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# The Influence of the Dam Construction on Plant Types in Shiyang River

**Wei Huaidong[1, 2], Li Jingjing[2, *], Zhang Bo[1], Li Ya[2]**

[1]Collage of Geography and Environmental Science, Northwest Normal University, Lanzhou, China

[2]Gansu Desert Control Research Institute State Key Laboratory Breeding Base of Desertification and Aralian Sand Disaster Combating, Lanzhou, China

**Email address:**
weihdgs@126.com (Wei Huaidong), jingjing890520@sina.com (Li Jingjing)

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**Abstract:** Shiyang River Basin, as the high extent of exploitation & utilization of its resources and severe ecological & environmental issues, has always received much attention from scholars at home and abroad. The research, with reference to previous scholars' conclusion and field survey, showed that the dam construction has resulted in the radical changes of water resource distribution as well as water resource utilization mode, which eventually had a strong effect on plant species and community change along the middle and lower reaches of the Shiyang River. The mainly result include: 1) The vegetation area, vegetation cover and biomass all decreased, plant types had changed from wet series to xeric series, *Tamarix ramosissima*, *Kalidium foliatum* and *Phragmites australis* etc community had gradually decreased, the vegetation with more drought tolerance had gradually occupy the dominant position, mainly includes *Nitraria tangutorum*, *Reaumuria soongarica*, *Lycium ruthenicum* etc, especially *Nitraria tangutorum* had become constructive species in most of the place in the middle and lower reaches of the Shiyang River since 1950's. 2) In the middle and lower reaches of the Shiyang River, The vegetation formed various adaptive way and xeromorphic characteristics in order to adapt the adverse environment such as the serious sand storm, the higher difference of temperature between day and night, the lower precipitation and the higher evaporation etc. The ring gate types gradually became the main types of structure of leaf in the region of relatively severe of human disturbance, the full gate types plants and normal types plants gradually increased in the region of relatively less of human disturbance, the type of structure of leaf changed from the ring gate types and normal types to irregular molding in the region of sharply decreased of groundwater. The dam construction caused reclaiming wasteland for farming on a large scale, disproportionate use of water resource, groundwater overdraft of and deterioration of water quality etc, and this eventually lead to change of areas and types of vegetation.

**Keywords:** Shiyang River Basin, Plant Types, Dams, Water Resources Utilization, Groundwater

## 1. Introduction

The Shiyang River Basin is one of the typical inland river basins in the arid area of Northwest China. Its landforms can be divided into four units: the southern Qilian Mountains, the central corridor plains, the northern hills and the deserts. The distribution of vegetation type has obvious zonal characteristics with the change of landscape, including alpine meadow, forest, desert, and oasis etc. In the 1950s and 1960s, nearly 30 dam reservoirs were built in the upper and middle reaches of the basin. Since then, the distribution of water resources and utilization model of underground water have been a fundamental change. Especially in the downstream, due to the interception of water resources in the middle reaches, coupled with the increase of cultivated land and population, a large amount of over-exploitation of groundwater forms a funnel-like groundwater level in the center of the oasis, and the vegetation has basically changed to rely entirely on rainfall for survival [1-5].

Shiyang River Basin, as an inland river basin with a high level of development and utilization in China and a prominent environmental problem, has become an ecologically sensitive area and a fragile zone [6]. It has attracted the attention of researchers at home and abroad. Vegetation as one of the important factors of the ecological environment, there are many related research reports, from the aspects of the adaptation of species diversity to water resources, the response of vegetation to climate change, the dynamics of vegetation cover, etc. The main factors of vegetation change are groundwater and air temperature. Vegetation manifests as species reduction, coverage decrease, and overall development in the direction of degradation [3-11]. However, these studies are mainly concentrated in the lower reaches of the river basin, or in a certain period of time, and there is a lack of systematic research on the process of vegetation change before dam construction in the basin. Studying the process of vegetation changes since dam construction and operation in the Shiyang River Basin, and analyzing the impact of dam construction on the basin's vegetation, is one of the important contents of the comprehensive assessment of the ecological benefits of dam construction in the Shiyang River Basin. Based on data collection and field surveys, this paper has studied the process of vegetation changes before the construction of dams in the Shiyang River Basin, and has focused on the change of plant type and its adaptation to the external environment, aiming to provide a reference for the study of the influence and response of the dam construction in the inland river basin, and to provide a scientific basis for the watershed water managers to develop a rational use of water strategy.

# 2. Materials and Methods

## 2.1. Overview of the Study Area

The Shiyang River Basin is located in the eastern part of the Hexi Corridor, northwest China, between the east part of the Qilian Mountains and the Bardan Jaran Desert and the Tengger Desert, east longitude 101°41'~ 104°16' and latitude 36°29'~ 39°27'. The drainage area is 4.16 × 104 $km^2$, and administrative districts includes part of Tianzhu County, the whole part of Liangzhou District, Gulang County, Minqin County of Wuwei city, the whole part of Yongchang County and Jinchuan District of Jingchang city, and part of Sunan County, Shandan County of Zhangye city [12, 13]. It is high in the southwest and low in northeast. The elevation is 1020 ~ 5254 m. The climate is typical continental temperate arid climate, long sunshine hours, high intensity, and large temperature difference. The amount of evaporation is high; however the amount of rainfall is little. The overall show the south is more and the north is less, the east is more and the west is less. In particular, the annual precipitation in the plain area is only 150 ~ 300 mm, the annual precipitation in the downstream desert area is less than 120 mm. However, the annual evaporation is up to 1300 ~ 2600 mm. The evaporation is much larger than the precipitation, and the drought index is above 52, is a typical temperate continental arid climate. This place is drought, cold, large temperature difference between day and night, little precipitation, large evaporation, strong wind and more sand, the natural conditions are very bad, and the ecological environment is extremely fragile [14]. The Shiyang River Basin is composed of Dajing River, Gulang River, Huangyang River, Zamu River, Jinta River, Xiying River, Dongdahe River, and Xidahe River, etc. from east to west. It consists of eight major rivers and many small rivers. The resource of feeding of a river are the precipitation in the mountainous area and melting of snow and ice in mountain streams, and the runoff producing area is $1.11\times10^4$ $km^2$, and average annual runoff is $1.56\times10^9$ $m^3$. In the past 20 years, the population of the whole basin has increased by 33%, and the irrigation area of farmland has increased by 30%, and the total amount of water resources has not increased and reduced by about 1%, and the water supply and demand are in sharp conflict. At present, the Shiyang River Basin has become the most densely populated watershed in the inland river basin in China, with the highest water resources exploitation and utilization, the most prominent contradiction of water use and the most serious ecological and environmental problems.

## 2.2. Research Method

### 2.2.1. Acquisition of Historical Data and Investigation of Vegetation Status

The vegetation historical data of Shiyang River Basin before the construction of the dam to the end of the last century can be acquired through the archives at all levels, museums, research institutes and other institutions [15-23].

In the Shiyang River Basin, 43 wasteland samples were selected as the survey object (22 in the middle reaches and 21 in the downstream). Field surveys were conducted between 2013 and 2017. Each wasteland survey recorded information on plant species, coverage, and biomass.

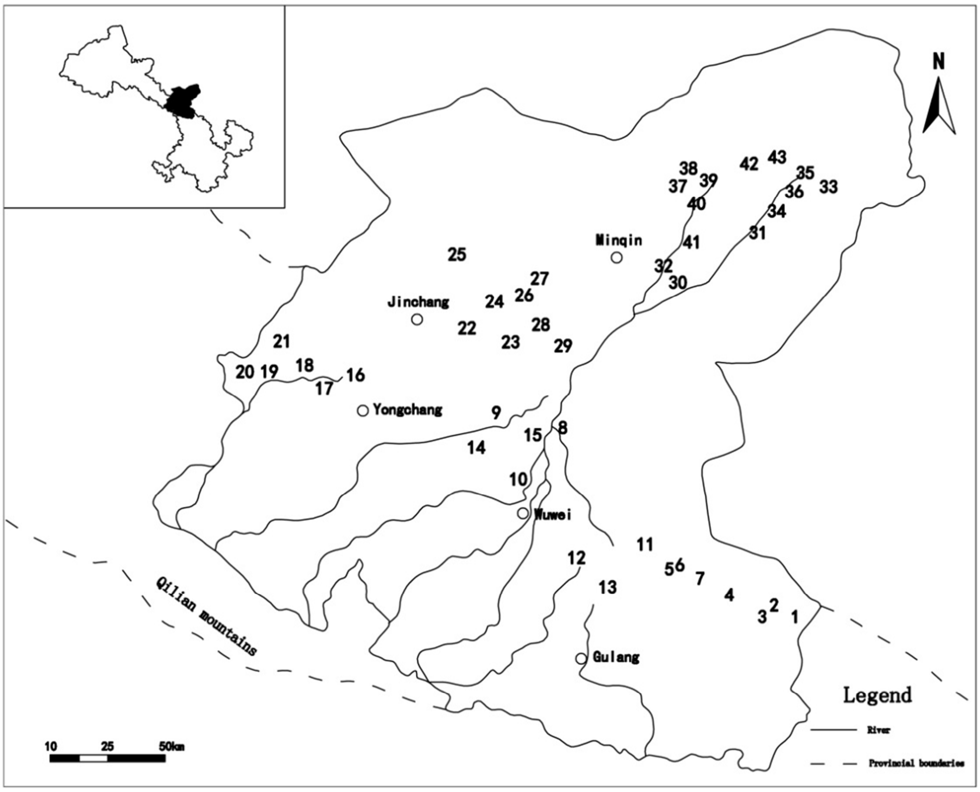


***Figure 1.*** *Location map of vegetation survey samples.*

1: Zhitan; 2: Haizitan; 3: Hongliugoukoutan; 4:Majiawantan; 5: Baibantan; 6: Malutan; 7: Huanghuatan; 8: Jiuduntan; 9: Labaquantan; 10: Taipingtan; 11: Wujiajintan; 12: Dajiazhaitan; 13: Huangyangtan; 14: Huangmaotan; 15: Hongxiangtan; 16: Bayi Farm; 17: Maobulaitan; 18: Yuelianghutan; 19: Baidunzitan; 20: Xiuhua Temple; 21: Huacaotan; 22: Shangtan; 23: Xiaojinzi; 24: Tianshengkeng; 25: Jijiquantan; 26: Changning Commune; 27: Nanbancao; 28: Beibanguitan; 29: Jiangoutan; 30: Zhongliuba; 31: Honghantan; 32: Hongliuduntan; 33: Hongshahutan; 34: Dongsangouchaiwan; 35: Donglvtan; 36: Yingketan; 37: Maotiaoshan Pasture; 38: Sanjiaocheng; 39: Hongshaliangtan; 40: Heshenggoutan; 41: Hongliuyuandongtan; 42: Juyuantan; 43: Qingtu Lake;

#### *2.2.2. The Investigation Method of Cover Degree*

Three plots of 100 m in length were placed on each sample plot in the area with even growth. The length of all plant lines on the sample line was recorded, and the percentage of the line length and the total length of the plant was calculated.

$$C = \frac{\sum B}{L} \times 100\%$$

C is the vegetation coverage, B is the length of the plant pressure line, L is the length of the sample line.

#### *2.2.3. Division of Plant Types*

In order to adapt to the arid environment, desert plants adapt to the external environment by changing the structure of the leaves. Referring to the related leaf classification literature of desert plants [24-29] and combining the morphological indicators of plants [30], according to the differentiation of the mesophyll and the arrangement of the cells, the main vegetations in the middle and lower reaches of the Shiyang River were classified into 6 types: normal types, full gate types, ring gate types, irregular molding, degenerate types, and grass types.

## 3. Results and Analysis

### *3.1. Plant Types and Their Changing Process*

#### *3.1.1. Plant Types in the Shiyang River Basin*

A total of 70 species of plant species were recorded by the field investigation of 43 wastelands in Shiyang river basin, including 37.14% of shrubs, 40.00% of perennial herbaceous plants and 22.86% of annual herbaceous plants. Most of the plant species showed the superxerophytic undershrub synusia, the strong xerophobic small shrub synusia and the xerophytic herbaceous synusia (Table 1). All the species are divided by vane type, the ring gate types plants accounted for the highest percentage, total number is 27 species, accounting for 38.57% of the total number of species, including shrubs 44.44%, annual herbaceous plants 37.04%, and perennial herb 18.52%. The plants of larger frequency mainly include: *Peganum harmala L., Artemisia desertorum spreng. Syst. Veg, Salsola ruthenica lljin in Coph. Pact, Bassia dasyphylla, Halogeton glomeratus, Kalidium foliatum, Artemisia scoparia*, and so on. Followed by the full gate types plants, a total number is 12, of which 33.33% of shrubs, 25.0% of annual herbaceous plants, 41.67% of perennial herb. The plants of larger frequency mainly include: *Corispermum* *patelliforme, Agriophyllum squarrosum, Inula salsoloides, Chenopodium glaucum, Astragalus membranaceus* and so on. The grass type plants accounted for 15.71% of the total species. There were no shrub species in the grass type, mainly is the perennial herb, accounted for 72.73%, and 27.27% of the annual herb. The plants of larger frequency mainly include: *Agropyron cristatum, Carex tristachya, Stipa glareosa, Phragmites australis, Chloris virgata, Setaria viridis, Eragrostis pilosa* and so on. Irregular molding plants accounted for 14.29% of the total species. There is no annual herbaceous plants in the irregular molding, among which perennial herb accounted for 60%, shrubs accounted for 40%. The plants of larger frequency mainly include: *Nitraria tangutorum, Nitraria sphaerocarpa, Echinops gmelinii, Heteropappus altaicus* and so on. The number of normal types and degenerate types is less, and the normal types accounted for 8.57% of the total species, of which 33.33% of shrubs, 66.67% of perennial herb. There is no annual herbaceous plant in normal types. The plants of larger frequency mainly include: *Reaumuria soongarica, Sophora alopecuroides, Sphaerophysa salsula, Limonium aureum, Tamarix ramosissima, Potentilla bifurca L,* and so on. The degenerate types accounted for 5.71%, only shrubs in this type, and without herbaceous plants in this type. The plants of larger frequency mainly include: *Haloxylon ammodendron, Calligonum mongolicm, Ephedra przewalskii, Anabasis brevifolia* and so on.

***Table 1.*** *Major proportion of plant types in middle and lower reaches of Shiyang River Basin (%).*

| Leaf types | Proportion | Shrub | Annual herbs | Perennial herbs |
|---|---|---|---|---|
| Normal types | 8.57 | 33.33 | 0.00 | 66.67 |
| Full gate types | 17.14 | 33.33 | 25.00 | 41.67 |
| Ring gate types | 38.57 | 44.44 | 37.04 | 18.52 |
| Irregular Molding | 14.29 | 40.00 | 0.00 | 60.00 |
| Degenerate types | 5.71 | 100.00 | 0.00 | 0.00 |
| Grass-types | 15.71 | 0.00 | 27.27 | |

### *3.1.2. Process of Plant Type Change*

The importance of different types of plants was calculated based on the importance of the plant in the community (Table 2).

In the middle reaches of the river basin: on sandy grassland, the plant type changes reflected as the important values of irregular type decreased from 80% in the 1950s era to 25.5% in 2013, and the important values of normal type, full gate type, and ring gate type plants are increased gradually. The important values of the ring gate type plants increased from 13.4% in the 1950s to 54.1% in 2013, which occupies an absolute dominant position, and is currently the main plant type in the region. On gravel grassland, the plant type changes reflected as the important values of ring gate type decreased from 67.9% in 1950s to 32.5% in 2013, gradually exited, and the number of norm type and full gate type increased gradually. The important values of normal type increased from 8.9% in 1950s to 44.7% in 2013. And it is currently the main plant type in this region.

In the downstream of the river basin: The changes of plant types are mainly reflected in four aspects. In salinized grassland, the normal type, irregular modeling, and grass type plants gradually withdraw, and the ring gate type plants gradually increased. The ring gate type plants reached 47.6% in 2010s, occupying absolute advantage. The normal type plant is dominated on sandy grassland in 1950s, reaching 54%. Then it gradually decreased, but it always occupied a dominant position, and is the main plant type in this region until in the 2010s. On gravel grassland, vegetation showed that the grass type plants gradually withdrew, and the full gate type plants gradually increased. The ring gate type plants occupied the absolute advantage, reaching 67.9% in the 1970s. At present, the normal type plants are the main constructive species, reaching 45%.

***Table 2.*** *Dominance changes at different time types of plants.*

| Habitats | | Period | Important values | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Normal types | Full gate types | Ring gate types | Irregular Molding | Grass types | Degenerate types |
| Middle reaches | Sandy grassland | 1950s | 0 | 0 | 13.40 | 80.00 | 6.70 | 0 |
| | | 1970s | 1.70 | 0 | 37.60 | 52.50 | 8.30 | 0 |
| | | 2010s | 2.00 | 11.90 | 54.10 | 25.50 | 6.50 | 0 |
| | Gravel grassland | 1950s | 8.90 | 0 | 67.90 | 7.50 | 15.70 | 0 |
| | | 1970s | 41.30 | 15.00 | 3.80 | 27.50 | 12.50 | 0 |
| | | 2010s | 44.7 | 9.10 | 32.50 | 0 | 13.80 | 0 |
| Downstream | Salinized grassland | 1950s | 12.5 | 12.5 | 25 | 25 | 25 | 0 |
| | | 1970s | 5 | 25 | 35 | 10 | 20 | 5 |
| | | 2010s | 4.8 | 19.0 | 47.6 | 9.5 | 14.3 | 4.8 |
| | Sandy grassland | 1950s | 54.00 | 2.00 | 22.70 | 9.30 | 12.00 | 0 |
| | | 1970s | 21.40 | 14.30 | 35.70 | 0 | 14.30 | 14.30 |
| | | 2010s | 35.30 | 0 | 25.00 | 23.00 | 0 | 16.70 |
| | Gravel grassland | 1950s | 33.30 | 0 | 16.70 | 16.70 | 33.30 | 0 |
| | | 1970s | 2.00 | 5.70 | 67.90 | 5.00 | 19.50 | 0 |
| | | 2010s | 45.00 | 10.30 | 24.30 | 10.70 | 9.70 | 0 |

### *3.2. Dam Establishment Affects Vegetation Change*

#### *3.2.1. Changes of Vegetation Area*

(1) Change of vegetation area in the middle reaches

From the 1950s to the present, with the continuous increase of population and the construction of dams, in the middle reaches of the river basin, except for the area between Baidunzitan and Shandan Xiuhua temple of Yongchang, the area was not reclaimed, and mainly animal husbandry, Most wasteland of the Gulang and Yongchang has been developed and utilized, but Liangzhou District has been developed in almost all areas except for a small part of Jiuduntan. Most of the developed wasteland has been used as farmland. Large-scale farms such as Huangyang Farm and Bayi Farm have been established in Liangzhou District and Yongchang County. From the 1970s to 2010, the area of cultivated land in the middle reaches increased by $1.5\times10^5$ $hm^2$ (Table 3). Dam construction triggered large-scale land reclamation, resulting in a drastic reduction in the area of vegetation in the middle of the past decades.

***Table 3.*** *Arable land changes of middle and lower reaches of Shiyang River Basin.*

Unit: $hm^2$

| Periods | 1973 | 1987 | 1994 | 1998 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Downstream | 67525.426 | 82860.276 | 101975.84 | 120787.61 | 140493.88 | 137834.95 |
| Middle reaches | 298106.72 | 329360.66 | 346004.09 | 367225.75 | 425330.62 | 447805.75 |

(2) Characteristics of changes in downstream vegetation area

The downstream Minqin area is limited by soil conditions. Although the intensity of land reclamation is lighter than that of the middle reaches, there has been relatively large-scale farmland cultivation in the past decades. From the 1970s to 2010, the area of downstream cultivated land has increased by $7.03\times10^4$ $hm^2$ (table 3). Because only the water stored in the Hongya Mountain Reservoir can be used for irrigation, it is far from satisfying the need for irrigation. Therefore, excessive groundwater is used for groundwater extraction. The groundwater level has dropped drastically, and most of the natural vegetation in Qingtu Lake, Dongzhen Community, and Sanjiao City has declined. The area of vegetation gradually decreased. At the same time, in most areas where the groundwater level has dropped drastically, most of the arable land has been abandoned due to its inability to water. According to incomplete statistics, as of 2001, nearly 60% of the newly reclaimed land in Minqin County was abandoned due to lack of water resources. There is a new vegetation growth in the arable land, so although the vegetation area in the downstream has also been reduced, it is relatively light in the midstream. The groundwater level has declined, which is one of the most important causes of the reduction in the area of vegetation, which is also caused by the unbalanced utilization of water resources caused by dam construction in the middle and upper reaches.

#### *3.2.2. Changes of Plant Species*

(1) Change of plant species in the middle reaches

Most of the wastelands in Gulang and Liangzhou districts are sandy grasslands before untapped and utilized. *Nitraria tangutorum* is the main constructive species, *Artemisia ordosica* is the main accompanying species, and then with the gradual fixation of sand dunes, *Nitraria tangutorum* gradually exits. The succession of the vegetation itself is accompanied by artificial spreading (mainly on the Malutan, Haizitan, Baibantan, Jiuduntan, etc.) *Artemisia desertorum* and *Artemisia ordosica* seeds. At present, *Artemisia desertorum* and *Artemisia ordosica* have become the region's Dominant population. Labaquantan of Yongchang, Baidunzitan, Shandan Xiuhua Temple and other places are typical gravel grassland in the middle reaches. Before being disturbed by humans, *Kalidium foliatum* dominated, and *Nitraria tangutorum* is the main accompanying species. With the gradual increase of grazing intensity and development and utilization, the groundwater level began to decline, coupled with the influence of global warming, the environment in the area gradually became more arid, *Kalidium foliatum* gradually withdraw. Drought-tolerant species such as *Nitraria tangutorum*, *Reaumuria soongarica*, etc. have gradually increased. At present, *Reaumuria soongarica* as a typical xerophyte has replaced *Kalidium foliatum* as the dominant population in the region (Table 4).

***Table 4.*** *Vegetation characteristics of different periods in middle and lower reaches of Shiyang River Basin.*

| Habitats | | Periods | types associations | Associated species | Coverage | Perennial species has disappeared |
|---|---|---|---|---|---|---|
| Middle reaches | Sandy grassland | 1950s | Nitraria tangutorum, Peganum harmala, Artemisia ordosica, Artemisia desertorum | Agropyron cristatum, Peganum harmala, Halogeton glomeratus, Artemisia scoparia waldst.et Kit | | |
| | | 1970s | Nitraria tangutorum, Peganum harmala, Artemisia ordosica, Oxytropis aciphylla Ledeb., Salsolacollina Pall., Achnatherum | Artemisia desertorum, Agropyron cristatum, Peganum harmala, Artemisia scoparia waldst.et Kit, Achnatherum splendens, Halogeton glomeratus, Salsolacollina Pall., Pugionium cornutum, Agriophyllum squarrosum, Heteropappus hispidus (Thunb.) Less., | 16.67 | |

| Habitats | | Periods | types associations | Associated species | Coverage | Perennial species has disappeared |
|---|---|---|---|---|---|---|
| Downs tream | | | splendens, Sophora alopecuroides | Echinops gmelinii | | |
| | | 2010s | Artemisia desertorum, Artemisia ordosica, Nitraria tangutorum | Agriophyllum squarrosum, Panzeria alaschanica Kupr, Echinops gmelinii, Heteropappus hispidus (Thunb.) Less. | 34.06 | Agropyron cristatum, Peganum harmala, Achnatherum splendens |
| | Gravelly grassland | 1950s | Kalidium foliatum, Achnatherum splendens | Nitraria tangutorum, Achnatherum splendens, Sophora alopecuroides, P. harmala L, Stipa capillata Linn., Limonium aureum (L.) Hill | 65.00 | |
| | | 1970s | Nitraria tangutorum, Reaumuria soongarica | Kalidium foliatum, Asterothamnus alyssoides (Turcz.) Novopokr., C. roborovskyi Kom, Convolvulus tragacanthoides Turcz., Oxytropis aciphylla Ledeb. | | |
| | | 2010s | Reaumuria soongarica, Achnatherum splendens, Peganum harmala | Convolvulus tragacanthoides Turcz., Kalidium foliatum, Asterothamnus alyssoides (Turcz.) Novopokr., C. roborovskyi Kom, Oxytropis aciphylla Ledeb., Stipa tianschanica Roshev. var. gobica (Roshev. ) P. C. Kuo, Stipa capillata Linn., A. mongolicum Bgl, Halogeton glomeratus, Achnatherum splendens, Peganum harmala, Stellera chamaejasme Linn, Carex rigescens | 45.00 | Nitraria tangutorum, Sophora alopecuroides |
| | Salinized grassland | 1950s | Kalidium foliatum, Phragmites australis, Nitraria tangutorum | Reaumuria soongarica, Glycyrrhiza uralensis, Agropyron cristatum, Karelinia caspica (Pall.) Less, Artemisia annua Linn. | | |
| | | 1970s | Kalidium foliatum, Artemisia scoparia, Phragmites australis, Nitraria tangutorum | Tamarix ramosissima, Salsola passerina Bunge, Artemisia ordosica, C. mongolicum Turcz, Oxytropis aciphylla Ledeb., Artemisia desertorum, Glycyrrhiza uralensis, Agropyron cristatum, Karelinia caspica (Pall.) Less, Astragalus membranaceus (Fisch.) Bunge., Stipa capillata Linn., Carduus crispus, Eragrostis pilosa, Peganum harmala, Lycium ruthenicum Murr | 15.00 | |
| | | 2010s | Lycium ruthenicum Murr, Nitraria tangutorum | Kalidium foliatum, Tamarix ramosissima, Salsola passerina, Artemisia ordosica, C. mongolicum Turcz, Oxytropis aciphylla Ledeb., Artemisia desertorum, Karelinia caspica (Pall.) Less, Astragalus membranaceus (Fisch.) Bunge., Artemisia scoparia waldst.et Kit, Stipa capillata Linn., Carduus crispus, Eragrostis pilosa, Peganum harmala, Halogeton glomeratus, S. ruthenica Iljin, Phragmites australis, Zygophyllum xanthoxylum (Bge.) Maxim | 13.85 | Glycyrrhiza uralensis |
| | Sandy grassland | 1950s | Tamarix ramosissima, Kalidium foliatum | Nitraria tangutorum, Salsola passerina, Phragmites australis, Agriophyllum squarrosum, Glycyrrhiza uralensis, Sophora alopecuroides, Agropyron cristatum | | |
| | | 1970s | Periploca sepium, Nitraria tangutorum | Populus euphratica Olivier, C. mongolicum Turcz, E. sinica Stapf, Glycyrrhiza uralensis, Sophora alopecuroides, Agriophyllum squarrosum, Artemisia scoparia waldst.et Kit, Achnatherum splendens, Agropyron cristatum, Alhagi sparsifolia Shap., Artemisia desertorum, Salsola passerina Bunge | | |
| | | 2010s | Tamarix ramosissima, Nitraria tangutorum, Haloxylon ammodendron | Artemisia desertorum, Halogeton glomeratus | 11.27 | Kalidium foliatum, Salsola passerina, Phragmites australis, Agriophyllum squarrosum, Glycyrrhiza uralensis, Sophora alopecuroides, Agropyron cristatum |

| Habitats | Periods | types associations | Associated species | Coverage | Perennial species has disappeared |
|---|---|---|---|---|---|
| Gravelly grassland | 1950s | Nitraria tangutorum | Achnatherum splendens, Sophora alopecuroides, Periploca sepium, Agropyron cristatum, Peganum harmala | | |
| | 1970s | Kalidium foliatum, Nitraria tangutorum | Achnatherum splendens, Phragmites australis | | |
| | 2010s | Reaumuria soongarica | Lycium ruthenicum Murr, Nitraria sphaerocarpa, Sympegma regelii Bunge, Salsola passerina Bunge, Nitraria tangutorum, Kalidium foliatum, Poacynum hendersonii (Hook. f.) Woods., Phragmites australis, Zygophyllum xanthoxylum (Bge.) Maxim | 21.46 | Achnatherum splendens |

(2) Changes of plant species in downstream

The groundwater level of salinized grassland was higher before reclaiming, and *Kalidium foliatum, Phragmites australis,* and *Nitraria tangutorum* were the dominant species of vegetation. After the abandonment of cultivated land, due to the drop of groundwater level and the change of soil conditions, *Lycium ruthenicum Murr* gradually developed into a dominant population, especially in Juyuantan, HongLiuyuan and other places, the groundwater drastic decline, and *Kalidium foliatum* has basically withdrawn, and *Lycium ruthenicum Murr* occupy an absolute advantage. In the 1950s of the sandy grassland, *Tamarix* and *Phragmites australis* were the main species. *Tamarix ramosissima* was a type of desert vegetation formed at a relatively high level of groundwater level. With the gradual decline of the groundwater level, *Tamarix ramosissima* was gradually degraded. *Tamarix ramosissima* is still the main species of the region which groundwater decline slowly. In Dongsangouchaiwan, the groundwater severe decline, in the 1950s, *Tamarix ramosissima* and *Phragmites australis* grew well. However, at present, *Tamarix ramosissima* died in large area, and *Phragmites australis* was distributed sporadically, and grew bad. The local vegetation is currently artificial *Haloxylon ammodendron*. However, in Hongshaliang which the most drastic drop in groundwater, the *Tamarix ramosissima* completely exits from the wasteland and is replaced by *Nitraria tangutorum*. There is only *Tamarix ramosissima* growth on the roadside, and *Phragmites australis* are visible sporadically. Gravel grassland is located in Shangtan, Jijiquantan of Yongchang County and Nanbancao of Minqin County. It was dominated by *Nitraria tangutorum* in the 1950s, and *Kalidium foliatum* dominated in the 1970s, after with the groundwater level gradually lowering, *Kalidium foliatum* slowly withdraws, followed by more drought-tolerant species such as *Reaumuria Linn.*, *Oxytropis aciphylla Ledeb*, and *Reaumuria Linn* is currently the main constructive species in these areas.

## 4. Discussion

Drought and water shortage are the most prominent ecological characteristics of vegetation succession [31]. In 1962, the groundwater level in Minqin was 2.26 m, and it dropped to 24.68 m in 2008 [32]. By 2010, the groundwater level in Quanshan District was close to 30 m [33], while the suitable water level of Vegetation such as *Tamarix* and *Haloxylon ammodendron* does not exceed 10 m [34]. In order to adapt to the ever-changing external environment, plants in the lower reaches of the Shiyang River have undergone succession from the wet series to the xeric series according to different heat level and moisture indexes [35]. Since the 1950s, the succession of vegetation has mainly manifested itself in the gradual withdrawal of vegetation with constructive species such as *Tamarix, Kalidium foliatum* and *Phragmites australis*, and more drought-tolerant plants such as *Nitraria tangutorum, Reaumuria Linn.*, and *Lycium ruthenicum Mur*r. [29, 36] gradually took a dominant position, and in particular, the *Nitraria tangutorum* became a constructive species in most parts of the Lower reaches of Shiyang River. This succession phenomenon is particularly prominent in areas such as Quanshan District where the groundwater level has drastically decreased. That is to say, the most important factor leading to the succession of vegetation is the change of groundwater level. The uneven distribution of water resources caused by the mid-stream dam construction is one of the important reasons for serious overdraft in the downstream. The decline of the groundwater level not only led to the phytosanitization of plant species, but most of the natural vegetation declined due to the difficulty of using groundwater to maintain life. In 1967, there were $40.2\times10^4$ $hm^2$ of natural grassland in various types of grassland in Minqin County. By the year 2000, only $14.5\times10^4$ $hm^2$ remained in the county. [37] The area and types of downstream vegetation have changed, and the cover degree and biomass have also decreased dramatically. In the 1950s-1960s, the vegetation coverage was 20-60% [38]. By 2013, the coverage was below 20%.

The construction of dams not only resulted in the reduction of surface water flow, causing serious over-exploitation of groundwater, drastically declining groundwater levels, but also the gradual deterioration of water quality and increased salinity. Particularly in the downstream Minqin area, large-scale arable land was abandoned again due to lack of cultivation. Changes in groundwater levels, water quality, soil conditions, etc., and plant species have also undergone significant changes. In land with relatively short abandonment time, some herbaceous plants such as *P* *harmala L* are the main vegetation, and there are a few distributions of *Lycium ruthenicum Murr.* With the gradual increase of abandonment time, the *Lycium ruthenicum Murr* have gradually developed into the main plant species of abandoned farmland, occupying an absolute advantage.

The morphological structure of the plant leaf not only adapts to its physiology, but also adapts to its external conditions. The mesophyll type of the xerophyte plant has a significant correlation with the environment. The stage of leaf type change can indicate the degree of drought of the external conditions [25, 27, 29]. In the middle and lower reaches of the Shiyang River, in the Liangzhou District and some wasteland in Gulang of middle reaches and Lake District and Quanshan District of lower reaches, in the process of vegetation succession, the structure of the lamina gradually changes to a ring gate type. The ring gate type plants have a well-developed water-storage organization that is close to xeric and is a high-level adaptation of plants [25, 27, 29]. In the northwest, northeast of Yongchang and southwest of Minqin of middle and lower reaches, the main areas of animal husbandry, the plants gradually developed toward the normal and full gate types. The normal and full gate types plants were thin lamina, relatively small water content and strong drought tolerance [25, 27, 29]. In Minqin Lake District and Quanshan District, where the decline in groundwater level is relatively severe, the type of vegetation leaves has undergone a complete transition from normal, ring gate type to Irregular Molding.

## 5. Conclusions

Since the last 50 years of the last century, the area of vegetation in the middle and lower reaches of the Shiyang River Basin has been greatly reduced, and the reduction in the middle reaches has been more severe than in the lower reaches. At the same time, the degree of reduction in vegetation coverage, biomass, etc. is also more severe. Large-area land reclamation caused by dam construction in the Shiyang River Basin, unbalanced utilization of water resources, serious overdraft of downstream groundwater, and deterioration of water quality are the main influencing factors for changes in plant types and areas.

Under the multiple influences of external factors such as groundwater and air temperature and the succession of vegetation itself, the plants in the middle and lower reaches of the Shiyang River Basin have changed from the wet series to the drought series since the last 50 years, with *Tamarix, Kalidium foliatum* and *Phragmites australis* and other plants gradually withdraw, and more drought-tolerant plants such as *Nitraria tangutorum, Reamuria soongorica (Pall.) Maxim,* and *Lycium ruthenicum Murr* gradually took a dominant position. In particular, *Nitraria tangutorum* has become a constructive species in most places. In the middle and lower reaches of the Shiyang River Basin, the plant has developed a variety of drought characteristics and adaptation methods in order to adapt to the unfavorable growth environment such as large wind and sand, high temperature difference, rare precipitation, and strong evaporation. The structure of the leaf plants in the relatively serious human disturbance gradually changed to the ring gate type; the plants with relatively mild human disturbances gradually developed toward the normal type and full gate type; the areas where the groundwater level decreased more severely, the plant leaf types have been a complete shift from normal type and ring gate type to irregular type.

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## Biography

**Wei Huaidong** (1972. 3-) is researcher, born in Jingtai, Gansu, China. He works in Gansu Desert Control Research Institute State Key Laboratory Breeding Base of Desertification and Aralian Sand Disaster Combating in Gansu Province. He is committed to work on remote sensing monitoring of desertification in arid regions and has hosted 3 National Natural Science Foundation projects.

**Li Jingjing** (1989. 5-) is engineer, born in Lanzhou, Gansu, China. She works in Gansu Desert Control Research Institute State Key Laboratory Breeding Base of Desertification and Aralian Sand Disaster Combating in Gansu Province. She is engaged in Desertification control.