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# Land Degradation in the Test Areas of China and Argentina Observed Processes and Expected Trends*

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摘 要: 叙述中国西北地区的黑河流域、塔里木盆地南缘和阿根廷西北的门多萨、圣地亚哥德埃斯特罗省等检验区的退化土地的类型、分布特征、影响因素及其相互关系。结合近百年来平原区气候变化有明显暖化和旱化,阿根廷半干旱区的降水波动,和人口增长对土地利用压力的加大趋势,可以预测在人工绿洲外围和河流下游,尽管人类在优化绿洲建设和合理利用水资源等方面可以取得很大进步,但土地退化的趋势还会继续,因此必须加强对这些生态脆弱边缘土地的资源管理和生态环境保护。

关键词: 土地退化; 过程与趋势; 阿根庭; 中国

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## 1 The features of the test areas

During last four decades the sandy desertification has shown a continued spread in the arid and semi-arid region of the North China. The sandy desertified land had expanded by 1 560 km$^2$ annually on the average from the middle of 1950's to the middle of 1970's, and in the last decade it has gone up to 2 100 km$^2$. The sandy desertified land has reached 197 000 km$^2$ [1,2].

Much of Argentina is made up of drylands, about 75% of the national territory is in the arid, semiarid and dry sub-humid bio-climatic zones. Here, 700~ 800 mm isohyets separate semi-arid from humid areas and 250~ 300 mm divide arid from semi-arid zones. The northern part of the country, north of Bruniard's climatic limit, is under the influence of the Atlantic semi-permanent anticyclone with rains in spring and summer. To the south of this climatic limit, in contrast, rainfall occurs mainly in the cold season (Pacific anticyclone). Maps of desertification hazards, ecosystem vulnerability and human pressure compiled by Roig *et al*[3] show that dominant processes and factors are aridity index, soil freezing, salinity, alkalinity, wind erosion, water erosion, vegetation cover, poverty, population density, livestock pressure, use of wood and firewood and fire in Mendoza Province. In the northwestern semiarid region, due to the 1970's positive rainfall fluctuations, the semiarid-humid boundary shifted westwards about 140 km on average along the humid plain border, and the semiarid-arid boundary also moved westwards about 88 km. This temporary increase in water availability encouraged people to deforest mainly for cultivation purposes[4]. Desertification has led to a loss of productivity between 20% ~ 40% of natural resources of Argentina.

## 2 Land degradation in the test areas

### 2.1 Hei River Basin in China

The Hei River Basin, 130 000 km$^2$ in area, is a

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great inland river watershed in the arid zone of Northwest China[5]. Land degradation in the Hei River Basin mainly caused by wind-sand, drought, salinization at the plain regions and water erosion at the mountain region of southern parts. Human activities such as inadequate development and misuse of water, lands and biological resources are also important reasons of land degradation in the basin. In the historic period, during 2 000 years from Han Dynasty to Qing Dynasty the development in the basin fell into interlaced development of agriculture and animal husbandry. Irrigation agriculture activities once had set up the famous Juyan-Heicheng Oasis at the lower reaches of the Hei River and the Loutuocheng Oasis at the lower reach of the Bailang river in the Hexi Corridor. These oases were ruined at deserts and some of them became sandy deserts.

According to natural features the degraded lands in the basin can be divided into five types (Tab. 1): ① The lands of water erosion, which occupy 20.8% of the mountain area, are distributed wholly in the mountain regions. ② The lands of aridification with less area are concentrated in the grasslands along rivers and around lakes of the plain regions in the basin. Aridification process is primarily manifested in land degradation and mainly occurred at natural oases with unstable groundwater and surface water supply. The aridification lands may form salinized lands because of salt accumulation in soils or sandification lands suffering wind-sand hazard. ③ The salinization lands are located in catchment depressions on banks of rivers and lakes and at margins of alluvial fans and is the one of main degraded types. ④ The sandification lands that are characterized by appearance of shifting sands and sand dunes are of the high level of degraded types in the arid desert areas. The sandification processes with biggest area in degraded lands of the basin are developing in the downstream regions. ⑤ The lands of vegetation degeneration occupied about 4.45% of degraded lands.

**Tab. 1 Degraded lands in the Hei River Basin**

| Degraded land type | Degraded area/km² | % of the degraded area | % of the basin area |
|---|---|---|---|
| Water erosion | 5 547.43 | 19.15 | 4.30 |
| Aridification | 1 169.38 | 4.04 | 0.91 |
| Salinization | 10 391.39 | 35.87 | 8.05 |
| Sandification | 10 571.78 | 36.49 | 8.19 |
| Vegetation degeneration | 1 290.30 | 4.45 | 1.00 |
| Total | 28 970.28 | 100 | 22.44 |

## 2.2 Southern rims of Taklimakan Desert in China

The Taklimakan Desert is situated in the inland Tarim Basin in which alluvial and lacustrine deposits are widely distributed. There are many rivers originating from the Kunlun Mountain and large or small oases along rivers in the southern marginal regions. In the marginal region there are many processes of land degradation, such as wind erosion, salinization and dunes encroachment. There are a lot of ancient cities and abandoned oases of Han and Tang Dynasties in marginal regions and along the Silk Road, which were buried by sands. All of those prove the environmental degradation and desertification. The major desertified lands were formed in the lower reaches of rivers, along the rivers and in the alluvial fan areas with different characteristics.

During the last century, the desertification in the marginal regions of the desert has shown an accelerated process. Misuse of water resources in the arid zone is the main cause of the process. Agricultural development consumed much water in the frontier plain. River runoff in the lower reaches has decreased year by year and groundwater level dropped dramatically in the outside of the artificial oases. With the decrease of water supply, beds of rivers and the lands in the lower reaches dried up gradually. Trees and shrubs on the banks lost their regenerative potential and died finally. Human excessive collection of fuel-wood reinforced the extension of exposed surface and fixed and semi-fixed sand dunes became active. Moving sand dunes and shifting sands gradually extended under wind force. Shifting sand could encroach on the farmland of the oases if there is no windbreak. Meanwhile in the artificial irrigated oases, secondary salinization of soil and water logging occurred due to over irrigation and reservoir and canal seepage. The desertification developed in the marginal regions of the Taklimakan Desert can be classified mainly into five types as in Tab. 2.

**Tab. 2 Desertified lands in the southern marginal regions of the Taklimakan Desert**

| Types of desertified land | Desertified area /$km^2$ | % of the total |
|---|---|---|
| activities of sand dunes | 14 000 | 62.9 |
| abandoned land due to aridification | 3 430 | 15.4 |
| vegetation degeneration land of P. Spp. & T. Spp | 1 418 | 6.4 |
| salinized farmland | 1953 | 8.8 |
| encroachment of sand dunes | 1 463 | 6.5 |
| Total | 22 264 | 100 |

## 2.3 Mendoza in Argentina

Mendoza is situated in Central West Argentina and belongs to the vast arid diagonal of South America. The total area of province is 148.827 $km^2$ and the land under irrigation is 359 523 $hm^2$, artificial oases cover only 3% of the total territory. Mendoza with population of 1.5 million inhabitants is the most important irrigated area of Argentina. Water resources depend on the five rivers: Mendoza R., Tunyuan R., Diamante R., Malargue R., and Atuel R., that come from the Andes mountain of western part to east plains. The annual surface water resources are over $57.71\times 10^8$ $m^3$. Groundwater is not considered in these surface flows. The water resource from Mendoza River accounts to $15.46\times 10^8$ $m^3$[6].

The desertification process could be traced back to Spanish conquest and subsequent colonization, which involved substantial changes of the native way of life. This process has been accelerated around the last 150 years[7]. At present, human population is largely concentrated in irrigated oases, but extensive livestock raising is practiced in the drylands, where the number of rural settlements is lower. The inadequate management of resources leads to critical situations: the expansion of saline areas with loss of productivity and exodus of rural people; decreased carrying capacity of grazing lands; increasing natural disasters. Except for the Andean desert, the entire territory of the Mendoza shows widespread deterioration. According to the case study, 72% of its territory present a high to very high desertification hazards[3]. Comparative analysis of maps of processes and factors indicates the most fragile ecosystems correspond either to the Andean relief or to plains showing intense processes of salinization and alkalinization, with unfavorable climatic conditions in either case. The vast piedmonts, hills and pediplain of volcanic relief are also highly fragile suffering water erosion. In piedmonts, deforestation and induced fires are very important degradation processes, both leading to water erosion and deterioration of vegetation. Thus, Martinez Carretero in 1983 measured, in burned areas, an increasing of 47% and 109% of sediment transportation in flat and slope locations respectively. The induced fires eliminate progressively shrubs with good protein content and increase the cover of grasses with lower nutrient quality[8]. The drylands of lower reaches of rivers are facing vegetation degeneration due to livestock pressure and deforestation. In the NE plain of sand dunes, with spring-summer rains of about 100 mm, forests develop because of the phreatic reservoir of saline water. According to an image classification of the area from 346.237 $hm^2$, only 6% is covered by "dense" forest and 36% is covered by forest with different degree of degradation and 40% are linear dunes mainly stabilized.

## 2.4 Santiago del Estero in Argentina

The vegetation of the northern semi-arid area of Argentina belongs to the forests of the Chaco region. At the beginning of the current century these forests played an important role in the economic development of Argentina, as reported by Ledesma

& Ledesma[9]. Since the last third of the XIX century, with the installation of railways, exploitation of these forests increased. This happened because of the remarkable quality of the wood from the Chacoan trees. The most important trees were *Schinopsis balansae* and *S. lorentzii* owing to their wood elasticity, high density and durability that made them ideal for railway sleepers. Thus, a "forest-mining or intensive misuse" of the forest started. Once the degraded forest was abandoned the remaining vegetation was used for raising animals, cattle and goats. The livestock degraded the vegetation and made soil compaction, apart from an extensive scrub invasion. These shrubs and small trees belong to the thorny undergrowth.

During the 1970's, as a consequence of the positive fluctuation of rainfall, water balance became more favorable, and dry periods grew shorter. This fact, along with profitable grain prices and a growing interest in the agricultural development of the semi-arid region, encouraged people to deforest and practice rainfed agriculture. Casas *et al.*[10] have evaluated the degradation processes in deforested lands after cultivation. These degradation processes are a decrease in organic matter, in nitrogen and in the index of soil structure; and an increase in apparent soil density. According to FAO's soil assessment criteria, the first five years of cultivation produce a high/very high rate of degradation of organic matter. Moreover, during the process of cultivation, soils become compacted. Unfortunately, this is also the period most farmers use for cultivating deforested lands. In addition to the soil evaluation done, Casas *et al.* also conducted an inquiry among farmers to detect the main processes of natural resource degradation. Results obtained were: soil encrusting (30%), patches (23%), water erosion (18%), decreased yield (12%), wind erosion (10%) and increased density of arable layer (7%).

Desertification impacts detected in the semi-arid Chaco are mainly related to changes in plant growth, in animal life, and in soil status. These changes have caused modifications in the microclimate as reported by Ledesma & Ledesma[9]. Air temperature is higher in degraded forests than in nearly virgin forests and in forests on their way to recovery, temperature ranges are also wider in a degraded forest. Consequently, there is an increase in evaporation and a decrease in air relative humidity in degraded forests. Therefore, degradation entails a dryer and more fragile ecosystem.

# 3 Expected trends of land degradation in the test areas

## 3.1 Trends of climate changes

### 3.1.1 Trends of climate changes at the southern Taklimakan Desert

In recent years, much attention has been given to climatic change in the Taklimakan Desert, particularly at the southern edges of the desert. It is still a controversial issue as to whether temperature increase, glacier shrinkage, snow line rise, or decrease in precipitation leading to sustained drought, may eventually cause severe desertification and a southward extension of the Taklimakan Desert. This would threaten the existence of oases on the southern edges. This follows a discussion on climatic change and trends in the near future, based on meteorological data for the last 30 to 40 years and the chronologies of annual rings of *Populus diversifolia* in the last 200 to 250 years[11]. From 1942 to 1980, the average temperature in this area increased by 1.4℃, tending to a warmer climate. On the other hand, precipitation dropped by about 16.0 mm with an annual reduction of 0.42 mm. These changes have led to the emergence of dry air, the accelerated evaporation and transpiration of water from plants and soil. These changes clearly indicate a significant alteration of climate over the past 40 years in the southern part of the desert. But a span of 40 years is perhaps too short for the study of an area's climatic change. Therefore, the chronologies of annual tree rings collected during the expedition in September–October of 1986 and its reconstructed growth temperature for 202 years at Qira were used. An annual precipitation curve for 197 years in Yutian and an annual runoff of the Keriya River for 253 years were reconstructed. It is clear that in 202 years from 1785 to 1986, the average growth temperature for *Populus* was 19.66℃. However, in the 21 years from 1960 to 1980, the average growth temperature was 20.71℃, an increase of 1.05℃. This signifies a trend towards a warmer climate. The conclusion is that during the 200 years, the climate at the southern Taklimakan Desert will tend to become warmer. The change in dryness and humidity can be clearly seen from the reconstructed precipitation curve in Yutian. Although there were periodic fluctuation, the general trend seems to point toward a drier climate. In addition, the curve of annual runoff of the Keriya River also shows a similar conclusion. During the 142 years from 1734 to 1875 annual runoff above or close to the historical average, but after 1875, it is in keeping with the reduction in precipitation, and consolidates the proposition that the climate is becoming drier.

#### 3.1.2 Climatic fluctuations in the semiarid Santiago del Estero of Argentina

From 1908 to 1987, rainfall fluctuations have been detected in the north of Argentina. These experienced two periods of rich water: 1920–1940 and 1968–1987 and two of negative fluctuations: 1908–1919 and 1941–1967. Evolution of annual rainfall (1903–1998) shows clearly these processes in the 20th century for Santiago del Estero station. As an ecological consequence of 1970's positive trend detected in the north of Argentina[10], the semi-arid/humid and the semi-arid/arid boundaries shifted westwards and about 800 000 km$^2$ become wetter during the 1970's. In the semi-arid area, the amount of rainfall increased about 27%; in some region the increase was 33%. Therefore, the arid diagonal of Argentina became narrower in 1970's when compared with the 1960's. The actual trend of precipitation should be analysed at a regional level. No satisfactory trend could be extracted from Santiago del Estero Station series with standard tools for tendency.

### 3.2 Trends of land use

#### 3.2.1 Trends of land use in the south Tarim

In the southern Tarim Basin, development of irrigated agriculture has a history of over two thousand years. But agriculture and animal husbandry were developed very slowly before 1949 because of poor transportation and remote geographic site. After 1949, agriculture production developed quickly, especially in food production. In 1990 the total grain yield reached 57.6 × 10$^4$ tons which was 5 times that of 1949. From 1949 to 1992 the population lived in Hetian District increased by more than two times, the number of livestock in 1985 was doubled compared to 1949. All of these not only increased land use pressure in the edge of the Taklimakan moving desert, but also enhanced the intensity of water resource development. These, combined with warmer and dryer of climate and shifting sand encroachment under prevail wind direction, make the artificial oases construction optimized and the ecological environment of natural oases outside artificial irrigated oases deteriorated.

#### 3.2.2 Trends of land use in NW Argentina

The temporary increase in water availability encouraged people to deforest mainly for cultivation purposes. These marginal areas, which are risk for crop production (rainfed agriculture); may allow for quick economic gain but they will be short-lived on account of the actual degradation of ecosystem and of the inevitable return to the usual rainfall level. A positive fluctuation of rainfall during the 1970's combined with profitable grain prices and a growing interest in the agricultural development of the semi-arid region encouraged people to deforest and practice rainfed agriculture. The majority of the areas surveyed were deforested for crop production and livestock rearing, during first five years farmer would grow crops to make a quick profit and thereby recover their investment[12]. About 171 600 $hm^2$ were estimated to have been deforested in the province of Santiago del Estero from the harvest period 1975—1976 to 1983—1984 and 60 700 $hm^2$ during the period 1996—1997 to 1997—1998. Such alternate land use (deforestation-cultivation-abandonment-cultivation) mainly contributes serious imbalance of ecosystems and the land degradation in the semi-arid regions[4].

### 3.3 Expected trends of land degradation in the test areas

Land degradation is an accelerated development process because of the increasing population pressure and drier trend of climatic changes in plains. Sandy desertification is a main kind of land degradation in the north China, which mainly caused by excessive human impact through wind erosion. In last four decades, although the sandy desertification has been controlled in local area, but it is still continuing to spread in the whole arid and semi-arid region of the north China. Desertified land had expanded 2 460 $km^2$ annually. In the given condition of the climatic change, the form and intensity of land use determine to a large extent the development and control of desertification in the arid and semi-arid region.

According to the trends of warmer and dryer conditions and more intensive land use, it is necessary to pay more attention to the drylands of marginal regions in the arid and semi-arid zones because the ecosystems there are very sensitive to climatic variation. With the technological progresses, artificial oases will become more graceful and the land degradation within the oases will be controlled and rehabilitated. But the lands outside the oases will continue to be deteriorated. So to make great efforts to combat land degradation is an urgent task.

## References

[1] Zhu Zhenda, Liu Shu, Di Xingmin. Desertification and rehabilitation in China [M]. Beijing: Science Press, 1989.
[2] Zhu Zhenda, Chen Guangting. Sandy Desertification in China Status and Trends [M] Beijing: Science Press, 1994.
[3] Roig F A, Gonzalez Loyarte. World Atlas of Desertification [Z], UNEP Ed. Arnold. 1992.
[4] Gonzalez Loyarte. Analisis espacial y dinamico de la vegetacion del NE de Mendoza I: Los bosques freatofitos [J]. Actas XXV Jornadas Argentinas de Botanica. 1996.
[5] GAO Qianzhao, Li Fuxing. Case study of rational development and utilization of water resources in the Hei river basin [M]. Lanzhou: Gansu Scientific and Technological Press, 1991.
[6] Morabito, José. Introduccion al riego. El riego en el mundo, Argentinary Mendoza [J]. Instituto Nacional Del Agua y del Ambiente. Mendoza, Argentina, 1997.
[7] Prieto M, Del R Y, Abraham E M. Historia Ambiental al sur de Mendoza Los factores criticos de un proceso de desertificacion [M]. Bamberger Geographische Schriften Bd. 15, S. Bamberger. 1998.
[8] Martinez Carretero E. El fuego en el piedemonte de la Sierra de Uspallata [A]. Roig, F. A. (Ed.). Deteccion y Control de la Desertificacion [C]. UNEP- CONICET/IADIZA- CRICYT, Mendoza, Argentina. 1989.
[9] Ledesma R N, Ledesma F A. La degradacion del ecosistema en el Chaco seco [M]. IDIA Nº Buenos Aires, Argentina. 1983.
[10] Casas R R, Mon R. Usoy Manejo de la tierra desmontataen la provinciade Santiago del Esttero [M]. IDIA N° Buenos Aires, Argentina. 1983.
[11] Ling Yuquan. Climatic characteristics and their changing tendency in the Taklimakan desert [A]. Jakel, D. and Zhu Z (Eds.). Reports on the 1986 Sino- German Kunlun Shan Taklimakan- Expedition [C]. DIE ERDE Erganzungsheft 6. 1991.
[12] Minetti J L, Sierra E M. La expansion de la frontera agricola en Tucuman y el diagnostico climatico [J]. Rev Ind y Agricola de Tucuman, 1984, 61(2): 109—126.