodlands were turned into the landscape of withered woodlands

Fig. 4 Land degradation along the Tarim River resulting from the lowering of the ground water level

References

CHENG, Q.(1992): The protection of the ecological environment of the green corridor in the lower reaches of the Tarim River. *Arid Land Geography*, Vol.15, No. 3: 31-35.

LEI, J. (1995): Some problems between the redistribution of water along the rivers and the oasis environment changes in Xinjiang, China. *Japan-China symposium on the desertification mechanisms*, Tsukuba: p1-8.

LI, J. L. (1984): Rational use on forest resources in Xinjiang. *Xinjiang Geography*, Vol. 7, No. 4: 4, 59-60p.

WANG, T. (1996): Land use and land degradation in the Tarim Basin, Xinjiang, China. *J. Arid Land Studies*, 5-2: 138-143.

YIN, S. (1992): Some characteristics of precipitation change in Rouqiang. *Arid Land Geography*, Vol. 15, No. 3: 65-70.

ZHU, Z. and WANG, T. (1996): The problem of desertification in the marginal regions of the Taklimakan Deser t. *J. Arid Land Studies*, 5-2: 131-136.

ZHU, Z. D., LIU, S. and DI, X. M. (1988): *Desertification and Rehabilitation in China*. Science Publishing , 34, 97, 123, 124p.

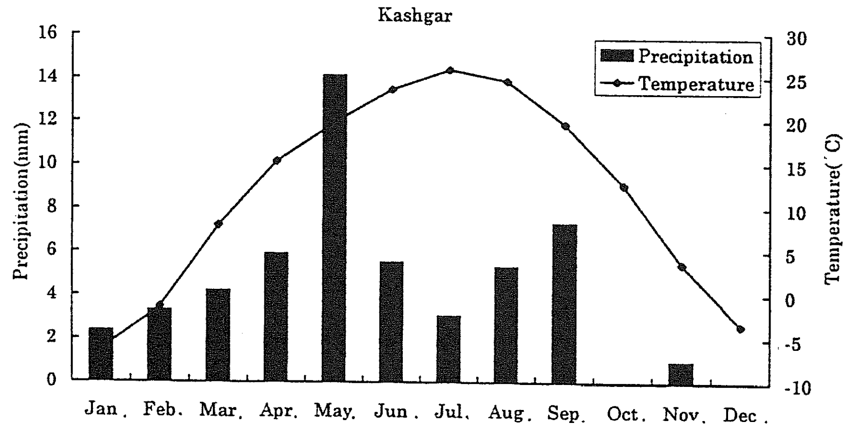


Fig. Monthly average precipitation and temperature at Kashgar(1959-1979)

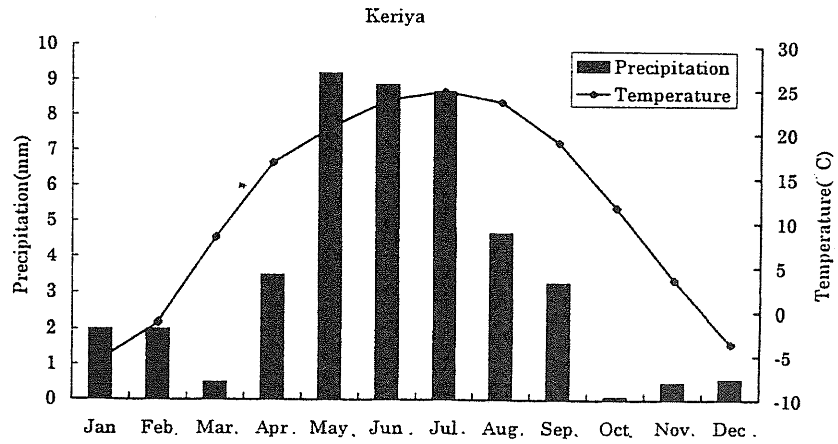


Fig. Monthly average precipitation and temperature at Keriya(1959-1979)

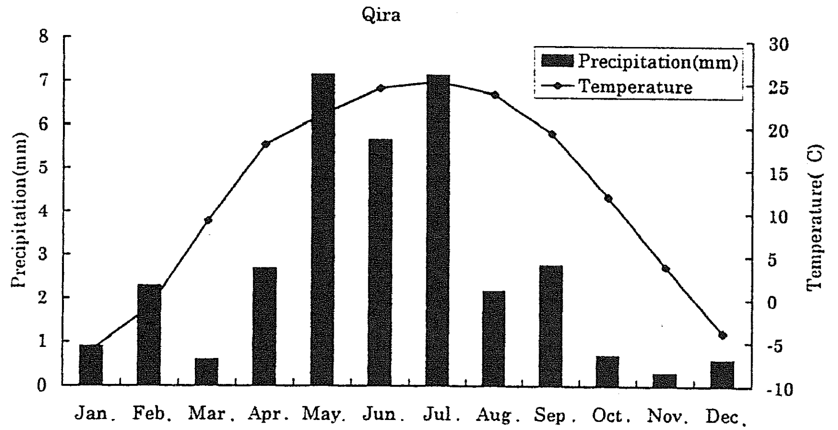


Fig. Monthly average precipitation and temperature at Qira(1959-1979)

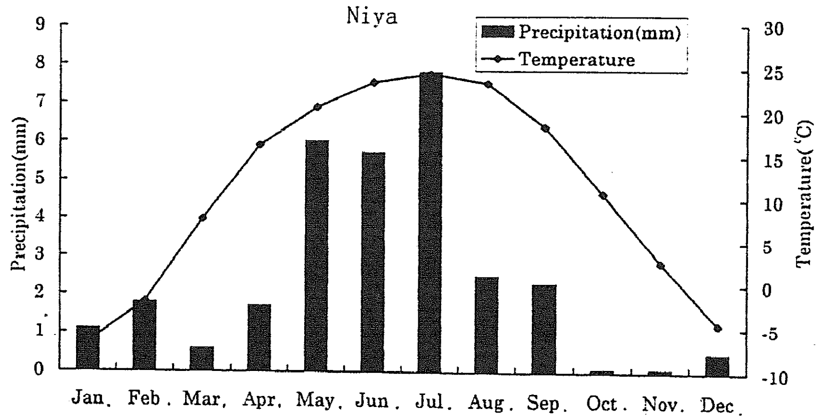


Fig. Monthly average precipitation and temperature at Niya(1959-1979)

Appendix Data 1(H. Takamura and Q. Muhtar)

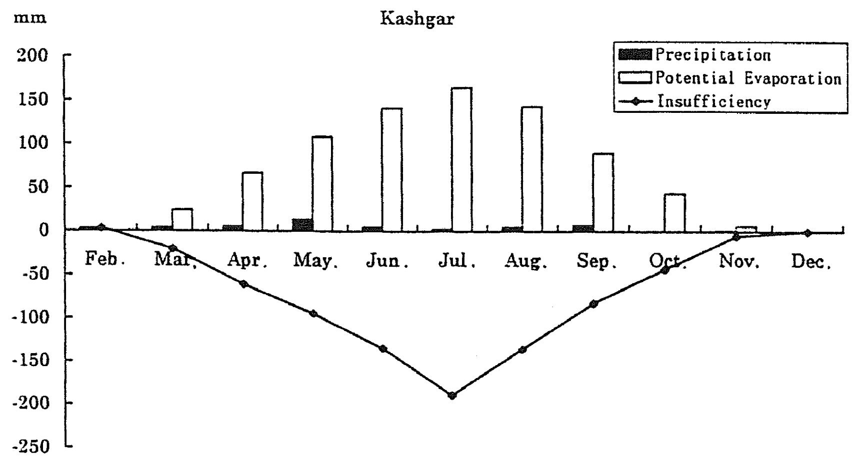


Fig.9 Monthly average precipitation, potential evaporation and water insufficiency at Kashgar(1959-1979)

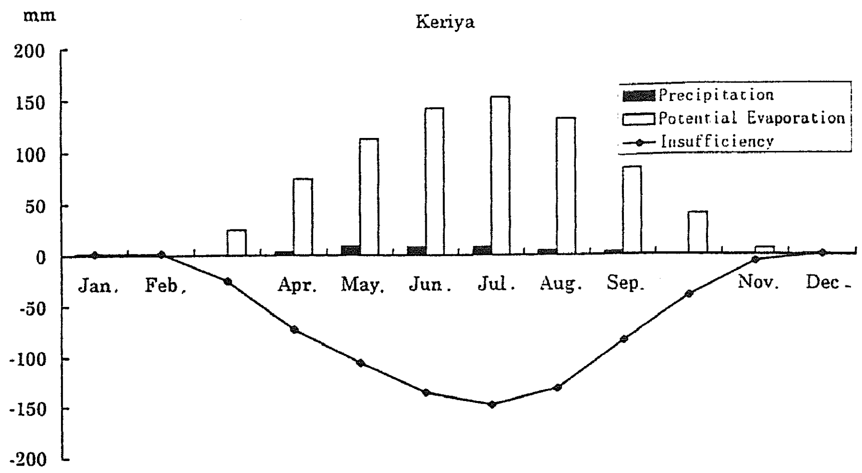


Fig.11 Monthly average precipitation, potential evaporation and water insufficiency at Keriya(1959-1979)

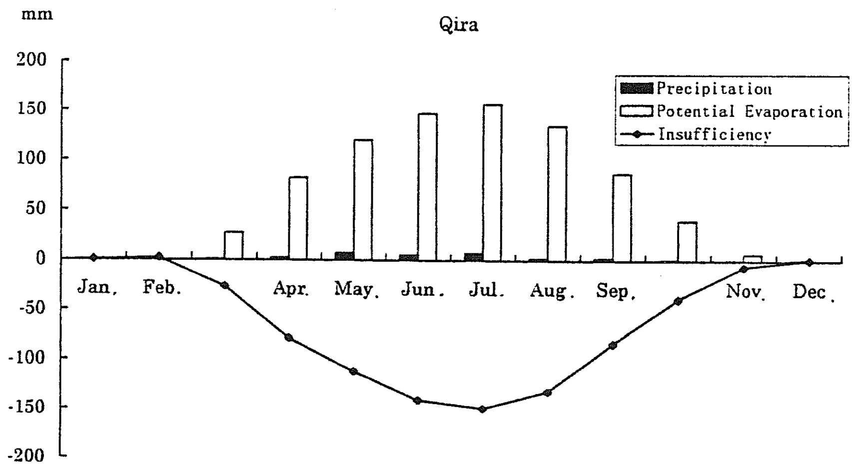


Fig.10 Monthly average precipitation, potential evaporation and water insufficiency at Qira(1959-1979)

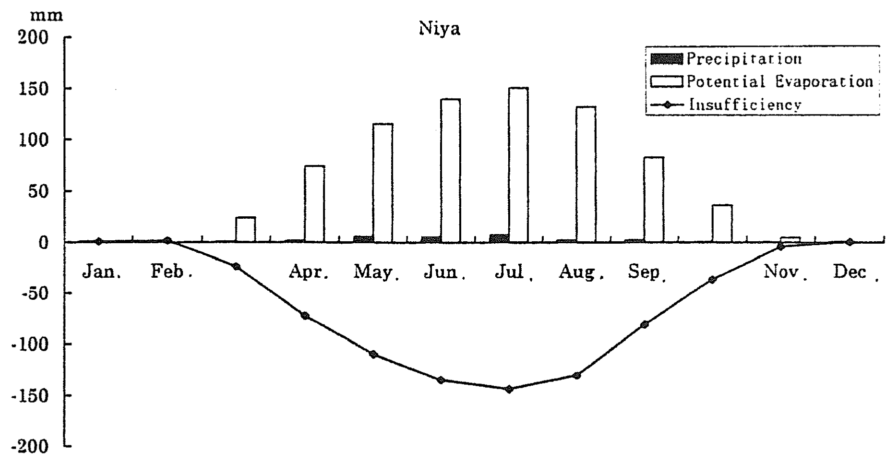


Fig.12 Monthly average precipitation, potential evaporation and water insufficiency at Niya(1959-1979)

Appendix Data 2(H. Takamura and Q. Muhtar)