Pak. J. Bot., 44: 51-57, Special issue May 2012.

POLICY STRATEGY FOR ECOSYSTEM CONSERVATION OF THE MINQIN OASIS OF NORTHWEST CHINA

DONG-XIA YUE[1, 2], SHENG ZHANG[1], XU-ZHE ZHAO[1], FEI MO[1], JIAN ZHANG[1], RAN WANG[1], GENG-RUI WANG[1, 3], GORDON M. HICKEY[3], HUI-LI WANG[1], YU-QIONG WANG[2] AND YOU-CAI XIONG[1]*

[1]State Key Laboratory of Grassland Agro-ecosystems, School of Life Sciences, Lanzhou University, Lanzhou 730000, China
[2]MOE Key Laboratory of Western China's Environmental Systems, Lanzhou University, Lanzhou 730000, China
[3]Department of Natural Resource Sciences, McGill University, 21111 Lakeshore Road,
Ste-Anne- de- Bellevue, Quebec, H9X 3V9, Canada
**Corresponding author e-mail: xiongyc@lzu.edu.cn; Tel / Fax: +86-931-8914500*
Dong-Xia Yue and Sheng Zhang are the common first authors

Abstract

The policy dimensions of endangered ecosystem conservation have recently received increased interest. This study focuses on the severely-degraded Minqin oasis of arid northwest China, which faces a similar fate to the vanished Lop Nur oasis. From 2000-2009, a series of conservation policies have been issued to prevent and control local desertification, including the "*water-saving, emigration* and *sandy dune control & forestation*" projects. Our objectives were to summarize the validity of these policies and offer an integrated paradigm for endangered ecosystem conservation using a range of methods, including GIS-based landscape analysis, field survey and historic document analysis. Our results indicate that conservation projects have played critical roles in water-saving, society establishment and natural resource management in the Minqin oasis. Over our study period, total water consumption decreased from 7.72 x 10^8 m^3 to 5.36 x 10^8 m^3 and the average area of fallowed cropland for ecological conservation increased to 4438.02 ha per year. Average annual forestation area was kept to 5020.5 ha and the average annual area of controlling sandy dunes was 2163.08 ha. Emigration policy was found to have led to a low birthrate of 5.15%, which will alleviate local population pressure and natural resource consumption. Based on these findings, it can be argued that conservation projects inhibited the aggravation of vegetation cover and the degradation of the groundwater table. Subsequently, we offer a tentative integrated conceptual model of policy strategy for the biophysical and socioeconomic conservation of endangered ecosystems in arid areas. The positive and negative effects of these policies are also discussed.

Introduction

The recent focus on the importance of developing policy strategies for ecosystem sustainability has renewed attention on the relationship between natural ecosystems and socio-economic systems (Marchlis *et al*., 1997; Luzadis *et al*., 2002; López-Hoffman *et al*., 2010). A large number of policy attempts have been made to move society towards a more integrated ecosystem model (Sterner, 1993; Hannam, 2010; López-Hoffman *et al*., 2010). As for any coupled human and natural system (CHANS), there are certain critical elements that need to be considered, such as natural resources and socioeconomic resources (Vitousek *et al*., 1997; Liu *et al*., 2008). These resources are the necessary supplies to maintain basic service and sustainable operation of CHANS; their flow and distribution are critical to ecosystem sustainability (Töpfer *et al*., 1999).

Minqin oasis is one of the world's typical endangered ecosystems, located in the Hexi Corridor, Gansu Province of northwest China (Li, 2008; Zhang *et al*., 2012). It lies in the long and narrow zone surrounded by two large and highly-activated deserts, Badain Jaran and Tengger. Water resource shortage is the most significant ecological feature in this area (Wei *et al*., 2006). Minqin is one of the most severely degraded oases in the world and has become a major source of sand and dust in northwest China (Zhu *et al*., 2009). Over last few decades, vegetation cover and groundwater table had experienced massive degradation (Zhang *et al*., 2012). Local government has subsequently initiated a series of protective programs to prevent and control local desertification extension (Zhu *et al*., 2009). In 2006, a large harnessing program named "The Pivot Harnessing Program of Shiyanghe Watershed", costing 4.47 billion RMB, was carried out following the guideline of "holding back Minqin from being a second Lop Nur" (a vanished oasis in Xinjiang of western China and now a pure desert). This was part of a series of policies made between 2000 and 2009 to control and prevent desertification (Wei *et al*., 2006), including the Pivot Harnessing Program of Shiyanghe Watershed (PH), the Project of Returned Cropland for Ecological Conservation (RC), the Emigration Project (EP) and the Project of Sandy Dunes Control and Forestation (SDCF) (Table 1).

Currently, one key obstacle facing more integrated management of this ecosystem is how to assess the validity of recent conservation policy and its relevant conceptual framework model (Marchlis *et al*., 1997). Relatively few case studies on CHANS are presently available (Thomas, 1956; Marsh and Lowenthal, 1965; Liu *et al*., 2008; Hannam, 2010). The main reason for this is that research efforts are often separated between social scientists and natural scientists, particularly ecologists (Machlis *et al*., 1997; Liu *et al*., 2008). The objectives of this study were to assess the validity of recent ecological management policy in Minqin oasis and develop an integrated conceptual model using the methods of GIS-based landscape analysis, field survey and historic document analysis.

Table 1. Background and major objectives of policy strategy for ecological conservation in Minqin oasis in 2000s.

Policy categories	Executive period	Major objectives
The Pivot Harnessing Program of Shiyanghe Watershed (PH)	2005-2009	The PH, as a critical water conservancy project, was designed to construct water transportation systems to achieve artificial control of groundwater and surface water distribution, and develop a sunlight greenhouse shed system to substitute traditional field production. The major objective was to assemble water resources from upstream of Shiyanghe watershed to downstream Minqin with a total investment of 4.47 billion RMB.
Project of Returned Cropland for Ecological Conservation (RC)	2005-2009	The RC was designed to save a large amount of water usage in agriculture by fallowing (returned almost 20 thousand ha cropland for ecological conservation) because total water consumption in cropland production was >80% of the total available water resource. Financial compensation was 3 thousand RMB per ha. Over 12,000 sets of sunlight palm houses (covering over 1,600 ha) were established as intensive agricultural systems to compensate the loss of fallowed croplands.
Emigration Project (EP)	2000-2009	The EP was designed to transfer part of the population outside the Minqin oasis to alleviate population pressure. There has been about 50 thousand people involved in this program. The approaches of EP included ecological emigration, educational emigration and technical emigration.
Project of Sandy Dunes Control and Forestation (SDCF)	2000-2009	The SDCF was designed to control the extension of moving sandy dunes using the methods of establishing sand barriers and building forest shelter belts. These included grass square checkerboard barriers, clay sand barriers and fence sand barrier, etc.

Note: Four ecological conservation programs were focused on improving water resource usage, restoring vegetation cover, optimizing land use pattern, transforming agricultural production system and improving farmers' livelihood.

Materials and Methods

Study site introduction: The Minqin oasis is a severely-degraded oasis located downstream of Shiyang River watershed of northwest China (102°03´-104°03´E-38°05´-39°06´N). It is an administrative county of Wuwei City, Gansu Province and geographically lies in the northeastern Hexi Corridor. The total land area is about 16 thousand km^2 with an altitude between 1000-1400 m. The weather type belongs to the continental desert climate with annual average air temperature of 7.6℃. Annual average rainfall is 110 mm but annual free evaporation is up to 2640 mm. The total population fluctuates around 310 thousand, 75% of which is rural. The majority of the GDP comes from agriculture and water resource consumption of agriculture occupies over 80% of the total water consumption.

MODIS data analysis and process: MODIS Terra satellite is one of the 15 satellites which are responsible for the NASA's earth observation system. It contains systematic data on land use and vegetation cover. MODIS NDVI data employ a new blend mode and amending method to get the NDVI value of every grid, and then correct the observed quantity to the zenith angle through the BRDF mode. The new blend mode guarantees the comparability between time and space, and the seasonal and annual changes in vegetation cover can be monitored. Our data resource derives from the website of NASA (http://ladsweb.nascom.nasa.gov/index.html). NDVI data were synthesized using a 16-day period of MODIS Terra sensor in 2000, 2005 and 2009 respectively. We selected a series of NDVI data with a normal resolution of 250m (46 scenes). The data of land use and vegetation cover were provided by Environmental and Ecological Science Data Center for West China (WestDC), and the vector map of land-use was derived from Landsat TM images (2000, 2005 and 2009), being assisted by field surveys with a nominal resolution of 30 metres at the scale of 1:100000. By comparing the data from the Landsat TM image with field survey, overall accuracy of classification (the ratio of the number of correctly identified localities to total reference number) was over 90%.

The measurement of returned cropland area: Since 2005, local government issued a strict policy to return cropland for ecological conservation. We made a field survey in 2008 and 2009 respectively. The temporal and spatial dynamics of fallowed croplands were investigated through basal database amalgamating the basic layer of resources satellite No. 2 images and TM satellite images, and further making comparative discrimination with field survey data harvested by RTK-GPS. The data accuracy of RTK field survey was up to the level of sub-metre length. This method was studied and developed as a new integrating technique by combining it with the method of satellite image discrimination, and supplying a mass and quick statistical process for land area and definite spatial distribution. Following the positive detection on remote-sensing images, the detailed information of returned cropland area can be achieved.

The socioeconomic development data harvest: The data of population, birthrate, water resource usage, water quality and policy implementation were harvested from Minqin Statistical Yearbook (2000-2009), Chinese Statistical Yearbook (2000-2009), the Communique of Domestic Economy and Social Development of Minqin (2000-2009) and other references published in Chinese Journals. Four critical policy strategies were considered

(Table 1). The data were analyzed using statistical regression method and linear comparison method.

Results

The changes in land use pattern as a result of ecological conservation policy implementation: During the three years of 2000, 2005 and 2009, the land use pattern was seen to change significantly, with clear variation between 2000 and 2005 and from 2005 to 2009. The NDVI presented a complicated spatial heterogeneity, in which agricultural area made major contributions in the central zone of Minqin oasis while marginal zone's contribution was weak. In general, the NDVI was increased from 2000 to 2005, but then decreased from 2005 to 2009 (Table 2). The highest value of NDVI was 0.17177 in 2005 (Table 2). In addition, dynamics of land use pattern appeared to be highly variable. The area of waters continued to decline due to double driving factors including regional warming and human activities, decreasing from 72.99 ha in 2000 to 45.13 ha in 2009. Rapid development of regional economy and agriculture led to a massive increase in residential land and farmland area while the areas of natural forest land and rangeland tended to shrink rapidly from 2000 to 2005. This was mainly due to the implementation of EP project before 2005, while the SDCF project was put into practice with a limited effect on ecological restoration. To some extent, the contribution made by the SDCF project could be seen in the increase in wasteland (i.e. undisturbed land) area. Furthermore, since the implementation of PH and RC projects in 2005, land use patterns tended to improve. A massive increase in the areas of forest land and rangeland was observed from 692.58 ha and 1,160.89 ha in 2005 to 5,467.51 ha and 15,182.16 ha in 2009 respectively. Simultaneously, the areas of farmland and residential land were decreased from 2005 to 2009 (Table 2, Figs. 1 and 2). This was largely associated with the adaptation and adoption of PH and RC projects. Also, the SDCF project played a critical role in newly-built forest shelter belt and artificial grassland. The EP project lessened the population pressure and accordingly reduced the artificial disturbance to vegetation cover.

Table 2. Dynamics of land use pattern in Minqin oasis during three typical years of 2000s.

Year	Dynamics of land use (ha)						NDVI
	Residential land	Undisturbed land	Natural forest land	Waters	Farmland	Rangeland	
2000	4,948.63	135,046	8,624.24	72.88	114,680.29	38,094.99	0.16127
2005	8,979.62	172,580.01	692.58	52.85	118,121.61	1,160.89	0.17177
2009	7,020.71	156,764.44	5,467.51	45.13	116,993.56	15,182.16	0.17046

The changes in water consumption and quality driven by conservation policy: Four projects of ecological conservation aimed to construct a water-saving society with the emphasis on reducing water consumption and stabilizing the tendency of groundwater decrease. Total water resource consumption remained a continuous decrease from $7.72*10^8$ m^3 in 2000 to $5.36*10^8$ m^3 in 2009, with an average decrease of $0.236*10^8$ m^3 per year (Table 3). However, the deterioration of water environment has become a strong trend due to rapid development of the regional economy, particularly in the outer upstream region of Minqin oasis. The depth of groundwater and its mineralization degree tended to be worse year by year. However, the circumstance was different between from 2000 to 2005 and from 2005 to 2009. The decrease in total water consumption in this area was $0.86*10^8$ m^3 from 2000 to 2005 and $1.5*10^8$ m^3 from 2005 to 2009 respectively (Table 3). What's more, the decrease in groundwater table was 3.051 m from 2000 to 2005 and 0.99 m from 2005 to 2009 respectively. The mineralization degree of groundwater was observed to increase by 0.3457 mg/L from 2000 to 2005 and 0.1451 mg/L from 2005 to 2009 respectively (Table 3). Another important program is the implementation of returned cropland for ecological conservation. Since 2005, total area of fallowed croplands reached up to 17.752 thousand ha (Table 4), which made a big proportion of contribution to decreased water resource consumption. This suggested that the adoption of four projects played a critical role in improving water environment in Minqin oasis.

Table 3. Dynamics of water consumption, availability and quality in Minqin Oasis from 2000 to 2009.

	Water consumption and water quality		
	Total water consumption (10^8 m^3)	Groundwater table (m)	Water mineralization degree (mg/L)
2000	7.72	13.634	2.0524
2001	7.67	14.256	2.1686
2002	7.45	14.687	2.2396
2003	7.21	15.66	2.3796
2004	7.02	16.201	2.488
2005	6.86	17.135	2.3981
2006	6.71	17.788	2.4453
2007	6.36	18.397	2.502
2008	5.76	18.796	2.5587
2009	5.36	18.134	2.5432

Note: the data are cited from the Communique of Domestic Economy and Social Development of Minqin (2000-2009).

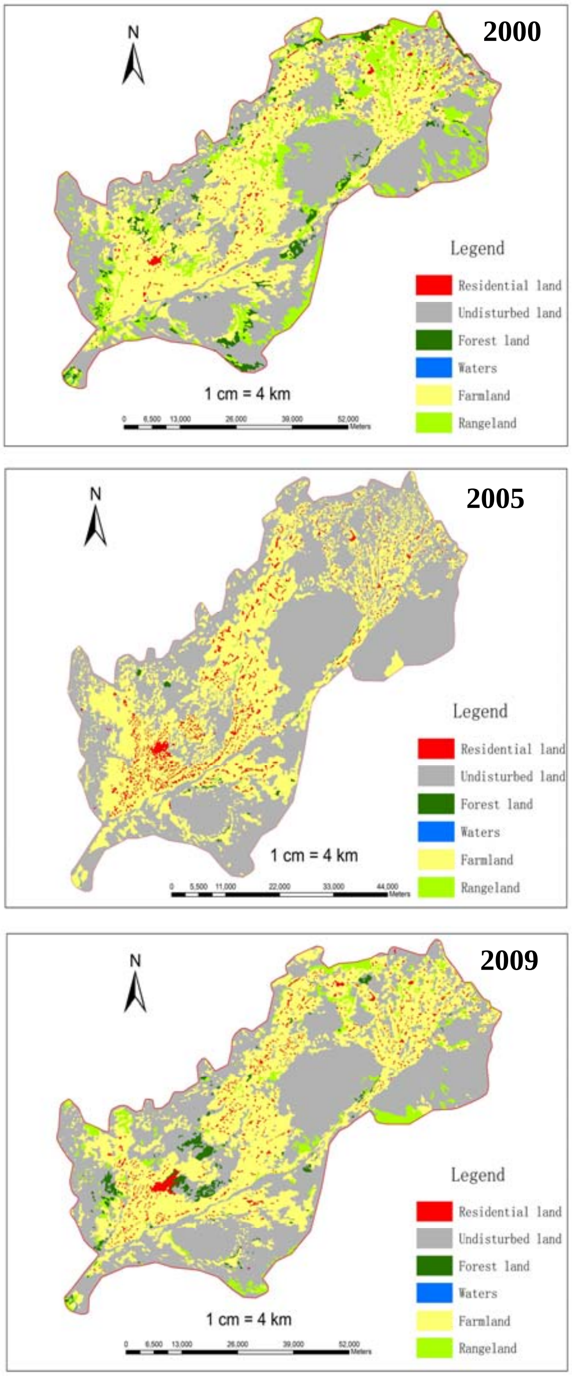

Fig. 1. Spatial distribution patterns of land use in Minqin oasis in 2000, 2005 and 2009.

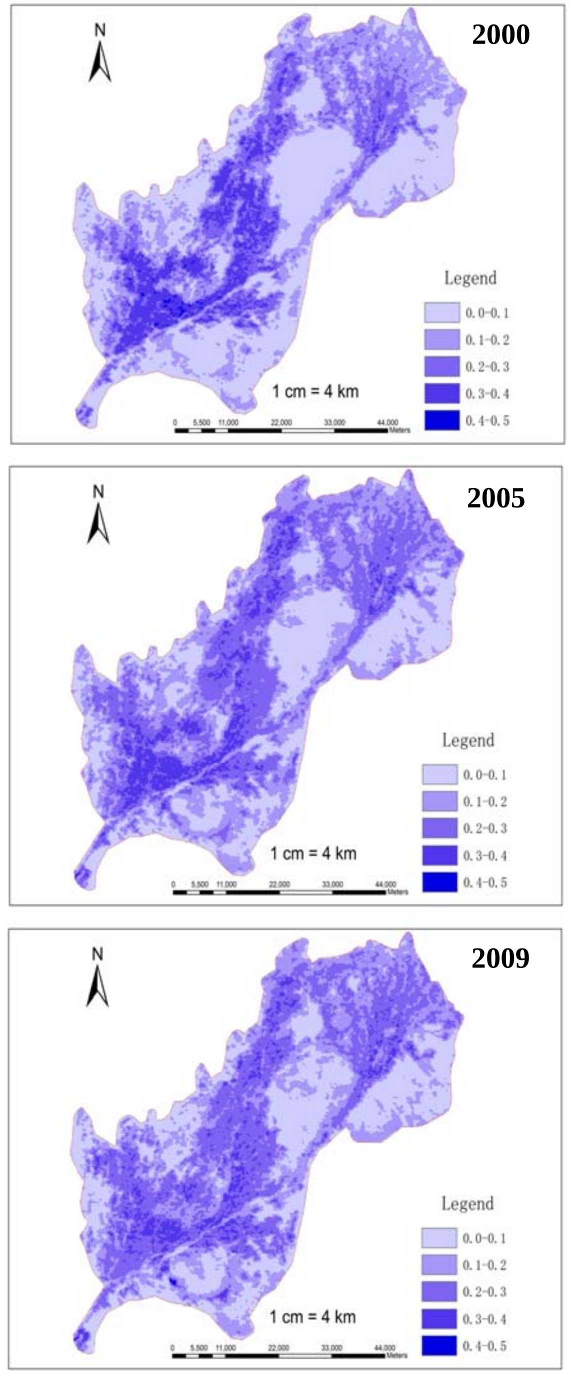

Fig. 2. The variation in NDVI spatial distribution in Minqin oasis in 2000, 2005 and 2009.

Sandy dune control and forestation development: Over the period 2000 to 2009, great efforts on artificial ecological conservation have been made. The average area of artificial forestation was up to 5,020.5 ha per year and the average area of forest seedling culture was 167.25 ha per year (Table 4). The area of controlling moving sandy dune generally tended to increase by an average of 2,163.08 ha each year. In particular, water demand for ecological conservation came from the saved water resource derived from the reduction of cropland area. Our field survey indicated that the area of returned cropland was up to 4,438.02 ha per year from 2005 to 2009 (Table 4). The positive effects of the SDCF project and other projects were obvious in restraining further deterioration of the Minqin oasis ecosystem.

Table 4. Dynamics of major ecological conservation strategy in Minqin Oasis from 2000 to 2009.

Year	Forestation area (ha)	Seedling culture area (ha)	The area of controlling moving sandy dune (ha)	Returned cropland area (ha)
2000	3,341.67	133.4	650.59	-
2001	4,268.8	85.38	873.77	-
2002	7,670.5	226.78	842.49	-
2003	10,538.6	220.11	1,956.18	-
2004	4,535.6	99.72	2,066.83	-
2005	3,455.06	140.07	2,001	-
2006	3,355.01	133.4	1,974.32	1,810.06
2007	3,154.91	86.71	2,014.34	3,588.86
2008	4,502.25	266.8	7,250.29	6,911.95
2009	5,382.69	280.14	2,001	5,441.19
Average	5,020.5	167.25	2,163.08	4,438.02

The forestation data are cited from http://gkdt.minqin.gov.cn/Item/18003.aspx, http://www.minqin.gov.cn/Item/29836.aspx and the Communique of Domestic Economy and Social Development of Minqin (2000-2009). The data of returned croplands are cited from our previous field survey in 2008 and 2009.

Population dynamics and birthrate: Heavy population pressure was extensively viewed as a critical factor to solve the trade-off relationship between resident livelihoods and ecosystem conservation. Our previous social survey indicated that the policy of emigration was a main component of water resource management in the Minqin oasis. In general, there were three major approaches to carrying out the policy: technical emigration, ecological emigration and educational emigration. Technical emigration involved the transfer of local farmer households to an outer residential site from Minqin County, where farmland, farming facility, residential provision and other fundamental establishment are provided with additional financial input by government. The objective of ecological emigration was to transform the farmers' identity from traditional crop growers to current ecological managers or other industrial workers. Some farmers involved in this program will not engage in farming production but instead plant desert-controlling forest or grassland with the support of government's salary supply. Others were able to choose the identity who will engage in agricultural production process and other service industries.

More importantly, educational emigration enabled almost all the young men aged from 18 to 20 to move to an urban area outside of Minqin. The young students around 18 years old chose to enter the university or other professional colleges following the graduation of high school, very few of which returned home. These emigrants in virtue of education led to a massive decrease in local birthrates. As indicated in Figure 3, the average birthrate in Minqin County decreased from 11.63‰ in 2000 to 5.15‰ in 2009, a significantly low value compared with the ~13‰ average birthrate of Gansu Province and China (Fig. 3). The decrease in birthrate directly caused a continuous decline in local population scale. In comparison with the increasing population trend in Gansu Province and China, the population of Minqin County displayed a gradual decreasing trend on the basis of statistical analysis. As shown in Fig. 3, the adoptions of the EP project effectively advanced the reduction in local population and accordingly helped alleviate population pressures and water resource consumption.

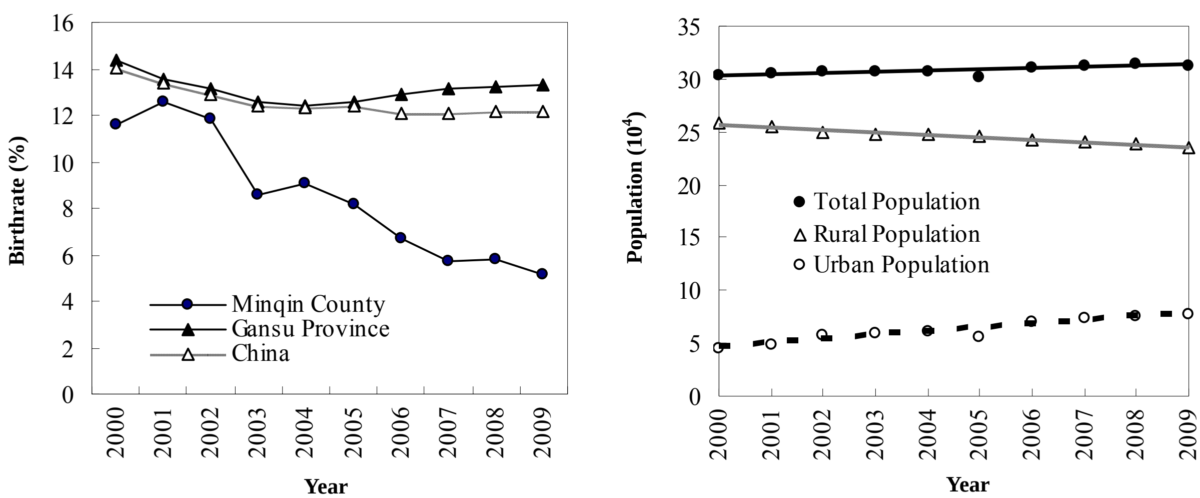

Fig. 3. Dynamics of population and birthrate in Minqin oasis from 2000 to 2009.

Discussion

A more integrated ecosystem conservation model needs to take human factors into consideration (Marsh and Lowenthal, 1965; Luzadis *et al*., 2002; Liu *et al*., 2007; Li, 2008; Liu and Diamond, 2008; Hannam, 2010). As for sustainable human ecosystem management, policy dimensions prove to be critical but existing ecological studies have rarely involved this aspect (Sterner, 1993; López-Hoffman *et al*., 2009). Traditional ecosystem management has been generally limited to the field of natural ecologists, largely separated from social scientists (Liu *et al*., 2007). Minqin oasis, as a typical endangered ecosystem, has received an extensive amount of concern from ecologists and sociologists. Yet, very few previous studies have tried to integrate understandings and findings from different disciplines. A key difficulty of this incorporation is to construct a conceptual framework of endangered ecosystem conservation, which can be accepted and understood by the scientists from natural and social disciplines. In this case, we attempted to develop this conceptual framework system from the perspective of policy. The past decade has seen the most policy implementation in the history of ecosystem conservation in China. From 2000 to 2009, a series of water and land management policies have been issued and implemented in Minqin County, and the four projects mentioned above played critical roles (Zhu *et al*., 2009; Zhang *et al*., 2012).

It is important to note that the adoption of the four management projects is a complicated systematic programme. Each project has had their respective effects on water resource usage and ecosystem conservation, both negative and positive. A large quantity of water was conserved through the PH and RC Projects (from 2005 to 2009) and transferred to the forestation program which improved groundwater status (Zhu *et al*., 2009). However, their negative effects are also obvious, in that the original surface/underground water transportation system was changed, and the topsoil quality of some fallowed croplands was degraded due to the withdrawal of irrigation water. One the other hand, the EP and SDCF proved to positively enhance the restoration of the ecosystem, despite the fact that thee two projects were to a large extent dependent on sustaining financial input and the active participation of local residents. Moreover, community management, such as the development and extension of Village-level Farmer Society for Water acted as an important organizing component of policy making, publicizing and fulfilling objectives. This is to say, the participation of local residents in ecosystem management policy is a dominant factor in success. Our case study may provide a paradigm base for a more integrated ecosystem management model.

The CHANS consist of natural systems, human social systems and their mutual interactions (Fig. 4). The changes in land, water, vegetation and agriculture would periodically bring biophysical feedbacks to the human social system. Similarly, social components, such as information, population, labor and industry will produce relevant feedback to cope with the changes in the natural ecosystem (Machlis *et al*., 1997). When developing the link between the two systems, policy instruments act as a strong and necessary tool. As Sterner proposed in 1993, policy instruments are an invisible but objective system to build the link between natural system and human social system (Sterner, 1993) due to the complexity of CHANS (Liu *et al*., 2007). For environmental management in developing countries, policy strategy as an organizing system generally comprises at least four components such as land, water, population and industrial management (Sterner, 1993; Töpfer *et al*., 1999). Further, it generally involves a series of socioeconomic and biophysical feedback loops, and is derived from inhabitant's participation, policy making processes, adaptation and adoption of innovation (Fig. 4). We therefore tentatively conclude a conceptual model of policy strategy for endangered ecosystem conservation. This model may provide a common framework platform for natural and social scientists and would help raise some strategies to manage endangered ecosystem on the basis of CHANS.

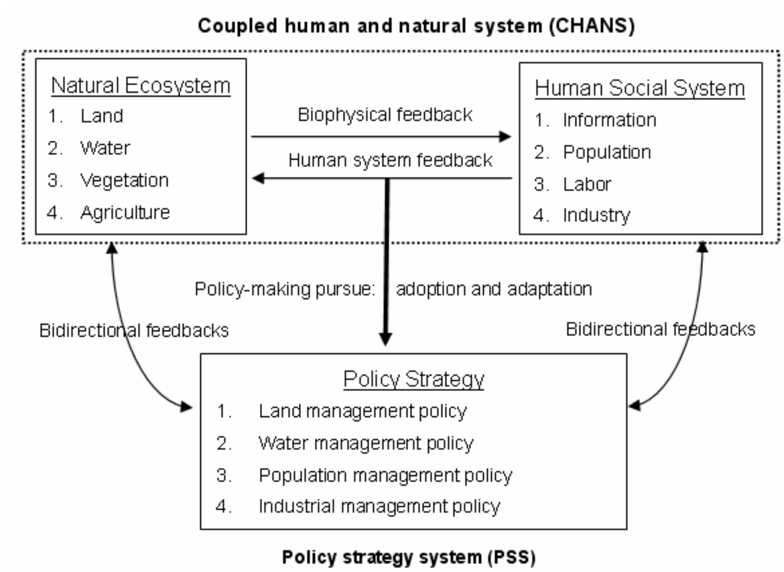

Fig. 4. A conceptual model of policy strategy for endangered ecosystem conservation.

Acknowledgements

This work was partly supported by the Natural Science Foundation of China (No. 31150110149 and 41171154). The data harvest and analysis were partly funded by the New Century Excellent Talents in University (NECT-09-0449), the National Social Science Foundation of China (No. 08XSH011) and Oversea Master Program of Ministry of Education (No. Ms2011LZDX059).

References

Hannam, I. 2010. Human dimensions of soil and water conservation: Mogolia. In: *Human dimensions of soil and water conservation: A global perspective* (Eds.): Ted L. Napier, Nova Science Publishers, Inc. New York, pp: 341-356.

López-Hoffman, L., R.G. Varady, K.W. Flessa and P. Balvanera. 2009. Ecosystem services across borders: a framework for transboundary conservation policy. *Front. Ecol.Environ.*, 8: 84-91.

Li, F.M. 2008. Ecological Approaches to Save Minqin Oasis. *China Development Gateway Web*, http://en.chinagate.com.cn/news /2008-02/25/content_10624643.htm

Liu, J. and J. Diamond. 2008. Revolutionizing China's Environmental Protection. *SCIENCE-NEW YORK THEN WASHINGTON* - pp. 319:37.

Liu, J., T. Dietz, S.R. Carpenter, M. Alberti, C. Folke, E. Moran, A.N. Pell, P. Deadman, T. Kratz and J. Lubchenco. 2007. Complexity of coupled human and natural systems. *Science*, 317: 1513-1516.

Luzadis, V.A., K.M. Goslee, E.J. Greenfield and T.D. Schaeffer. 2002. Toward a more integrated ecosystem model. *Society & Natural Resources, Taylor & Francis*, pp. 15: 89-94.

Marsh, G.P. and D. Lowenthal. 1965. Man and nature. *University of Washington Press*, pp. 341-347.

Machlis, G.E., J.E. Force and W.R. Jr. Burch. 1997. The human ecosystem, Part I: The human ecosystem as an organizing concept in ecosystem management. *Society & Natural Resources*, Taylor & Francis, 10. pp: 347-367.

Sterer, T. 1993. Policy instruments for a sustainable economy. In: Economic instruments for environmental management in developing countries, Proceedings of a workshop held at OECD Headquarters in Paris on 8 October 1992. Paris, France: *Organization for economic conoperation and development*, Chapter 5.

Töpfer, K., P.E. Jongh and S. Captain. 1999. Our common journey: a pioneering approach to cooperative environmental management. *Zed books*, pp. 108-112.

Thomas, W.L. 1956. Man's role in changing the face of the earth. *Chicago, London,* pp. 10-13.

Vitousek, P.M., H.A. Mooney, J. Lubchenco and J.M. Melillo. 1997. Human domination of Earth's ecosystems. *Science* 277:494-499.

Wei, F.Z. and H.L. Li. 2006. Evaluation of ecological environment and water resource in the Minqin County-Empirical studies on basing population development on water resource. *Popul. Econ.*, 6: 53-58. (In Chinese with English abstract)

Zhang, R.J., Z.H. Duan, X.H. Chen and M.L. Tan. 2012. Analysis of water resource ecolgocial environment stress during 2000-2009 in Minqin County, Gansu Province, China. *J. Desert Res.* 32(2): 558-563. (In Chinese with English abstract)

Zhu, S. J., X.Z. Zhao, W.F. Xiong, X.J. Hu, J.N. Li, H.Y. Kong, Y.C. Xiong, G.J. Sun and F.M. Li. 2009. Survey and remote monitoring study on share-planned irrigation area in mid- & down- stream region of Shiyanghe Watershed based on "3S" technology. *Sciencepaper Online* (ISSN2095-2783), http://www.paper.edu.cn,2009(10).

(Received for publication 16 April 2012)