9. Challenges to Water Resource Management and Land Degradation Prevention in Marginal Land

Minjun Shi
University of Tsukuba, Japan

1. Situation and Problems in Water Resource Management and Environmental Conservation in Marginal Land

What is marginal land? Marginal land is the regions that are ecologically fragile but have high density of population. High population pressure on fragile ecological environment is the most important characteristic of marginal land. Most marginal areas are facing serious conflict between improvement of human well-being and environmental conservation. Especially coordination of water resource management and land degradation prevention is a severe challenge to sustainable development as most of marginal areas are arid land.

There is about 25% of population living on fragile lands in the world. In Sub-Saharan, Middle East and North Africa, East Asian and pacific and South Asian, more than 24.4% of population are living on fragile lands (Table1). Most of these areas are arid land. These fragile lands and the Southern Plains of North America face similar climatic and soil characteristics but different political, financial, and institutional constraints (World Development Report 2003). Another important point is different density of population between the fragile lands and the arid land of North America. The dense population living on these marginal lands depends upon dryland agriculture.

The problems in water resource management and environmental conservation in marginal lands can be outlined as follows:

(1) Conflict between limited supply and increasing demand of water resource with rapid population growth and economic development;
(2) Incompatibility between efficient utilization of water resource and technical, financial, and institutional constraints to smallholders;
(3) Tradeoffs in water resource allocation among human survival, bioproduction and environmental conservation

Next follows a case of marginal land facing challenge to water resource management and land degradation prevention, Shiyang River watershed of China.

Table1 Regional distribution of people living on fragile land in 2000

Region	Population (millions)	Population on fragile lands by region	
		Number (millions)	Share of total (%)
latin America and the Caribean	515	68	13.1
Eastern Europe and Central Asia	475	58	12.1
Middle East and North Africa	293	110	37.6
Sub-Saharan Africa	658	258	39.3
South Asia	1,355	330	24.4
East Asia and Pacific	1,857	469	25.3
OECD group	850	94	11.1
Other	27	2	6.9
Total	6,030	1,389	24.7

Source: World Development Report 2003, pp.61

2. Challenge to Water Resource Management and Land Degradation Prevention: The Case of Shiyang River Watershed

2.1 Water resource supply and demand

Shiyang River watershed is located in arid area of Western China, with an area of 41,600km^2. The watershed includes upstream Qilian Mountain Range, Wuwei Oasis in midst, and

Table2 Change in water resource supply in Shiyanghe River watershed

Unit: 10^8m^3

	1950s	1960s	1970s	1980s	1990s	2000
Runoff	14.6	11.9	11.8	11.9	13.2	
	1957	1969	1976	1980	1990	2000
Runoff	13.3	13.1	14.0	13.0	14.1	13.0

Source: (1) Yang Yongchun et al, 2002. The human mechanism research of Minqin Oasis change in the lower reaches of the Shiyang River. Geographical research, Vol.21, No.4: pp.449-458
(2) Sun Xuetao, 2003. Analysis on water resource Utilization in Minqin Oasis. China Water Conservance, Vol. 2003, No. 12: pp.35-38

Table3 Regional distribution of economy and population in Shiyanghe River watershed

Units: 10^4Yuan, person, hm^2

	GDP	Population	Urban population	Rural populatio	Cultivated land	Sowing area	Wheat	Corn
Wuwei	427,607	946,469	272,308	674,161	97,253	116,370	34,590	28,970
Minqin	87,600	302,082	42,332	259,750	64,120	47,720	21,630	6,740
Wuwei/ Minqin	4.88	3.13	6.43	2.60	1.52	2.44	1.60	4.30

Source: Gansu Statistics Yearbook 2001

Table4 Demand of water resource in Shiyanghe River watershed in 2000

Units: 10^4Yuan, person, hm^2

	GDP	Population	Urban population	Rural populatio	Cultivated land	Sowing area
Wuwei	20.85	19.15	0.43	0.15	0.25	0.77
Minqin	6.49	6.25	0.15	0.02	0.07	
Jinchang	5.78	4.20	1.10	0.15	0.06	0.27
Total watershed	26.63	23.35	1.53	0.30	0.41	1.04
Wuwei / Minqin	3.21	3.06	2.87	7.50	3.57	

Source: Sun Xuetao, 2003. Analysis on water resource Utilization in Minqin Oasis. China Water Conservancy, Vol. 2003, No. 12: pp.35-38

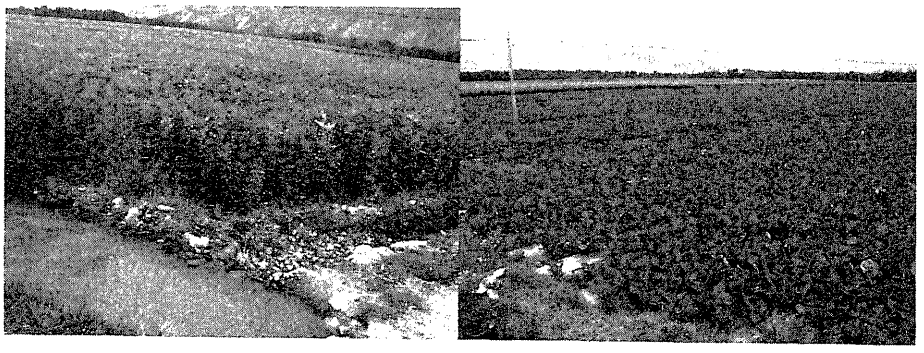

Figure1 Utilization of water resource and intensive farming in upstream region

downstream Minqin Oasis. Annual precipitation is more than 200mm in upstream range, from 150mm to 200mm in Wuwei Oasis, and from 100mm to 150mm in Minqin Oasis. Most of water resource supply is from precipitation and melted glacier. In downstream Minqin area, water resource supply depends on surface runoff and underground water permeation.

Table 2 indicates water resource supply in Shiyanghe River watershed is relatively steady. The problem is from increasing demand of water resource with rapid population growth and economic development. Table3 highlights regional distribution of economy and population in Shiyanghe River watershed. Table4 shows demand of water resource in the watershed in 2000. About 80% of water resource of whole watershed is used by Wuwei Oasis. In other word, Wuwei Oasis with 4.9 times of GDP and 3.1 times of population but 1.5 times of cultivated land is consuming 3.2 times of water resource than Minqin Oasis. A problem of allocation of water resource between upstream and downstream regions arose in water resource management.

2.2 Allocation of water resource between upstream and downstream areas

As water resource supply of whole watershed was relatively steady in past decades, increased occupation of water resource with industrial development and population growth in upper Wuwei Oasis caused a decline in water resource supply. Table5 indicates changes in water resource supply to downstream Minqin Oasis. In contrast with 1960, runoff to Minqin in 2000 has decreased 75%, from $4.58\times10^8m^3$ to $1.15\times10^8m^3$. The upstream region is enjoying the use of abundant water resource, but the downstream region is suffering a severe shortage of water resource. The reservoir and irrigation canals in Minqin Oasis have dried up due to the decline in surface and underground runoff from upper region.

Table5 Change in water resource supply in Minqin Oasis(downstream)

Unit: 10^8m^3

	1940s	1956	1960	1970	1980	1990	2000
Runoff to Minqin	6.50	6.00	4.58	4.40	2.38	1.97	1.15
	1940s	1957	1969	1976	1980	1990	2000
Runoff to Minqin		4.64	3.94	2.68	2.21	1.70	0.98
	1940s	1950s	1960s	1970s	1980s	1990s	2000
Underground water supplement			0.33	0.22	0.17	0.12	0.11

Sources: (1) Yang Yongchun, 2003. The Analysis of the Oasis Environmental Change and its Reason of the Lower Reaches of the Arid Region. Human Geography, Vol.18, No.4: pp.42-47

(2) Sun Xuetao, 2003. Analysis on water resource Utilization in Minqin Oasis. China Water Conservancy, Vol. 2003, No. 12: pp.35-38

Figure2 Dried-up reservoir in Minqin Oasis

2.3 Incompatibility between efficient utilization of water resource and technical and financial barriers

Table6 indicates the results of estimation of water resource demand and supply in Minqin Oasis in 1990s. The gap between usable water resource and actual use of water resource reaches at 500, $420\times10^3m^3$. Especially, as surface runoff is limited, the way to fill in the gap is to draw underground water. Even so Minqin's economy and livelihood is still suffering shortage of water resource supply. There is obvious difference in crop productivity between irrigated fields and non-irrigated fields.

As diverting water from other watershed cannot fill fundamentally in the gap, to adjust

Figure3 Dried-up canal

Figure4 Slim flow of canal in Minqin

Table6 Estimation of water resource demand and supply in Minqin Oasis in 1990s

Units: 10^4m^2

Items	Water resource supply	Items	Water demand	Gap between supply and demand
Total	29,676	Total	78,133	-48,457
Surface runoff	15,010	Agri-production needs	77,265	
Underground water	11,290	Household living	868	
Precipitation	3,376	and industry needs		
Items	Usable water resource	Items	Actual use of water resource	Gap between supply and demand
Total	28,090	Total	78,133	-50,042
Surface runoff	12,900	Surface runoff	12,900	0
Underground water	15,190	Underground water	65,233	-50,042

Source: Yang Yongchun et al, 2002. The human mechanism research of Minqin Oasis change in the lower reaches of the Shiyang River. Geographical research, Vol.21, No.4: pp.449-458

Figure5 Well irrigation

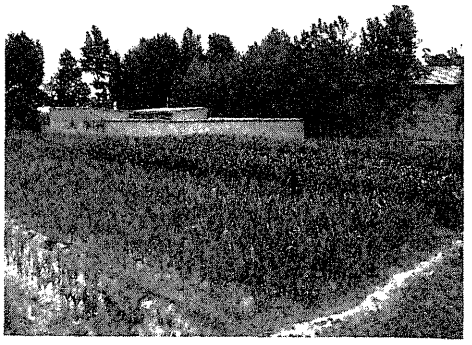

Figure6 Difference of crop productivity

land use system and to improve efficiency of water resource utilization is the essential solution to relieve the gap between demand and supply of water resource. However, possibility to improve efficiency of water resource utilization is not so optimistic due to technical, financial and institutional barriers for smallholders to improve efficiency of water resource utilization. One of the barriers is farmers have to continue flood irrigation in order to prevent soil salinization, because if field dried up salt will rise along soil capillary and then soil will be salinized. Development and extension of water-saving irrigation technology is the basic solution to overcome technical barriers to improve efficiency of water resource utilization. Trickle irrigation may save water and improve the utilization efficiency. However, it is so expensive for poor smallholders to adopt trickle irrigation technology. There are urgent needs in development of appropriate technology suitable to fragile arid land.

2.4 Effects of decrease in water resource supply on land degradation

A great quantity of over-withdrawing underground water results certainly in decline in underground water table. Table7 indicates underground water table has dropped from 8.5m to 14.9m during 1984 to 1994. At the center of underground water funnel, underground water table has fallen at 20m (He Yajuan and Pan Xuebiao, 2003). Simulation results of land use and its effects on underground water table show if current land use system go on to practice, underground water table will continue to deepen in Minqin region (Ma Xingwang et al, 2002).

One of consequences following decline in underground water table is progress in land degradation. Table8 shows that the area of irrigable field has decreased from 26,514hm^2 to 8,392hm^2 during 1978 to 1995. In the same period, forest land decreased from 3,368hm^2 to 1,503hm^2. In contrast, abandoned farmland has reached at 14,845hm^2. Meanwhile, soil salinization spread rapidly. The area of saline land has increased from 7,560hm^2 to 9,147hm^2. A great area of salinized farmland can only grow salt-enduring plants such as fennel. A lot of trees, grass and bushes withered due to decline in underground water level. As a result, desertification spread. Sandy dune moved forward and farmland fell back.

Decrease in water resource supply also causes negative impact on human livelihood. An extreme case is households of whole hamlet migrated out due to shortage of water resource.

2.5 Challenges to water resource management and land degradation prevention

The problems of water resource management in Shiyanghe River watershed embody tradeoffs in regional allocation of water resource. Unfair allocation of water resource between upper region and downstream region results in severe shortage

Table7 Change in underground water level in Minqin Oasis

Items	1984	1985	1987	1988	1989	1991	1992	1994
Precipitation(mm)	113	139	131	140	76	82	116	157
Underground water level(m)	8.53	9	10.08	10.55	11.26	12.73	13.55	14.9

Source: Ma Jinzhu and Weihong, 2003. The ecological and environmental problems caused by the excessive exploitation and utilization of groundwater resources in the Minqin Basin, Gansu Province. Arid Zone Research, Vol.20, No.4: pp.261-265

Table8 Progress in land degradation

Units: hm^2

Year	Irrigable field	Forest land	Grassland	Salinized land	Sandy land	Abandoned cultivated land
1978	26,514	3,368	5,879	7,560	15,411	
1995	8,392	1,503	10,107	9,147	13,963	14,845

Source: Ma Jinzhu and Weihong, 2003. The ecological and environmental problems caused by the excessive exploitation and utilization of groundwater resources in the Minqin Basin, gansu Province. Arid Zone Research, Vol.20, No.4: pp.261-265

Figure7 Abandoned cultivated land

Figure8 Soil salinization

Figure9 Planting in salinized field

Figure10 Desertification

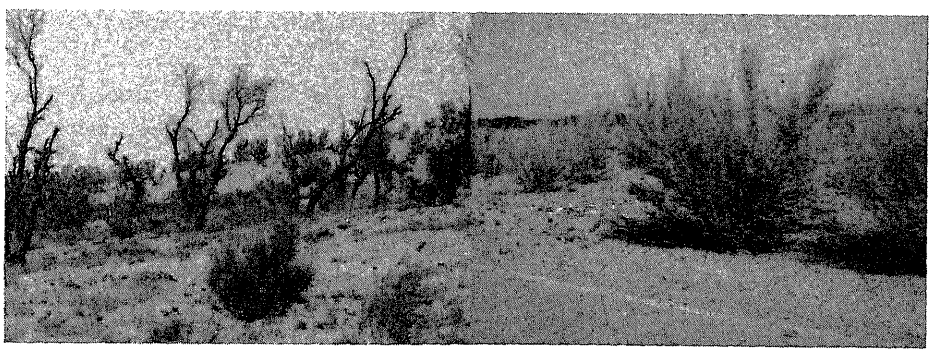

Figure11 Withered trees and grass

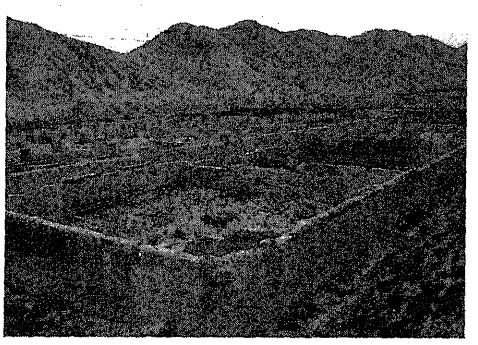

Figure12 Out-migrated hamlets

of water resource supply and consequent land degradation in downstream Minqin Oasis. One of considerable solution to manage water resource allocation is introducing transaction of right of water resource use. While assuming right of water resource (quota) use should be allocated fairly between upper Wuwei Oasis and downstream Minqin Oasis, if the upper region exceeded the quota of water resource use, the upper area should compensate the downstream region for its excessive use of water resource.

Concomitant problems are how to allocate the quota of water resource use and how to determine the amount of compensation. Allocation of right of water resource use needs to balance efficiency of water utilization and equity principle and objective of environmental conservation. Amount of compensation should be determined on the basis of evaluation on economic and ecological values of water resource. Costs of economic recession and environmental degradation caused by decline in water resource supply should be taken into account in evaluation of economic and ecological values of water resource.

3. Future Issues for Japanese Researchers in International Cooperative Research on Water Resource Management and Environmental Conservation in Marginal Land

Some research issues on water resource management and land degradation prevention in marginal land can be listed up for Japan's institutes as topics of international cooperative research in future.

(1) What is the principle and method to allocate of right of water resource use in marginal land;
(2) How to develop the mechanism of transaction of right (quota) of water resource use;
(3) How to account economic and ecological values of water resource in marginal land;
(4) How to establish institutional and organizational scheme of participatory water resource management in marginal land.

References

He Yajuan and Pan Xuebiao, 2003. The changes of planting structure and rational use of water resource in the oasis of Minqin County, Gansu Province. Chinese Journal of Eco-Agriculture.Vol.11, No.4: pp.121-123.

Ma Jinzhu and Weihong, 2003. The ecological and environmental problems caused by the excessive exploitation and utilization of groundwater resources in the Minqin Basin, gansu Province. Arid Zone Research, Vol.20, No.4: pp.261-265.

Ma Xingwang et al, 2002. Modeling the influence of land use on groundwater in oasis: The case of Minqin Oasis. Resource Science. Vol. 24, No.2: pp.49-55.

Sun Xuetao, 2003. Analysis on water resource Utilization in Minqin Oasis. China Water Conservance, Vol. 2003, No. 12: pp.35-38.

Yang Yongchun, 2003. The Analysis of the Oasis Environmental Change and its Reason of the Lower Reaches of the Arid Region. Human Geography, Vol.18, No.4: pp.42-47.

Yang Yongchun et al, 2002. The human mechanism research of Minqin Oasis change in the lower reaches of the Shiyang River. Geographical research, Vol.21, No.4: pp.449-458.

JAPAN: DISCUSSION

Comment (from some of the delegates): Basically all the problems mentioned in your presentation exist in other countries as well. The water allocation is indeed a problem, the need to increase water use efficiency seem to be a common thing among nations. Another particular issue, which, seem to be very common is the extensive irrigation activity in the upstream areas. The farmer's perspective as to the use of irrigation scheme and cropping pattern somehow need to be re-oriented to be more environment friendly and more sustainable water resources.

Comment (from some of the delegates): There seem to be a need to increase the awareness among the upstream and downstream water users with regards to the most appropriate irrigation scheme.