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Land use change and its effects on water quality in typical inland lake of arid area in China

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Abstract

Land-use change is very important for determining and assessing the influence of human activity on aquatic environment of rivers and lakes. The present work with Bosten River basin as the subject, analyzes features of dynamic land-use change of the basin from 1993 to 2013, in order to study the influence of land-use pattern change on the basin water quality, according to the land-use / land-cover(LUCC) chart from 2000 to 2013 made by ArcGIS and ENVI. It shows cultivated land, wetland and forestland constitute most of Bosten River basin, taking up over 41.7% of the total; from 1993-2000, LUCC of the basin is relatively small, with an increase of cultivated land, residential-industry land, water wetlands by 15.09%-18.33%,most of which are transformed from forestland, grassland and unused land; from 2000-2013, LUCC of the basin is relatively significant, with a continuing and bigger increase of cultivated land and Residential-industry area, most of which are transformed from water wetlands and unused land. Based on analysis of land-use pattern and water quality index, it can be told that water pollution is positively correlated to cultivated land and residential-industry area and negatively correlated to water and grassland. Also, the influence of land-use pattern change on water quality has been discussed, whose finding can serve as the scientific evidence for land-use optimization and water pollution control.

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Introduction

Land use and land cover change (LUCC) is a basic parameter used to quantify changes in the natural environment and human activity. (Kibenna *et al.,* 2014; Xie *et al.,* 2014). Land-use is a primary factor causing habitat degradation and poor water quality. Development activities such as agriculture, urbanization, forestry and industries often lead to more intensive land use which increases runoff, and consequent transport of pollutants directly into the rivers. These LUCCs have impact on water quality, mainly on surface water degradation caused by surface runoff from artificial and agricultural areas, factory discharge and cultivated land sewage caused by sewage discharges from agroindustry and urban sprawl (Ahearn, 2005; Hong *et al.*, 2011; Smith *et al.*, 2013).

The study of land use and land cover changes (LUCCs) has been developed in recent times in many countries (e.g. Portugal, Spain, France, and others), mainly to understand the impact of these changes in the territory, in the economy and in the environment, and also to understand the implication on achieving sustainability within development strategies (Hao *et al*., 2007; Wang *et al*., 2006). As a crucial component of global change and sustainable development, LUCC has major effects on ecosystems. climate change and grain yield (Cheng et *al.,* 2015).

Several studies have addressed general relationship between land use patterns and water quality; however, a full understanding of correlation has not yet been achieved because land use types as a whole are actually mutual reflections of multiple factors, such as geomorphic characteristics and anthropogenic activities. For many years, salinization of fresh water related to agricultural practices has been recognized as an environmental problem especially in the arid region of Northwest China (Fang *et al.*, 2013; Guo *et al.*, 2015). They conclude that agricultural land use strongly influences nitrogen phosphorus, and sediments in stream water.

Most rivers and lakes in the arid region of northwest China, affected by human activity and natural conditions like temperature, evaporation and sunshine duration, all experience water quality deterioration of different degrees, featuring increasing salinization of natural water in middle and lower reaches (Chuluun *et al.*, 2002; Lioubimtseva, 2005). As human exploit and utilize land and rivers, irrigation agriculture develops, resulting in more groundwater evaporation and higher salinity of water.

Currently, researches on Bosten River basin are mainly about its climate and hydrological characteristics, features of water quality spatial-temporal change, and relation between biological diversity and groundwater; but studies on LUCC, especially relationship between LUCC and surface water environment pollution by using satellite images and data from *on-site* investigation is meagre. In the present study, Bosten River basin was selected as study area and the remote sensing image interpretation and transition matrix methods were used to analyze the characteristics of land use and varying patterns from 1993 to 2013. By studying correlation between the proportion of different land use and major water pollution indicators such as salinity, COD, TN and TP, this study briefly analyzes the change's impact on water quality of river, which will be the theoretical basis of coordination between aquatic ecological environment protection and rational utilization of land resources in arid areas as well as improvement of the above two work.

Materials and Methods

Study area : Kaidu River, the sole supply to Bosten Lake, originates from the southern slope of Yilianhabierga Mountain in the Central Tianshan Mountains whose peaks are covered with snow throughout a year. From there, it flows a distance of 560 km before entering Bosten Lake. It covers watershed area of 22 000 km^2 and has an average annual runoff of 33.62 million m^3. In this river basin, there are 840 modern glaciers. Kaidu River's discharge is dominated by snow melt water during spring and ice-melt water and rainfall recharges during summers. About 70% of the runoff occurs from May to October. The present study classifies the land into 4 regions (Fig.1). A region refers mainly to forestland and grassland; B region refers mainly to cultivated land, water area and wetland; C region refers mainly to cultivated land and residential-industry land for construction, both with possible increase; D region refers mainly to cultivated land and water area, the latter one of which has seen possible decrease.

Data sources and processing : Land-use and land-cover data are obtained from man-computer interactive interpretation of Landsat TM /ETM remote-sensing data provided by Scientific Data Center of Computer Network Information Center of Chinese Academy of Science, including spatial-temporal data in 1993, 2000 and 2013. The present study deals with water quality monitoring data of Dashankou, Yanqi and Bosten Lake from 1996 to 2013, studies such four water quality indices as salinity, COD, TN and TP out of several indices. The data is from the Water Resources Bureau of Bayinguole and Bosten River Scientific Research Institute.The data is from the research by Li Weihong and other people(Xie *et al.*,2011), Bazhou Environmental Monitoring Station in Xinjiang and monitoring materials of Bosten River Scientific Research Institute over the years. The population and total output value of first industry come from Xinjiang Statistical Yearbook and Xinjiang Production and Construction Group Statistical Yearbook from 1991-2011.

In the present study, using ENVI and ArcGIS9.3, the remote sensing image processing software and GIS software, processed the remote sensing images of three phases including resolution resampling, geometric correction, radiation correction and image enhancement. Then, based on visual interpretation, land was classified into six categories like cultivated land, forestland, wetland, water area, residential-industry area and unused land, and chooses classified samples and accuracy evaluation samples. Next, these images were interpreted by maximum likelihood classification method, which is often adopted in supervised classification. At last, accuracy evaluation on the extracted land-use chart was made by confusion matrix to qualify

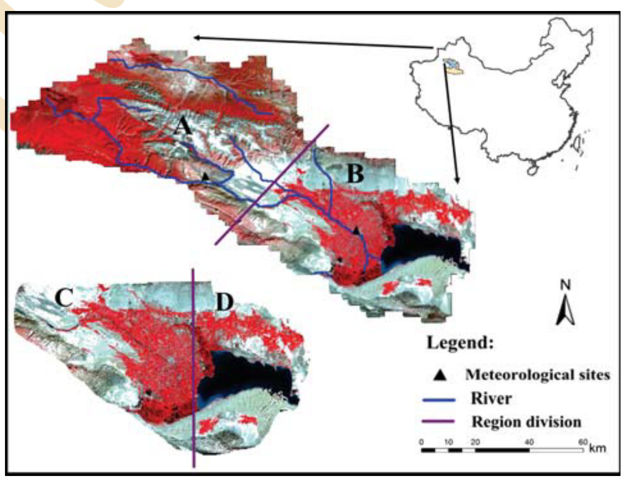

Fig. 1 : Location and its region division of the study area

interpretation accuracy. The results demonstrate that the accuracies of classified images for 2000 and 2013 were 87.75% and 84.18%, The total classification accuracy was 84%, and the Kappa coefficient was 0.8216.

To examine the suitability of data for correlation analysis, KMO and Bartlett's test were performed. KMO is the measure of sampling adequacy that indicates the proportion of variance which is common variance, *i.e.,* which might be caused by underlying factors. High value (close to 1) generally indicates that principal component/factor analysis might be useful, which is the case in this study (KMO=0.716).

Model of land-use/ land-cover area change : Range of land-use change: Area change of land-use patterns is significant for regional land-use change, and land area change is first reflected in total area change of different land-use patterns. Through analysis of land-use area change, the general trend of land-use change and land-use structural change can be perceived. The range of land-use change refers to the area change of land use, demonstrating the total area change of different land-use patterns. Its formula of mathematical model is as follows (Basnyat *et al*., 1999):

$$R_L = \frac{U_b - U_a}{U_a} \bullet 100\%$$

In the formula, R_L means change range of one certain land-use pattern within study period; U_a means the area of one land-use pattern in initial stage of the study, while U_b means in the final stage.

Dynamic degree of single land-use pattern : Under the influence of natural and human factors, the area of all land-use patterns with the region changes with different ranges and speeds at different stages, as well as spatial differences. Dynamic degree of single land-use pattern showed the area change of one certain land-use pattern within certain time range. The formula of mathematical model is follows (Wang *et al*., 2001):

$$K = \frac{U_a - U_b}{U_a} \bullet \frac{1}{T} \bullet 100\%$$

Where, K means dynamic degree of one certain land-use pattern in the study period; when T is set as year; K means the annual change rate of certain land-use pattern within the research area.

Land-use transition matrix model : To analyze dynamic change process of all land-use patterns and its source dynamic change charts of land-use at different time through superposition of each two of land-use/ land-cover charts in 1993, 2000 and 2013 was obtained and further works out land-use transition matrices of different periods. The matrix reflects structures of land-use patterns at initial and final stage and transition of all patterns, which is helpful to study the transition direction of all the patterns at initial stage and their source and structure at final stage. The transition model is shown in the following formula (Wang, 2000):

$$A = \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ \cdot & \cdot & & \cdot \\ \vdots & \vdots & & \vdots \\ A_{n1} & A_{n2} & \cdots & A_{nn} \end{bmatrix}$$

Where, A is the area; n is the number of land-use patterns; i is the land-use pattern at initial stage while j is final stage.

Correlation analysis : Based on the results of land-use change research, this paper classifies the land into 4 regions (Fig.1). A region refers to mainly woodland and grassland; B region refers to mainly cultivated land, water area and wetland; C region refers to mainly cultivated land and residential-industry land for construction, both with possible increase; D region refers to mainly cultivated land and water area, the latter one of which has seen possible decrease. This paper calculates the area of each land-use pattern of four regions in 1993, 2000 and 2013 via ENVI software, and Pearson correlation analysis of sample water quality index and area of all land-use patterns via SPSS16.0 was calculated. This model was successfully used in Bai Yang Dian river and analyzed the change in impact on water quality of river.

Results and Discussion

Based on the processed remote sensing data, three time series of land use data were acquired for analysis in the present study (Fig. 21). Statistics analysis showed that the land types used in this basin were mainly cultivated land, water and forest land, which covered 41.7% of total area. Among them, water wetland and cultivated land covered the most (30%). This conclusion is consistent with the latest reports (Chen *et al.,* 2012; Du *et al.,* 2014; Ye *et al.,* 2014). From land distribution, cultivated land was mainly centered in the north and the west of the lake, and had a tendency to expand in the north eastern part.

From Fig. 3 and Fig. 4, it can be perceived that from 1993 to 2000, LUCC of the basin was relatively small, with an increase of cultivable land, residential-industry land, and wetlands. Wetlands increased 18.33%, while residential-industry land and cultivated land showed increase of 16.18% and 15.09%. However, grassland, forestland and unused land showed a respective decrease of 15.36%, 14.48% and 6.25%. Meanwhile, unused land, cultivated land, water wetlands experience greatest changed in terms of area are as follows : 395.7896km^2, 230.7km^2 and 267.7578km^2, while residential-industry land showed small change of 55km^2. In all land-use patterns, dynamic degrees of cultivated land, residential-industry land, water area and wetland were relatively big, about 2%.

From 2000 to 2013, LUCC of the basin was significant. Cultivated land and residential-industry land continued increase with a greater changing range of 49.79% and 27.08%, respectively, than the previous stage, and forest land also showed a slight increase while grassland and unused land decreased. In terms of changing area, cultivated land and unused land changed a lot, with an increase of 875.6538km^2 and a decrease of 816.898km^2, respectively. Dynamic degree of land-use patterns, except cultivated land and residential-industry land was relatively small, with their absolute value less than 1%.

During the whole study period from 1993 to 2013, cultivated land and residential-industry land continued to increase, cultivated land's area takes up 14.7% of the total in 1993, and then the number grows to 17.0% in 2000 and over 25.4% till 2013. Land under construction increased from 350

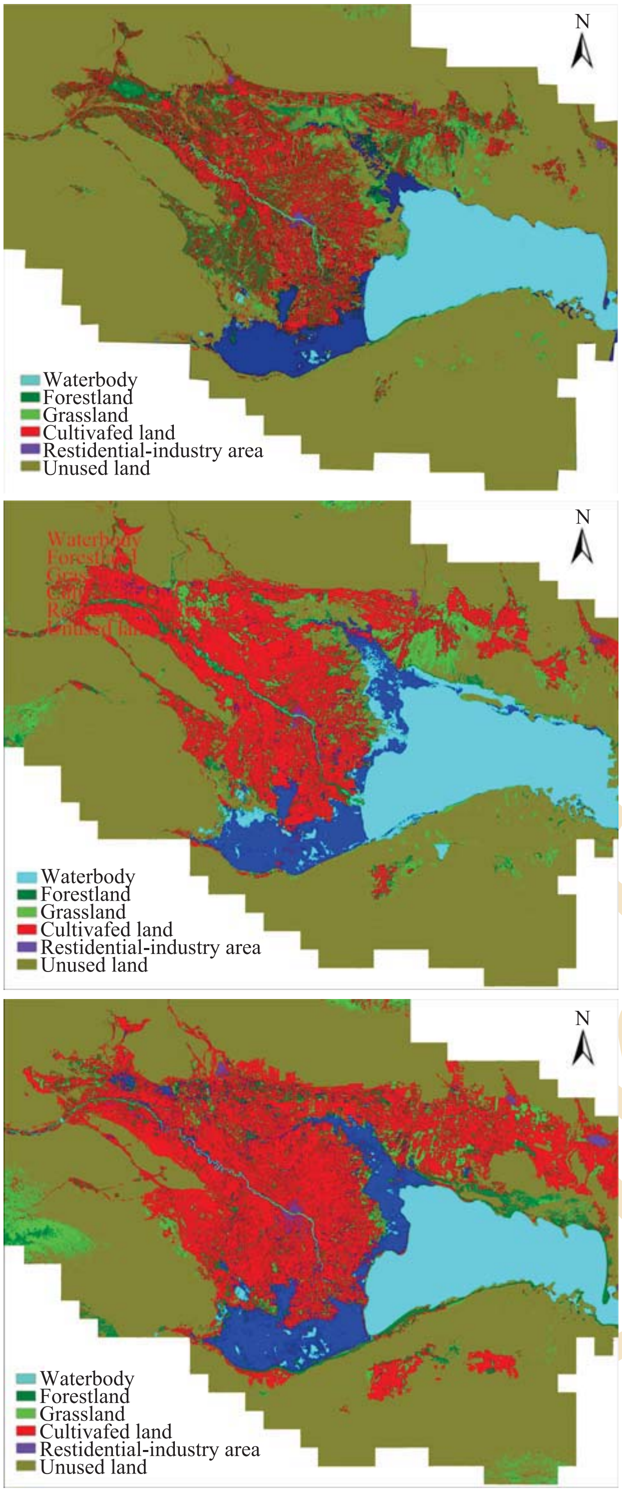

Fig. 2 : Land uses in the Bosten Lake in 1993, 2000, and 2013

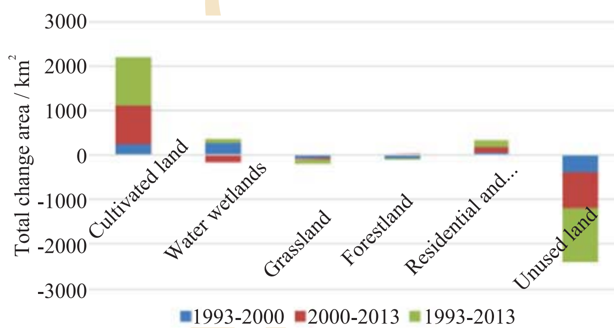

Fig. 3 : The total change of study area

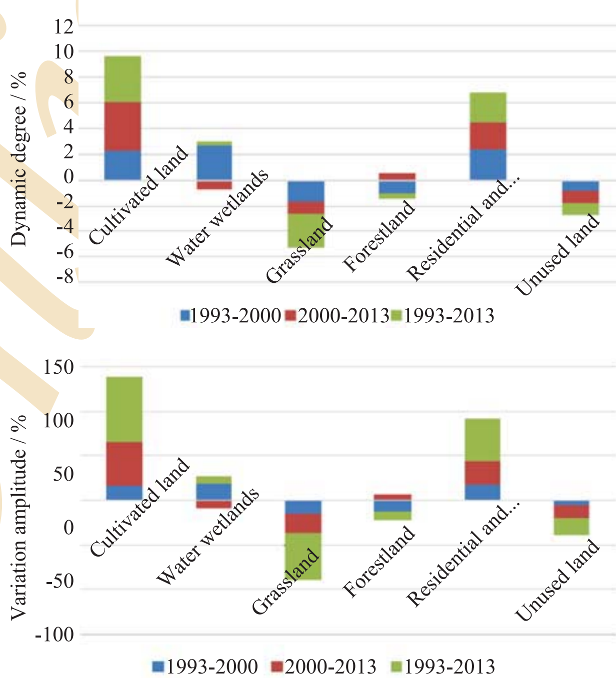

Fig. 4 : Percentage of dynamic degree/variation amplitude in the study area

km^2 to 502 km^2; grassland and unused land decreased; wetlands increase and then decreased; forestland decreased and then increased, respectively.

For better understand and studying the law of land-use change in the study, transition matrix for different land-use patterns were made to know transition direction of all the patterns in spatial and temporal dimension. The analysis of land-use and land-cover transition matrix from 1993 to 2013 (Table. 1) revealed that in 1993 cultivatable land mainly turned into wetlands with an area of 56.37km^2; forestland and grassland mainly turned into cultivatable land (138.66km^2) and water area of 71.59km^2; construction land mainly transformed into cultivatable land (54km^2) and grassland (21km^2); unused land was converted into cultivatable land of 116.05km^2 and wetlands of 145.74km^2, respectively.

In terms of transition source, in 2000, cultivatable land increase highly, mainly from forest land, grassland and unused land with a total area of 138.6km^2 and 116.05km^2; forestland and grassland mainly came from unused land of 73.94km^2; wetland area mainly came from unused land of 145.72km^2 and cultivatable land of 56.37 km^2; residential-industry land mainly came from unused land of 106km^2 and grassland area of 24km^2, respectively (Zulpiya *et al.,* 2014).

The land-use and land-cover from 2000 to 2013 were analyzed, as the transition matrix (Table 2) shows, in 2000, in the aspect of transition direction, cultivated land is mainly turned into wetlands and forest lands with the acreage of 64.8km2. Forest lands and grassland are mainly turned into farmland and unused land, the conversion area are 136.5km2 and 22.96km2 respectively. Water area and wetland are mainly transformed into cultivated land of 155.26km^2 and forest land of 76.38km^2; unused land mainly becomes cultivated land of 608.54km^2 and forest land of 73.6km^2.

And in 2013, considering the contribution of transition source, cultivatable land showed a significant increase, mainly from wetlands of 155.26km^2, as well as unused land of 608.54km^2; forestland and grassland mainly came from unused land of 133.69km^2; wetlands mainly came from unused land of 19.35km^2 and cultivatable land of 54.89km^2; residential-industry land mainly comes from

Table 1 : Nature of the land cover changes from 1990 to 2000 (km^2)

2000/1993	W	C	G	F	R	U
Water wetlands(W)	1454.88	0	0	6	0	0
Cultivatedland(C)	56.37	1450.1	13.61	0	8	0
Grassland(G)	29.55	76.52	48.52	42.03	24	0
Forestland (F)	42.09	62.15	0	323.95	0	45.96
Residential-industry(R	0	54	21	8	257	0
Unused land(U)	145.75	116.05	48.46	25.49	106	5895.9

Table 2 : Nature of the land cover changes from 2000 to 2013 (km^2)

2013/2000	W	C	G	F	R	U
Water wetlands(W)	1483.62	155.26	0	76.38	0	13.47
Cultivatedland(C)	54.89	1683.8	0	10.01	10	0
Grassland (G)	4.69	50.55	37.37	2.36	29	7.07
Forestland (F)	0	86.3	0	270.27	33	15.97
Residential-industry(R)	0	50	6	0	339	0
Unused land(U)	19.35	608.54	60.09	73.6	91	5088.4

Table 3 : Pearson's correlation coefficients between land use types and water-quality index

Water quality index	Land use type				
	C	W	G	F	R
salinity	.948**	-.949**	-0.411	.934**	.922**
COD	.663*	-.786**	-0.366	.702*	.609*
TN	.704**	-.484	-0.673*	.646*	.654*
TP	.250	-.583	-0.247	-.457	.676*

*. Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed)

unused land of $91km^2$, respectively.

Factors' response to land-use patterns can be evaluated by establishing a correlation between water quality index and the area of corresponding patterns (Liu *et al.,* 2010; Zhou *et al.,* 2014) as shown in Table 3. Cultivatable land and residential-industry land were positively correlated to salinity, COD, TN and TP, which means cultivated land irrigation drainage and sanitary and industrial waste water are main contributors to water pollution. Cultivatable land is less correlated to TP while residential-industry land are more correlated, which means the latter mainly has organic pollution on water quality owing to sanitary and industrial sewage (Huang *et al.,* 2011; Yu *et al.,* 2014).

Water and grassland were negatively correlated to salinity, COD, TN and TP, which means that the relative area increased of them improves water quality. It is in that water area increase can not only dilute pollutant concentration to some extent (Bu *et al*., 2014; Buck *et al.*, 2004), but also degrade some organic matters by self-purification of water, which improves water quality of rivers. Grassland was positively correlated to salinity, COD, TN and TP, which was different from many previous researches. It is mainly because that although the policy of returning cultivated land to forest land has achieved some progress, the forest land returned from cultivated land was much less than that turning into cultivated land and residential-industry land in the past two decades. Thus, the positive influence of grassland on the water quality of rivers was masked.

Industrial enterprises have always been one of the major pollution source in that they drain their sewage in concentration through constant drainage outlet. Urban industrial and sanitary sewage produces more and more serious pollution every passing year. A large amount of grassland and wetland are reclaimed as cultivatable land, leading to significant increase in irrigated cultivatable land area with more water consuming and deteriorating water quality. At the same time, use of excess chemical fertilizer in cultivatable land area, increases soil salinity and drains chemical fertilizer into Bosten River. Researcher have shown that about 21.69×10^4t salt enters Boston river deteriorating the quality of river water (Gkiougkis *et al.,* 2014; Yan *et al.*, 2010).

During the past two decades, land-use structure of Bosten River basin has gone through severe changes. Through analysis of area transition matrix, mutual transformation between LUCC patterns explains that, a large amount of grassland, forestland and unused land were transformed to cultivatable land (Xu *et al*., 2013). Factors' response to land-use patterns can be evaluated by establishing a correlation between water quality index concentration and the area of corresponding patterns. Weatlands cultivated land, residential-industry land were positively correlated to salinity, COD, TN and TP, while water and grassland were negatively correlated. Forestland showed another kind of correlation with water quality indices.

The research results, serving as scientific evidence for land-use optimization and water pollution control, would guide the policy makers to coordinate spatial development and aquatic environment protection. Also, further study could be combined with water chemistry and indication of river self-purification mechanism to water quality indices.

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References

Ahearn, D.S., R.S. Sheibley and R.A. Dahlgren: Land use and land cover influence on water quality in the last free-flowing river draining the western Sierra Nevada, California. *J. Hydrol.,* **31**, 234–247 (2005).

Basnyat, P., L.D. Teeter and B. Lockaby: Relationships between landscape characteristics and non-point source pollution inputs to Coastal Estuaries. *Environ. Manage.*, **23**, 539-549 (1999).

Basnyat, P., Teeter L.D. and B. Lockaby: Relationships between landscape characteristics and non-point source pollution inputs to Coastal Estuaries. *Environ. Manag.*, **23**, 539-549 (1999).

Bu, H., W. Meng and Y. Zhang: Relationships between land use patternsand water quality in the Taizi River basin, China. *Ecol. Indic.,* **41**, 187–197 (2014).

Buck, O., D.K. Niyogi and C.R. Townsend: Scale-dependent of land use effectson water quality of streams in agricultural catchments. *Environ. Pollut.,* **130**, 287–299 (2004).

Chen, Z.S., Y.N. Chen and B. Li: Quantifying the effects of climate variability and human activities on runoff for Kaidu River Basin in arid region of northwest China. *Theor. App. Climatol.,* **111**, 537-545 (2012).

Cheng, L., P. Jiang and R. Zhao: Impacts of LUCC on soil properties in the riparian zones of desert oasis with remote sensing data: A case study of the middle Heihe River basin, China. *Sci. Total Environ.,* **506-507**, 259-271 (2015).

Chuluun, T. and D. Ojima: Land use change and carbon cucle in arid and semiarid lands of east and central Asia. *Sci. China,* **45**, 48-56 (2002).

Du, Q., H.L. Xu and H.B. Ling: Changes in land use/cover change and fragmentation of landscape in the Kaidou-Kongque River valley in recent 20 years. *J. Ecol. Rural Environ*., **30**, 795-799 (2014).

Fang, S.F., J.W. Yan and M.L. Che: Climate change and the ecological responses in Xinjiang, China: model simulations and data analyses. *Quater. Inter.,* **311**, 108-116 (2013).

Gkiougkis, A. Kallioras and V. Diamantis: Assessment of soil salinization at the eastern Nestos River Delta, N.E. *Greece. Catena.*, **28**, 132-145 (2014).

Guo, M., X. Zhou, J. Li, W. Wu and J.Y. Chen: Assessment of the salinization processes in the largest in land fresh water lake of China. *Stoch Environ. Res Risk Assess.,* **33**, 89-104 (2015).

Hao, X.M., Y.N. Chen and R.F. Zhao: Analysis of socio-economic driving forces on land use and land cover change in Tarim River Basin. *J. Desert Rese.,* **27**, 405-411 (2007).

Hong, Z., L. Hailin and C. Zhen: Analysis of land use dynamic change and its impact on the water environment in Yunnan plateau lake area - a case study of the Dianchi lake drainage area. *Procedia Environ. Sci.,* **10**, 2709–2717 (2011).

Huang, J.L., M. Ho and P.F. Du: Assessment of temporal and spatial variation of coastal water quality and source identification along Macau peninsula. Stoch. Environ. *Rese. Risk Assess.,* **25**, 353-361 (2011).

Kibenna, J., I. Nhapi and W. Gumindoga: Assessing the relationship between water quality parameters and changes in landuse patterns in the Upper Manyame River, Zimbabwe. *Phy. Chem. Earth*, **67-69**, 153-163 (2014)

Lioubimtseva, E., J.M. Adams and G. Kapustin: Impacts of climate and land-cover changes in arid lands of Central Asia. *J. Arid Environ.,* 62, 285-308 (2005).

Lioubimtseva, E., J.M. Adams and G. Kapustin: Impacts of climate and land-cover changes in arid lands of Central Asia. *J. Arid Environ.,* **62**, 285-308 (2005).

Liu, F., J.L. Liu and T. Zhang: Land use change and its effects on water quality in Baiyangdian lake of north China during last 20 years. *J. Agro-Environ. Sci.*, **29**, 1868-1875 (2010).

Ma, J.Z. and Q.Z. Gao: Water resources system and eco-environmental problems in the inland river basin of arid northwest China. *Arid Land Resour. Environ.,* **11**, 15–21 (1997).

Smith, A.P., A.W. Western and M.C. Hannah: Linking water quality trends with land use intensification in dairy farming catchments. *J. Hydrol.*, **476**, 1–12 (2013).

Song, Y., Z. Fan and Z. Lei: Water resources and ecological environmental problems in Tarim River of China. *Science in China*, **47**, 1053-1064 (2000) .

Statistical Bureau of Xinjiang Uygur Autonomous Region, 1991-2011. Xinjiang Statistical Yearbook. China Statistics Press, Beijing.

Tong, S.T. and W. Chen: Modeling the relationship between land-use and surface water quality. *J. Environ. Manag.,* **66**, 377-393 (2002).

Wang, T.: Land use and sandy desertification in the North China. *J. Des. Rese.,* **20**, 103-107 (2000).

Wang, X.: Integrating water quality management and land-use planning in a watershed context. *J. Environ. Manag.,* **61**, 25-36 (2001).

Wang, X.Z., Y.H. Zheng and S. Li: Analysis of land use and landscape pattern change in west of Hainan Island. *J. Des. Rese.,* **26**, 409-414 (2006).

Xie, G.J. and J.P. Yang: Spatio-temporal heterogeneity of water quality (2010-2011)and succession patterns in Lake Bosten during the past 50 years. *J. Lake Sci.,* **23**, 837- 846 (2011).

Xu, C.C., Y.N. Chen and Y.P. Chen: Responses of surface runoff to climate change and human activities in the arid region of Central Asia: a case study in the Tarim River Basin, China. *Environ. Manag.,* **51**, 926-938 (2013).

Yan, Z.L., X.G. Wang and Q. Huang: Monitoring analysis on spatio-temporal changes of the soil salinization in the upper stream of Tarim River. *J. Arid Land Reso. Environ.,* **10**, 105-110 (2010).

Ye, Y., X. He and W. Chen: Seasonal water quality upstream of Dahuofang Reservoir, China– the effects of land use type at various spatial scales. *CLEAN – Soil Air Water*, **42**, 1423–1432 (2014).

Yu, S., Z. Xu and W. Wu: Spatial variation of water quality and its response to landuse in the Beiluo River Basin. *Acta Scien. Circumst.,* **34**, 1309-1315(2014).

Yu, S., Z. Xu, W. Wu and D. Zou: Effect of land use types on stream water quality under seasonal variation and topographic characteristics in the Wei River basin,China. *Ecolog. Indic.,* **60**, 202-2012 (2016)

Zhang, T.: Water resource utilization and ecological environment in the arid areas of China. *Nat. Resour.,* **1**, 62–67 (1987).

Zhou, H. and W.H. Li: Water-salt succession patterns (1951-2011) and its response to climate change in Lake Bosten. *Lake Sci.,* **26**, 55- 65 (2014).

Zulpiya, M., Y. Hamit, E. Anwar, A. Ablimit: Response of ecosystem services value to land use/cover change in the Yanqi Basin of Xinjiang, China. *J. Desert Rese.,* **34**, 275-283 (2014)