

AREAL DIFFERENTIATION AND CONSTRUCTION OF OASIS AGRICULTURAL ECOSYSTEM IN THE SHIYANG RIVER BASIN

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ABSTRACT: On the basis of the study on areal differentiation of the natural environment of oasis agriculture ecosystems in the Shiyang River Basin, this paper comparatively analyzes the natural productivities, water economic benefits, production efficiency, ecological stabilities and developmental conditions of the Wuwei Oasis agricultural ecosystem in the middle reaches of the river basin and the Minqin Oasis agricultural ecosystem in the lower reaches. Under a same management level and investment of material and energy, primary productiveness and economic benefits of the former are higher than those of the latter. Construction directions of Wuwei and Minqin oases should be different in order to alleviate the water-use contradiction between the middle and lower reaches. The construction objective of Wuwei Oasis should be efficient irrigated farming production system and Minqin Oasis should become a mixed forestry-pastoral-farming ecosystem taking ecological protection as its major function.

KEY WORDS: oasis agricultural ecosystem, areal differentiation, oasis construction, the Shiyang River Basin

Situated in eastern Hexi Corridor, the Shiyang River Basin is one of the arid inland river basins in northwest China. It has an irrigated oasis area of 5157.61 km², accounting for 12.74% of the basin's total land, which is also one of China's most highly utilized inland river basins. However, the unreasonable exploitation and utilization of water resources such as the over-use of irrigation water in the middle reaches of the Shiyang River, have resulted in a series of ecological, economic and social problems in its lower reaches. A serious of problem water-use contradiction exists between Wuwei Oasis located in the middle reaches and Minqin Oasis in the lower reaches, coupled with a desertification problem in the latter.

I. THE REGIONAL ENVIRONMENT INFLUENCING THE FORMATION OF OASIS AGRICULTURAL ECOSYSTEM IN THE SHIYANG RIVER BASIN

The Shiyang River drainage system starts in the north slope of the Lenglong Mountain situated in the east Qilian Mountains. The basin declines from south to north and can be divided into three sections : the upper reaches (Qilian Mountains), the middle reaches (Wuwei basin), and the lower reaches (Beishan Mountain and Minqin Basin). These are rather different in many aspects of their physical environment, water resource situation, water-supply condition, landtypes, production potential, and regional development direction. Irrigated oases are mainly scattered in the Wuwei and Minqin basins.

The structure of land type in the upper reaches is characterized by “frigid mountain type”, from bottom to upper, which are semidesert sierozem hill and low mountain-steppe chestnut middle mountain-meadow steppe chernozem middle mountain-spruce forest leached greyish drab soil middle mountain-frigid shrubby sub-alpine mountain-meadow high mountain-taiga extremely high mountain-glacier and eternal snow extremely high mountain. In the middle and lower reaches, land type structure has an outstanding characteristic of arid temperate zone desert, where dry denudated hill and low mountain, gravel gobi, sandy desert, swampy depression, salty depression, oases are distributed crisscross(Fig.1).

With a frigid climate and relatively heavy rainfall, the upper reaches act as a water-conserving area consisting mostly of grassland and woodland. Only intermontane basins and valleys are formed. Here, annual mean temperature is generally $2-4^{\circ}\text{C}$, frost-free season is 100—120 days, annual sunshine time is 2,500—3,000 hours, accumulated $>10^{\circ}\text{C}$ temperature is only 200—1,600 $^{\circ}\text{C}$. And the frigid mountains over 2,500 m a.s.l. receive an annual precipitation of 400—800 mm and have an annual temperature of less than 2°C . Snow and glaciers appear above 4,400 m, having a glacial area of 64.82 km^2 and a reserve of 2.143 km^3 , which acts as “natural solid reservoir” feeding the oases in the Shiyang River Basin. In the areas where pastoralism and forestry can be expected to be well developed, farming is low-productive and unstable. For the sake of agricultural development, ruthless cutting and burning of forests, shifting cultivation, and over-grazing should all be strictly prohibited, and much attention should be paid to soil and water conservation.

The middle reaches lie mainly on the arid corridor plain, which is a major region of irrigation agriculture. Annual precipitation there total only 100—200 mm, yet high-quality irrigation water is plentiful and irrigation conditions are excellent. Heat resources are richer, being full of sunshine, which can satisfy the need that spring wheat, potato and so

on ripen once a year.

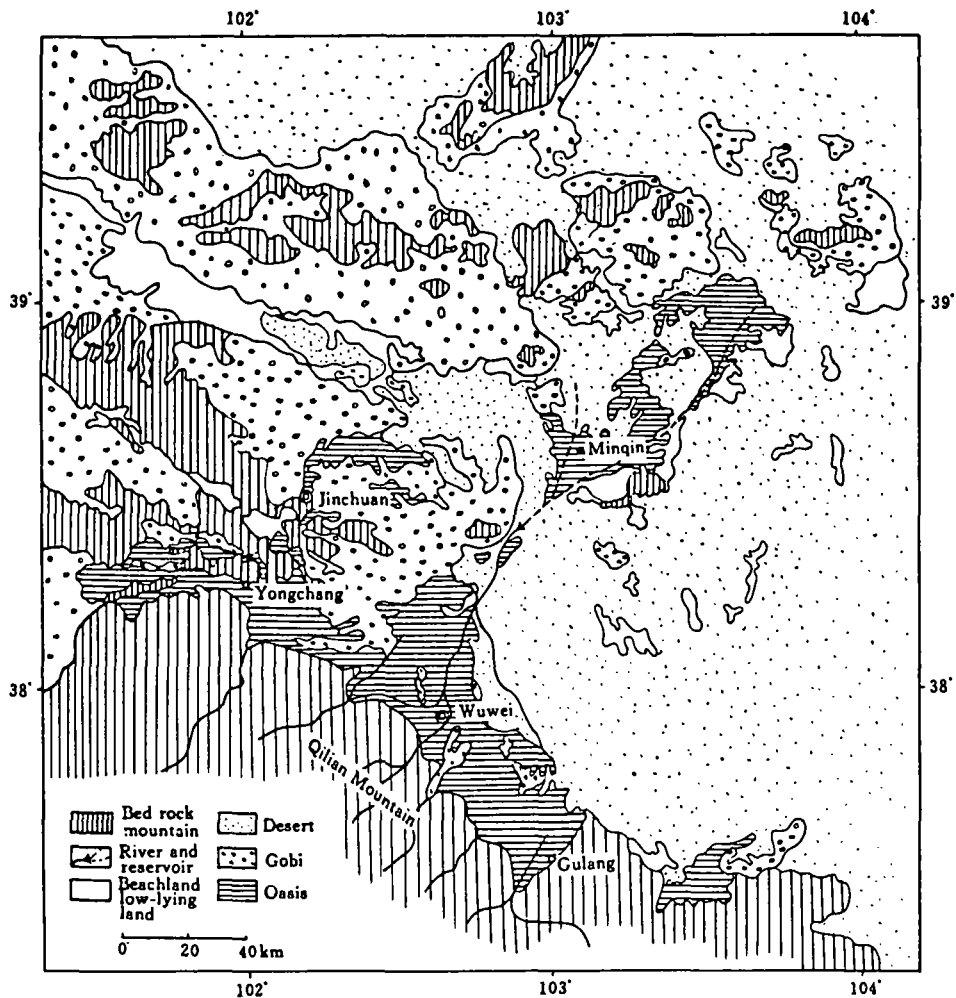


Fig.1 Land types and distribution of oases in the Shiyang River basin

The lower reaches are an extremely arid zone, with an annual rainfall of only 50—100 mm in normal years and an accumulated $> 10^{\circ}\text{C}$ temperature of more than 3,100 $^{\circ}\text{C}$. Oases are interspersed among gobi, sandy land, clay flat land, hills and low mountains. Minqin Oasis is encircled by the Tengger Desert and the Badain Jaran Desert in the east, north and west. Ecoenvironments of this kind are precarious and unfavorable for farming and animal husbandry. The primary limiting factors involve drought, sand hazards, and salinization, which are responsible for low and unstable yields of crops and grasses.

In the Shiyang River Basin, the suitability of climatic conditions gradually decreases from the middle reaches to the lower reaches (Table 1). The highest elevation for planting

crops is commonly 2,800 m. Crops ripen once a year in montane areas, and two or three times every two years in basins and valleys. According to correlation analysis, during its growing season (April–July in river valleys, May–August in montane areas), there is a power function relationship between altitude (from 1,450 to 2,800 m) and precipitation, with a correlation coefficient of 0.9851. The regression equation is

$$P = 0.1651 \times 10^{-7} H^3$$

where P refers to precipitation and H refers to altitude.

Table 1 Agricultural climatic conditions in the Shiyang River Basin

Location (altitude)	Gulang (2,027 m)	Huangyang (1,766 m)	Wuwei (1,530 m)	Minqin (1,376 m)
Precipitation(mm)	246	216	161	115
Frequency of dry hot wind (time/ year)	0	0.7	1.2	1.7
Dust storm (days/ year)	4.5	12.0	15.9	27.9
Frequency of drought from May to August	18	36	30	39

Autumn crops consist mainly of millet, Irish potato, and corn in the basin. Their upper growing limits are 1,900 m, 1,900 m, and 1,700 m, respectively. Their growing season is from May to September in river valleys and from May to August in montane areas. During this period, precipitation is proportionally related to altitude, with a correlation coefficient of 0.99563⁽¹⁾. The regression equation is

$$P = -149 + 0.1797H$$

where P refers to precipitation and H refers to altitude. From the view of correlation analysis between soil organic matter and altitude, soil fertility decrease from the middle reaches to the end of the Shiyang River Basin, while the content of the organic matter in the soil is positively correlated to altitude, with a correlation coefficient of 0.9527. The regression equation is

$$S = -2.2913 + 0.002363H$$

where S is refers to soil organic matter and H refers to altitude.

II. CONTRASTIVE ANALYSES ON PROPERTIES AND PRODUCTION EFFICIENCIES OF THE OASIS AGRICULTURAL ECOSYSTEMS

1. Natural Production Capability in Wuwei Oasis Is Higher than That in Minqin Oasis

Wuwei Oasis is situated in the front of piedmont plain in the middle reaches where groundwater emerges from springs, and Minqin Oasis is located in lacustrine-alluvial zone in the lower reaches. In order to qualitatively analyze the difference of natural production capabilities in Wuwei and Minqin oases, a correlation analysis is made between spring wheat yield and three independent variables (precipitation in the growing season for spring wheat, content of organic matter in the soil, and the area of irrigated land per person). Regression equation (1) is supported by the data from more than sixty villages and towns in Wuwei and Minqin counties; equation (2) is based on the data from fourteen irrigated areas in the same two counties.

$$Y = 513.084 + 1.7715X_1 + 142.022X_2 - 131.7368X_3 \quad (1)$$

$$Y = -71.2994 + 1.0265X_1 + 456.8937X_2 - 0.5258X_3 \quad (2)$$

where Y stands for spring wheat yield, X_1 is precipitation, X_2 is organic matter content, and X_3 is the area of irrigated land per person.

For equation (1), the complex correlation coefficient is 0.6677, and for equation (2), the coefficient is 0.9236. Supposing that both Wuwei Oasis and Minqin Oasis have 18 ha of irrigated land per person, which is normal in the lower piedmont plains of the Shiyang River Basin, then we calculate spring wheat yields in different places with equation (2). It is shown that the natural yield of spring wheat decreases evidently from the middle reaches to the lower reaches (Table 2).

Table 2 The difference of natural qualities in various sections of the Shiyang River Basin

Item	Irrigated area among mountains	River-water irrigated area	Well-spring irrigated area	Lacustrine plain
Precipitation during growing season for summer crops(mm)	98.7	88.6	67.5	20.7
Content of soil organic matter(%)	1.65	1.42	1.33	0.72
Natural yield of spring wheat(kg/ ha)	5572.5	4995.0	4522.5	2085

2. Economic Benefit of Water Utilization in Wuwei Oasis Is Higher than That in Minqin Oasis

Water is an important factor limiting agricultural development and oasis construction in arid lands. It is of special significance to make effective use of water resources in such areas. To do this, we need to determine the optimum irrigation water quota in different parts of the Shiyang River Basin. Data concerning experimental spring wheat yield and irrigation water amounts in six experimental irrigation stations (Jinta, Huangyang town, Wangjǐngzhai, Xiaobakou, Quanshan, and Zhouqu) were collected from 1980 to 1985. According to calculating results, the optimum irrigation water quota are as follows :

Wuwei Oasis:	3,675 m ³ / ha
Dyke area in Minqin Oasis:	4,440 m ³ / ha
Lake area in Minqin Oasis:	4,260 m ³ / ha

It is obviously shown that the economic benefit of water utilization decreases from Wuwei Oasis to Minqin Oasis, with a reduction of grain yield from middle reaches to the lower reaches.

For the irrigation quota of farmlands (first crops) in the Shiyang River Basin, their distribution is not very balanced. For example, it is 4,500 m³/ ha in Wuwei County's mountain area, 7,425 m³/ ha in the river-water irrigated areas, 8,025 m³/ ha in the well-spring water irrigated areas, 6,405 m³/ ha in the Minqin County's irrigated area along the river, 6,900 m³/ ha in the Hongyashan irrigated area, and 6,525 m³/ ha in the Changning irrigated area. Actual irrigation quation here is much higher than the optimum. A lot of water resources are extravagant because oases in different section don't use water reasonably according to their optimum irrigation quota.

From the view of the grain yield per unit water in irrigated areas with different water-source types in the Shiyang River Basin, the comprehensive irrigation benefit of well-spring irrigated areas is highest, owing to the superior condition of water and land resources. The second highest occurs in river-water irrigated areas, and the lowest is in the lacustrine plain. For instance, the grain yield per unit water is 0.305 kg/ m³ in the lacustrine plain in Minqin County.

The above-stated analysis shows that oases in the middle reaches, especially in the front of piedmont plains where groundwater emergers from springs, are high-quality and efficient agricultural production systems, but others, in the lower reaches, have relatively low productivity; and oases with the lowest economic benefit appear in the end of arid inland river basins. In order to obtain the same harvest in the lower reaches as in the middle reaches, more irrigation water is needed. Historically, Wuwei Oasis, located in the well-spring irrigated area, were always the most prosperous and stable section in the Shiyang River Basin, but the Minqin Oasis, located in the end of the river basin is going to decline.

3. The Development Conditions and Ecological Stability in Wuwei Oasis Are More Superior than That in Minqin Oasis

Not only does ecological climatic suitability for crops gradually decrease from Wuwei Oasis to Minqin Oasis, but also both water supply and water quality in the former are more superior than that in the latter, and salt content in soil obviously increases from the middle reaches to the lower reaches. Now the degree of mineralization in soils is too high, generally up to 3—4 g/ L, even to 25 g/ L in some places. Generally speaking, the underground water with a high degree of mineralization for irrigation for a long time, and the content of salt in soils is speedily raised from 0.27% in the 1950s to 0.5%—1.5% at present. In Minqin County, a large cultivated land has been salinized, in which the areas of soils with light salinization, with medium salinization and with heavy salinization account for 48%, 21%, and 15% of the total cultivated land area, respectively⁽²⁾, which lead to an obvious reduction of land productivity. On the other hand, the Minqin Basin has a low-lying landform, which is unfavorable to the deserts in the east, north and west, with serious sandinization and salinization, and its ecological stability is worse.

III. OASIS CONSTRUCTION AND DEVELOPMENT DIRECTION

Although 0.3×10^8 — $3.5 \times 10^8 \text{ m}^3$ of groundwater was over-used a year in the Shiyang River Basin, yet the need of irrigation for present cultivated land here cannot be satisfied, and the rate of assuring irrigation is only about 68%. Water resources are so limited in the basin, and it is almost impossible for the lower reaches to get enough water. To remedy this situation, the following measures should be taken: determining farmland area according to amount of available water, compressing farmland area according to lower reaches, developing intensive farming, making full use of water, increasing the input of chemical fertilizers and new techniques, ameliorating the low-medium yield farmlands, increasing per unit yield, etc.

1. Making Wuwei Oasis as an Intensive Efficient Irrigated Farming Production System

Wuwei Oasis lies on the arid corridor plain, with a flat landform, large concentrated farmlands suitable for tractor-ploughing. Here agricultural production base and irrigation conditions are better, and economic benefit of water use is the highest in the Shiyang River Basin, which is favorable to specialization of agricultural production. The development direction of Wuwei Oasis should take grain production as leading, focus on the amelioration of cultivation system, carry out intensive management, make a comprehensive development of agriculture, forestry and animal husbandry. Through inputting enough power, pesticides and agrotechniques, as well as intensive cultivation, main attention is paid to ameliorating

the low-medium yield farmlands, increasing soil fertility and per unit grain yield. Other measures are to make well the construction of shelter forest system along oasis border and farmlands, and to strengthen the protection of natural vegetation and the measures of sand-fixation in the shifting sands east to Wuwei Oasis. From now on limited water resources should be fully and intensively used, strengthening the study and application of oasis agriculture and water-saving techniques, ameliorating the low-medium yield farmlands, controlling secondary salinization of soils, making Wuwei Oasis become into a high-quality, efficient commodity grain production base in the Hexi Corridor.

2. Making Minqin Oasis Become a Mixed Forestry-Pastoral-Farming Ecosystem Taking Ecological Protection as Its Major Function

Minqin County is an emphasized area in the "Three North" Shelter Forest Belt. At present, Minqin Oasis is a typical desert oasis in the Alxa Plateau, and large deserts lie in its interior. In addition, vegetation is rare and declines, ecoenvironment is very fragile. Here groundwater quality is bad, water source for irrigation is seriously lack, and large area of cultivated land have been abandoned. Since the 1950s, many wells have been driven and the over-exploitation of undergroundwater has led to the gradual reduction of the groundwater table, which seriously restricts the production of grain and herbage. During the recent one hundred years, large oases east to the Daxi River were engulfed by shifting sand. At present, shifting sand is swallowing farmlands and oases with a speed of 8 metres a year in the lake area. Minqin Oasis is the outpost preventing sands going on, so its construction objective should firstly be ecological protection. On the basis of keeping a few irrigated farmland, developing protective forestry and animal husbandry, strengthening the construction of shelter forest belt along the borders of oases, artificial grassland and animal husbandry, having Minqin Oasis become a mixed forestry-pastoral-farming ecosystem taking ecological protection as its major function. This is also a way to solve the water-use contradiction between Wuwei Oasis and Minqin Oasis.

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