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# WATER RESOURCES AND OASIS CONSTRUCTION IN TARIM BASIN

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**ABSTRACT:** Based on the description of the main characteristics of water resources in Tarim Basin, the paper discusses the relationships between utilization of water resources and oasis construction, and the protection and development of the oasis in Tarim Basin.
KEY WORDS: water resources, oasis construction, Tarim Basin

In this paper, Tarim Basin includes the mountainous area on the southern slope of the Tianshan Mountains. and the northern slope of the Kunlun Mountain range, but includes neither the closed inland basins such as Turpan Basin, Hami Basin, nor the internal drainage regions.[1](Fig.1)

## I. ENVIRONMENTAL FEATURES

The Tarim River system includes the rivers flowing to Tarim Basin from the southern slope of the Tianshan Mountains and the northern slope of the Kunlun Mountain range. In ancient times, the Kaxgar River, Weigan River and Keriya River all converged in the Tarim River. The Konqi River also joined it. Now, only the Aksu, Yarkant and Hotan rivers have water flowing into the Tarim River.

Tarim Basin is surrounded by mountains. In the north and east, there is the Tianshan Mountains with its ridge over 4,000 m high, and in the south stand the Pamir Plateau, the Karakorum, the Kunlun and Altun mountains which are called the Kunlun Mountains range. Its ridge is over 5,000 m high, and the highest point, Qogir peak, reaches 8,611 m, it is the second highest summit in the world. Only, the east of Tarim Basin is relatively open. Because of these surrounding mountains, the precipitation in Tarim Basin is the least in China. However, its vertical distribution is notable. The annual precipitation in the basin center is less than 25 mm, but on the northern slope of the Kunlun Mountains, it reaches

400 mm and on the southern slope of the Tianshan Mountains about 500 mm.

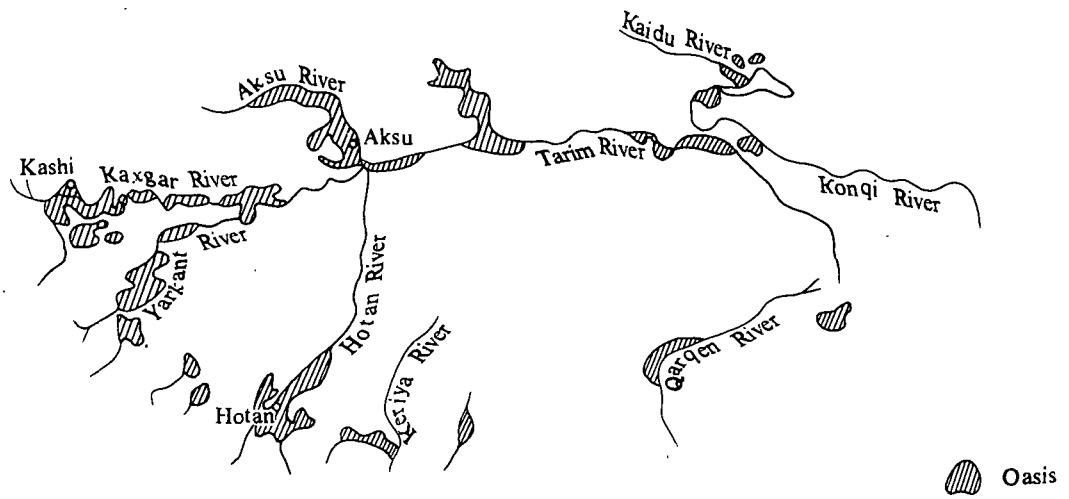


**Fig.1** A sketch map showing the river system and oasis in Tarim Basin

## II. THE GENERAL CHARACTERISTICS OF WATER RESOURCES

Under the influence of the above-mentioned geographical environment, the characteristics of water resources are as follow:[2]

1. Runoff is the main water source in Tarim Basin. Runoff relies on rainfall supply in mountainous area and meltwater from high mountains. In the plain, runoff cannot be formed but only depleted. For example, from junction of the Aksu River and Yarkant to Taiema Lake, the Tarim River's runoff decreases constantly.

Over 80% of ground water resources in Tarim's piedmont plain comes from surface water seepage which includes river seepage, canal seepage, field seepage and storm and flood seepage, etc..

By the recent estimation, the surface water in Tarim Basin is 32.72 billion cubic meters when $p$ is 50%, and 29.29 billion cubic meters when $p$ is 75%. The ground water is 2.016 billion cubic meters in the present situation of utilization of surface water, but it will change along with different conditions of utilization of surface water.

2. Surface water and ground water exchange frequently. In mountainous area, ground water replenishes rivers in the form of base flow, and the rivers, when flowing out of mountain mouth, refill ground water through seepage. Then, at fan fringe ground water outflows in spring and becomes the main part of plain river. Finally, both surface and ground water vanish in irrigated fields, or inland lakes, or desert plain. Such exchange is very useful in reusing water resources.

Meanwhile, the Tarim River runs eastwards and thus rearranges water resource in the

east and the west. Water in the Tarim River comes mainly from three tributaries. According to the measurement at Arlar Station from 1958 to 1979, its average annual runoff is 5.03 billion cubic meters, of which, 13.0% (0.656 billion cubic meters) is from the Yarkant River, 22.5% (1.13 billion cubic meters) from the Hotan River, and the rest 64.5% from the Aksu River.

3. The Variation in an annual runoff is small. The runoff *Cv* of main rivers in Tarim Basin is generally less than 0.3. Both rainfall and meltwater regulate the runoff mutually. In a dry year the rainfall decreases and the meltwater increases, while in a humid year the case is reversed. There appear a few unusual droughts or flooding years which are important for development of oasis. In the local area, disaster exists. For instance, at Langan Station of the Kuqa River the mean annual precipitation is 114.4 , but in 1958 it reached 197.0 mm. The average runoff was 10.3 cubic meters per second in 1958 and it rose up to 14.1 cubic meters per second. They increased by 73% and 37% respectively.

4. The runoff is not well-distributed within a year. Except the Kidao River and those originating in Pamir area, the rivers in Tarim Basin have their runoff which concentrates in summer, especially in July and August. The rivers originating in the northern slope of the Kunlun Mountains are more typical. For instance at Tonguziuok Station of the Yurungkax River, the mean runoff in July occupies 35.3% of the total annual runoff, in August, 32.9%, and that in summer covers 80.6%. The uneven distribution of runoff leads to drought in spring and flood in summer which cannot meet the wheat-irrigating demand. So food grains other than wheat and rice occupy a higher proportion in crop structure. Drought in spring and flood in summer are the main natural calamity to the agriculture in Tarim Basin.

## III. WATER RESOURCES UTILIZATION AND OASIS CONSTRUCTION

1. The basic model for oasis development. From the present oasis to Taklimakan Desert, many ruins of ancient oasis have been found, such as the ancient Jinggue to the north of Minfeng County. Some hold that it is a proof that the climate has turned dry, the desert has invaded southwards and the oasis has receded toward mountainous area.

Recent investigation in Tarim Basin shows that the South Xinjiang has been dry for more than 60,000–70,000 years, though there were some transient humid periods which did not form sedimentary deposit.

Study gives many reasons for the disappearance of the ancient oasis and the formation of the modern oasis, in which the most important reason is that the way of utilization has changed. The primitive agriculture began only in the lower reaches of the inland rivers with even terrain, fertile land and handy water. Under the condition of sparse population, rare farmland and lower productivity, the overflow belt was selected first to plant, where spring water is even during a year and has a higher temperature in winter. With the increase of

population and development of economy, these areas are getting into agricultural regions with cities as their centers and oases their base. To get more knowledge in using water and knowing how to irrigate the land with river water, the man moved from the lower to the upper reaches and set up new agricultural regions. On the other hand, the old irrigated land in the lower reaches became abandoned for the lake of water source. Obviously the water source was deprived by the newly irrigated land at the upper reaches. Moving upward along the rivers, the oasis and irrigated area are enlarged until it is stable near the mountain mouth where water was opulent.

The model described above explains the disappearance of the ancient oasis and the formation of contemporary oasis.

2. The oasis size is closely related with water volume. Generally, the more the annual runoff is, the larger the oasis area is or reversely. The oasis in Tarim Basin plays a key role in Xinjiang, where the cultivated land covers 22 million mu (1 m = 1/ 15 ha), the pasture covers 28 million mu and woodland 14 million mu. They each occupy almost over half of total corresponding land area in Xinjiang. The larger oases in Tarim Basin are all based on big rivers. The Kaidao River at the south slope of the Tianshan Mountains with its runoff 3.38 billion cubic meters, runs into Bosten Lake in Yanqi Basin with other small rivers, and then outflows as the Konqi River to form the Yanqi—Kaidao—Yuli great oasis. There are many tributaries in Weigan drainage, in which the Muzat River is the biggest, has an annual runoff of 1.45 billion cubic meters at Ahebulong Station. It has brought up Baicheng, Xinhe and Xaya oases. The Aksu River is a huge river in Tarim Basin. According to the volume outflow from the mountain mouth, the annual runoff is 4.48 billion cubic meters at Xiehela Station of the Kunmalik River, and 2.61 billion cubic meters at Shaliguilank Station of the Tuxishgan River. The huge volume of water has not only formed Aksu, Wensu Awat oases, but also provided 5 billion cubic meters of water to the Tarim River per year and nurtured the oasis along Tarim Basin.

Kashi is one of the largest oasis in Xinjiang. It comes from the rivers in Kaxgar drainage, including Kizi, Gaizi, Kushan, Kalangoulik, Qakmak, Bugozi rivers and so on. Although each river is small, the total is remarkable. Moreover, the main river, the Kezi River, is a lengthwise valley. In east—west direction the oasis extends longer. Furthermore, several main rivers gather at the lower reaches and set up an arc—shaped oasis containing nine counties of Kashi, Artux, Wuqia, Shifu, Shule, Akto, Yengisar, Yupurhu and Jiashi.

The Yarkant River is the longest river in Tarim Basin. Its annual runoff is 6.45 billion cubic meters at Kaqung Station. With some neighboring rivers such as the Tiznap River, it has constructed Yecheng, Shache, Zepu, Markit and Bachu oases, and set up a unique oasis zone crossing Taklimakan Desert and extending hundreds of kilometers.

The Hotan River oasis, including Hotan, Moyu and Lop, is the biggest oasis at the north slope of the Kunlun Mountains in Xinjiang. Its water source is the Yurungekax River and the Karakax River, and their average annual runoff at mountain mouth is 2.31 and

2.19 billion cubic meters respectively. After converging of these two rivers about 2.2 billion cubic meters of water runs into Taklimakan Desert.

Besides the large oases mentioned above, many middle or small-sized oases are also formed by the independent river system, such as Kuqa oasis of the Kuqa River, Qira oasis of the Qira River, Yutian oasis of the Keriya River and Pishan oasis, etc.

In a word, the oases in Tarim Basin are closely related to their river flow (see Table 1).

**Table 1 Water resources and irrigation area in Tarim Basin**

| River system | Land area ($km^2$) | Cultivated area ($10^4$mu) | River runoff ($10^8m^3$) | Ground water resource ($10^8m^3$) | Total quantity of water resources ($10^8m^3$) |
|---|---|---|---|---|---|
| Kaidu | 4.14 | 149.07 | 38.7 | 1.64 | 40.34 |
| Konqi | 0.89 | 59.57 | — | — | — |
| Dina | 1.24 | 22.91 | 5.80 | 1.06 | 6.86 |
| Weigan | 4.25 | 278.90 | 34.3 | 4.15 | 38.45 |
| Aksu | 4.88 | 302.88 | 43.0 | 4.49 | 47.49 |
| Tarim | 1.79 | 103.85 | — | — | — |
| Kaxgar | 8.01 | 371.97 | 44.8 | 4.25 | 49.05 |
| Yarkant | 7.62 | 428.12 | 67.2 | 1.47 | 68.67 |
| Pishan | 1.24 | 51.72 | 7.44 | 0.41 | 7.85 |
| Hotan | 4.87 | 169.36 | 45.6 | 0.63 | 46.23 |
| Keriya | 4.26 | 90.14 | 21.9 | 1.16 | 23.06 |
| Qarqen | 14.05 | 18.85 | 18.2 | 0.67 | 18.67 |

From Table 1, it can be found that the cultivated area is closely related to the total quantity of water resources. The equation is:

$$y = 48.04 + 6.7x \qquad r = 0.89 \qquad n = 10$$

where $y$ — cultivated area (10,000 mu)

$x$ — total quantity of water resources (100,000,000 $m^3$)

$r$ — coefficient of mutuality

$n$ — term number

3. Oasis in Tarim Basin can be divided into the following three types. 1) Fan-shaped oasis. This type of oasis is in the upper-middle part of piedmont alluvial fan near the mountain mouth, where water is rich and available soil is mainly made of sandy loam and mild clay, thick and fertile; ground water table is deep and runs freely; water quality is good with no steeping of the second salinized soil. Oases of Kashi, Hotan, Aksu and so on belong

to this type. With a long-lived history, these oases are important political, economic, cultural centers as well as industrial and agricultural bases. 2) Oasis along rivers. This kind includes the terraces and alluvial plains at the lower reaches of the middle or large inland rivers, where water is sufficient. As salinization is slight, the narrow and long regions are widely cultivated, such as Markit and Bachu, etc.. 3) Delta oasis. They distribute on dry deltas at the end of the medium or large inland rivers, with plain terrain, convenient water leading, and unsteady water supply. The water supply is affected by the change of river source and human activities at the upper reaches, such as the ancient Loulan oasis, Jinggue oasis and Yumi oases. Most of these oases have been abandoned because their water sources is unstable and the agricultural development on the uppar reaches of the river broke off the water source.

Another kind of old dry delta oasis lies in the river end. With even and low plain, fine and sticky soil and poor drainage system, the salinization is serious and improving is difficult, Yupurhu, Jiashi, Kalabaoy are examples.

At the upper-middle section of the delta formed by the river out of the mountain mouth, such as Korla, various degrees of salinization exist inside the oasis, as there are plenty of surface water and fine soil.

The lakeside delta plains spread mainly in Yanqi of Bosten Lake. The oasis has various degrees of salinization. The cultivated land in Yanqi, which concentrates on the upper middle section, is propped by lake water. However, in the lakeside region, most part of the area is occupied by reed lakes. The salinization is severe.

## IV. PROTECTION AND DEVELOPMENT OF OASIS IN TARIM BASIN

Based on the fact that future oasis industry relies agriculture, maintaining and developing appropriately the present oasis are synthetically determined by many factors. It consists of sandstorm impairing salinized soil improvement, as well as the utilization of agricultural energy resources and so on[3]. But the crucial problem is how to use water resources rationally.

### 1. Developing Water-Saving Agriculture

Developing water-saving agriculture is not only the urgent task at present, but also a long-term goal. Now, the average gross irrigated quota is about 1,000 $m^3$ per mu in Xinjiang, and the highest average gross irrigated quota at Qiemo, Yarqi, Aksu in Tarim Basin can reach 1,500 $m^3$ per mu. On the other hand, the average effective utilized coefficient with the total canal system in Xinjiang is about 0.36. In Tarim Basin the coefficient is far less than it. Comparing with the relatively developed cultivated land in Shihezi, Xinjiang, Tarim Basin's average quota is twice as much as it and the utilized rate is only halfas much

as it. According to the research, if the gross irrigated quota is lowered from 550 to 600 $m^3$ per mu, the irrigated area will become twice as much as the present irrigated quantity. Its potential is very notable.

The serious cropland salinization in Tarim Basin is one reason for the quota limit of irrigation unable to decrease by a wide margin. There must be one time to use water to wash away salt band to decrease alkali in autumn and winter each year, so that the quota is much higher. There are two kinds of regions. One is the fan-shaped land, where water is plentiful, such as Alsu, Yarqi and Baicheng, and where the second salinized area is enlarged year after year because of the convenient water leading, sufficient water source, and the ground water leading, sufficient water source, and the ground water level rising by over-irrigation. The correct method is to use ground water in a planned and rational way, and gradually to control ground water level, reduce the salinized degree and spare water quantity for washing away salt and alkali. The other kind of region is the dry delta oasis at the lowest-lying part of the inland rivers at the lower reaches, such as Jiashi, Yupurhu and Yengisar. Although the improvement in salinization is difficult, the irrigated quota can also be decreased if proper steps are taken.

**2. Ecological Water**

In order to ensure the existence and the development of oasis in Tarim Basin, the ecological environment must be protected, but it is impossible without water. This part of water is generally called ecological water, which should be put forward separately, deducting from the total water. Then the consumption in industry, agriculture and living is considered.

There are two kinds of ecological water in Tarim Basin. One is the water for afforestation and improving ecological environment around oases. For example, because of the severe damage of sand-storm in Qira, breaking sand-storm as well as sand-fixation must be carried out. In the lower part of the Tarim River, there is also the task of protecting and maintaining the "Green Corridor." The other kind is to keep the lake surface area, so that the lakes will not become drought, nor the water level decreased, nor the water quality be damaged because of natural or human disturbance. Bosten Lake is such an example. Surely, it is unnecessary and impossible to rebuild Lopnur and Taitema Lake inside Tarim Basin because the water here will be only exhausted by evaporation and is not brina much beneficial to environment. Based on rough estimation, about 10 billion $m^3$ of ecological water is needed per year in Tarim Basin.

**3. The Protection of the "Green Corridor" in the Lower Reaches of the Tarim River**

Tarim Basin is an enclosed basin except a gap in the southeast, which becomes the "Green Corridor". The Tarim River crosses the "Green Corridor". The corridor is the most

important section of the Silk Road in history. Besides, it runs through by Ili—Ruoqiang highway and the planned Qingxiu road as well as the second strategic channel connecting Xinjiang and the interior, which holds an important position. However, in recent years, after it reaches Daxihaizi reservoir, the Tarim River has stopped sluicing down, and as a result, numbers of *Populus diversifolia* woods have died out, near 300 km from Daxihaizi reservoir to Taitema Lake. Taklimakan Desert is on the verge of destruction. The "Green Corridor" protection is a great environmental problem, and initially, to protect the "Green Corridor" means to utilize rationally the water resources of the Tarim River.

At Alar Station, the average annual flow of the Tarim River from 1957 to 1981 was 4.922 billion $m^3$, out of which, the Aksu River was 72%, the Hotan River was 22.5%, the Yarkant River 5.5%. Before 1974, the Hotan River was 22.5%, the Yarkant River 5.5%. Before 1974, the Yarkant River was an overflowing river. But from 1974 to 1978, it became a seasonal river, and dried up from 1979 to 1983. In 1984, it had some water pouring into the Tarim River, and dried up once a time after Xiaohaizi reservoir enlarged its water storage. Similarly, the Hotan River has water only from July to September. Only the Aksu River has water all the year round. The Tarim River does not construct the river flow in plain regions.

The runoff loss of the Tarim River at various stations from Alar Station are as follows: from Alar to Xinquman, the annual flow was reduced from 4.922 billion $m^3$ to 4.102 billion $m^3$, exhausting 8.90 hundred million $m^3$; from Xinquman to Tarim dam, the annual flow decreased to 3.054 billion $m^3$, depleting 1.048 billion $m^3$; from Tarim dam to Kala, the annual flow went down to 9.32 hundred million $m^3$, losing 2.122 billion $m^3$; then from Kala to Daxihaizi reservoir's irrigation region, it exhausted 1.62 hundred million $m^3$.

From the analysis above, the key step to protect the "Green Corridor" is to use the resources of the Tarim River flow reasonably, which includes the following aspects.

1) It must be based on the scheme of overall tributary's valleys of the Tarim River in order to map a rational utilizing plan with due concerning of Aksu, Hotan and Yarkant strictly, or the project to distribute the whole flow resources will be unable to be accomplished.

2) An authoritative management system toward the Tarim River's resources utilization must be set up in order to assign and apportion it as a whole. Because the Tarim River valley covers a large area of Aksu, Bayingolin Mongolia Autonomous Prefecture and many units of production and construction corps in Xinjiang (if including tributaries, the area is even larger), there must be an unconventional and powerful organ which can act out of the whole benefits. Only in this way can the water resources be used rationally and scientifically.

3) To minimize the water loss in the middle reaches is in most urgent need, because the Tarim River's annual flow changes little at Alar Station but loses horribly in the middle reaches. At present, there are totally 250 to 260 thousand livestock, besides 80 thousand mu

of farmland that yielded only 77 jins (1 jin = 0.5 kg) of average annual unit income in 1980. The gain is really no compensation for the loss to waste 2.123 billion $m^3$ water to produce such a little receipts. According to the previous ration, the probably irrigated area will come up to nearly 8.7 billion mu, equal to the whole Keriya River oasis.

In the middle reaches, the Tarim River has numerous tributaries, among which the Usman River loses water as much as 1.288 billion $m^3$, so it should be brought under control first of all. The Usman River runs eastward to a series of lakes and sunken grounds. During the flooding period, the sunken grounds and lakes combine into a whole, with the area about 200 square kilometers. The annual water wastes in this part is nearly 0.7 billion $m^3$. For a short-term consideration, we can set up a water-control gate to control the influx water to the Usman River. For a long-term, we can make appropriate canals to decrease more effectively the unnecessary water waste. Meanwhile, special grassland irrigating canal systems can be built. Since some *Populus diversifolia* woods that depends on the flood-over flow in the middle reaches will wither away, they can be substituted by manu-woods. In recent years, the technology of *Populus diversifolia* tree's reproduction has been resolved. There are more reasons to develop woods in desert.

Moreover, there are about 20 water-leading points in the lower reaches of the Tarim River, in most of which, it is departed on cutting Chinese tamarist and *Populus diversifolia* trees to temporarily hold up water. This has prolonged the flood-leading time and increased the unnecessary loss and damaged the surrounding vegetation. Therefore the water exiles must be gathered promptly and a permanent or half-permanent canal system should be built to satiate the requirement of irrigation in Kuqa, Xayar, Luntai and Yali etc..

4) The utilization of water resources in the Tarim River is inalienable to the oasis protection and development. To consider the oasis protection and development and the oasis in the lower flow resources is not enough. It should be related with the Kaidu River-Bosten Lake-the Konqi River system.

The Kaidu River is one of the eight large rivers in Xinjiang. Its average annual flow is nearly 3.4 billion $m^3$ (if added up with the small rivers around Bosten Lake, the figure is 4 billion $m^3$). Once it is used for the "Green Corridor" protection, a large amount of unnecessary wasted water will be saved. The records of the water surface evaporating at the station of the upper reaches reservoir over the Aksu River show that the annual surface evaporation reaches 1,300 mm, when seepage loss of water becomes even worse.

But to harness the Kaidu River will certainly touch upon the management of Bosten Lake, which is a very complicated problem. The key solution is how to accelerate the ground water exploitation and utilization in Yanqi Basin. If the water of the Kaidu River is used to protect the "Green Corridor", the flow transformation at the lower reaches of the Tarim River will be limited and some water be saved.

5) Although the Tarim River could carry water from west to east, in term of reasonable using and developing oases, the rationality of the long distance transmission is open to

discussion. Under the condition of realizing water-saving agriculture at the upper reaches, it is certainly rational to develop many oases at the upper reaches. But it should not break the lower reaches of the Tarim River, because the *Populus diversifolia* woods on both sides of the river are very helpful to control dunes and protect environment.

6) The protection of the "Green Corridor" does not mean to reconstruct Taitema Lake, but to keep the corridor unblocked. It is roughly estimated that the aim will be reached if 3 hundred million $m^3$ of water that annually flows down from Daxihaizi reservoir could be got in twice a year.

To sum up, there is no oasis construction in Tarim Basin without water resources. According to the formula, we have estimated grossly the development scale and potentiality of the oases under the present water source utilization, and have drawn a conclusion that in order to maintain the present environment in Tarim Basin, about 10 billion $m^3$ of water is needed, and to protect the "Green Corridor" about 0.3 billion $m^3$ of water is needed too.

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