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Land-use/land cover changes and their driving forces around wetlands in Shangri-La County, Yunnan Province, China

Gang Wu^a, Ya Gao^a, Yi Wang^a, Yangyang Wang^b and Dong Xu^{c*}

^aState Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China; ^bDepartment of Forestry and Natural Resources, Purdue University, 715 West State Street, West Lafayette, IN 47907, USA; ^cDepartment of Tourism Management, School of Tourism & Hospitality Management, Shenyang Normal University, Shenyang 110034, China

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The Shangri-La County of the Yunnan Province, SW China, is an economically and ecologically important area. This is especially true for Jiantang that is famous for the Napahai, Bitahai and Shudu Lake wetlands. However, continuing development has threatened the wetland ecosystems and the associated biodiversity in these areas. To better document such changes in land use and their effect on the ecosystem, land use was mapped using a time series of satellite images acquired in 1974, 1993, 2000 and 2012. The results of this survey suggest that forest cover first decreased and then increased. The most obvious changes occurred in cultivated and developed land types, each expanding 1.6× and 17.6×, respectively. Population growth, and previous large-scale deforestation, converting cropland to forest and grassland project, and tourism development were the main socio-economic driving forces. It was also apparent that the rapid development of the tourism industry played a key role in the land-use change, especially after 2000. These data suggest that some regulation to the region's tourism industry and implementation of a sustainable land management policy should be considered to ensure preservation of the Jiantang wetlands.

Keywords: Shangri-La County; land-use change; wetland; tourism industry; spatial variation; temporal change

Introduction

Land-use change has been one of the focal points of global change studies over the past several decades (Lindgren 1985; Lambin & Geist 2006; de Freitas et al. 2013) as it directly or indirectly affects water cycling, soil conservation, air quality, ecosystem structure and function, biodiversity and climate (Hudson et al. 2006; Torbick et al. 2006; Malaviya et al. 2010; Zhang et al. 2010; Naik et al. 2011; de Freitas et al. 2013). The goal of such studies has been to better understand temporal dynamics and spatial variations in land use, and to better understand key factors that drive land-use change. These data are essential for the success of efforts to determine effective ways to balance the relationship between human activities and preservation of land resources (Sairinen 2004; Hudson et al. 2006; Dai et al. 2012; de Freitas et al. 2013; Gao et al. 2013; Lin et al. 2013).

Wetlands provide essential habitat for wildlife, improve water quality and regulate biogeochemical cycles (Howard-Williams 1985; Gren et al. 1994; Woodward & Wui 2001; Brander et al. 2006; Mitsch & Gosselink 2007; Muangthong et al. 2012; Xie et al. 2012; Kaffashi et al. 2013; Li et al. 2013). Plateau wetlands are of particular importance (Li et al. 2013). In China, most plateau wetlands are located in the upstream regions of major rivers, including the Yangtze, Yellow and the Mekong. These wetlands directly or indirectly affect the health and environment of the downstream regions (Li et al. 2013). As

such, the wetlands in Shangri-La County are very valuable for ecological and scientific research.

Although the need to protect the plateau wetlands in Shangri-La County has been widely recognised, basic research on plateau wetlands remains limited. Much attention has focused on the diversity of wild edible plants or their dynamics within such wetlands (Liu et al. 2009; Liu & Constable 2010; Li et al. 2011, 2013; Ju et al. 2013), but land-use changes, both inside and outside these areas, have received relatively little attention. Converting wetland into other land uses is common in forested or wetland areas and doing so has consequences beyond degradation. In this study, we quantified land-use change in wetland, cultivated land and developed land within Jiantang, in which three wetlands – Bitahai, Napahai and Shudu lake – are located. We also compared land-use change in the town in order to ascertain probable causes for such. These data improve our understanding of the factors driving such land-use change, which is critical to preservation of wetland resources in the Shangri-La area.

Materials and methods

Study sites

Shangri-La County is located in the far northwest corner of China's Yunnan Province. Shangri-La is one of the highest mountain wetland regions in the world. In the

*Corresponding author. Email: xudong1222@126.com

Figure 1. Location of the study area.

second half of the twentieth century, the county was called Zhongdian County but was renamed Shangri-La in 2001 in order to increase regional tourism. Although measures are being implemented to safeguard Shangri-La from the negative effects of the tourism industry, there remains considerable concern regarding the preservation of the local indigenous communities and protection of the region's environment. Jiantang (the county seat) was used as the primary study site (Figure 1).

Image data and classification

Landsat images acquired in 1974 (MSS), 1993 (TM), 2000 (ETM+) and 2012 (ETM+) were used to develop time-series data sets of land use for Jiantang between 1974 and 2012. Data processing included: (1) registration and geometric correction of the original imagery into UTM WGS84, (2) classification of rectified images with supervised classification methods and recoding of spectral classes into forest land, cultivated land, snowfield, wetland (classified into water and grassland in this study for more detailed analysis) and developed land with ERDAS IMAGINE using the general national land-use classification system and last (3) post-classification processing and accuracy assessment with ERDAS IMAGINE. In addition to the original Landsat data bands, the normalised difference vegetation index (NDVI) was included in image data classification. NDVI was computed as follows:

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED}) \quad (1)$$

where NIR and RED represented red and near-infrared bands, respectively (Jensen 2004).

The accuracy of land-use data in 2000 and 2007 was assessed by direct comparison with Google Earth historical images. The land-use data in 1974 and 1993 were assessed with forest inventory data, relief map and/or aerial photographs depending on the availability. We established a minimum accuracy of 90% for the purpose of landscape quantification (Shao & Wu 2008; Rooney et al. 2012). Image data classification processes were enhanced by increasing the number of spectral classes until the omission and commission errors were balanced and the highest overall accuracy was obtained (Shao et al. 2003; Lang et al. 2008).

Land-use data analysis

The dynamic percentage and dynamic rate of land-use change were computed as follows:

$$P = (S_b - S_a) / S_a \times 100 \quad (2)$$

$$K = (S_b - S_a) / S_a / (T_2 - T_1) \times 100 \quad (3)$$

where P is the land-use dynamic rate (%) within the given time period, K is the land-use dynamic rate (%), S_a and S_b are the areas of a given land-use type in the beginning (T_1) and end (T_2) of a study period.

The land-use intensity comprehensive index is expressed as follows (Shi et al. 2010).

$$I = 100 \times \sum_{i=1}^n (G_i \times C_i) \quad (4)$$

where I is the land-use intensity comprehensive index (the higher the value of I , the more land is effected by human activity) and G_i is a land-use intensity grade value of the i th land-use type (the higher the value, the higher the degree of human disturbances). Land-use types are divided into several grades according to their change intensity to relative to a natural 'equilibrium status' (Shi et al. 2010). In this study, snowfield and water were assigned grade 1; forest land and grassland were assigned grade 2; cultivated land was assigned grade 3 and developed land was assigned grade 4. C_i is the area percentage of the i th land-use type and n is the number of land-use types.

Spatial overlay analyses were performed to create transition matrixes and derive more detailed information about land-use change of the variable cover types.

Results and analyses

The basic characteristics of land-use changes

Land-use maps of the four periods were obtained (Figure 2). In order to eliminate the influence of season for snow and simplify land-use change analysis, snowfield and forestland were considered together.

In Jiantang, forestland was the dominant land-use type throughout the study period, but the cover of forestland decreased steadily from 111,673 ha in 1974 to 107,783 ha in 2012 (Table 1). The biggest change in area occurred in grassland, decreasing by 4377 ha. Developed land increased from 120 to 2119 ha between 1974 and 2012. Cultivated land was the second-highest growth rate, increasing from 2673 to 4232 ha. The water area also increased, due to the construction of the Sangna reservoir.

From 1974 to 1993, the developed land changed the most (22.39%), increasing from 120 to 633 ha. Cultivated

Figure 2. Land-use maps of various periods.

Table 1. Proportion of different land-use types between 1974 and 2012.

Land cover type	1974		1993		2000		2012	
	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)
Forest land	121,405	83.9	119,692	82.7	122,699	84.8	121,720	84.1
Cultivated land	2673	1.8	6335	4.4	5108	3.5	4232	2.9
Water body	989	0.7	869	0.6	818	0.6	1496	1.0
Grassland	19,544	13.5	17,201	11.9	15,108	10.4	15,167	10.5
Developed land	120	0.1	633	0.4	997	0.7	2119	1.5

Table 2. Dynamic percentage of different land-use types between 1974 and 1993, 1993 and 2000, as well as 2000 and 2012.

Land cover type	1974–1993		1993–2000		2000–2012	
	Dynamic percentage (%)	Dynamic rate (%)	Dynamic percentage (%)	Dynamic rate (%)	Dynamic percentage (%)	Dynamic rate (%)
Forest land	–1.41	–0.07	2.51	0.36	–0.80	–0.07
Cultivated land	137.02	7.21	–19.37	–2.77	–17.16	–1.43
Water body	–12.14	–0.64	–5.81	–0.83	82.81	6.90
Grassland	–11.99	–0.63	–12.16	–1.74	0.39	0.03
Developed land	425.45	22.39	57.64	8.23	112.48	9.37

Table 3. Land-use intensity comprehensive index (*I*).

	1974	1993	2000	2012
Total	201.33	204.65	204.34	204.82

land increased by 3662 ha, much more than developed land, likely since agricultural was the major industry in this period, with a second-highest increase (by 7.21%). Grassland decreased by 2343 ha, and the forest land decreased by 1713 ha (Table 2). The *I* value increased from 201.33 to 204.65 (Table 3), indicating that the developed land area increased.

From 1993 to 2000, the developed land increased from 633 to 997 ha. However, in contrast to 1974 to 1993, cultivated land decreased by 1227 ha, although this was much less than grassland (2092 ha) (Table 2). The forestland gained 3007 ha during this period. The *I* value was nearly equal in 1993 and 2000, suggesting that land-use change was still highly affected by human factors during this period. However, the role of influencing land-use changes was less than that in the earlier period (Table 3). This was mainly a result of government policies driving the return of farmland to forest and grassland, and limiting the reclamation for ecological protection.

From 2000 to 2012, developed land gained 1122 ha, increasing more than any previous period. Water body increased due to construction of the Sangna reservoir and other water conservancy projects (Tables 1 and 2, Figure 2). The *I* value ranged from 204.82 to 204.34 (Table 3), higher than that in the earlier period, suggesting that the study area was affected more by human factors during this period.

Transformation of land-use/cover changes

There were obvious differences in land use in the periods examined in this study (Figure 3). From 1974 to 1993, forestland was largely converted into cultivated land (241 ha) and developed land (64 ha), and a part of cultivated land was converted into developed land (134 ha) (Figure 3). Grassland was primarily converted into cultivated land (4327 ha), or converted into developed land

(301 ha). This was the largest type of land transformation. There were more than 100 ha of water converted into cultivated land, mainly distributed in the nearby Napahai wetland (Figures 2a and 2b).

From 1993 to 2000, forestland and grassland were primarily converted into cultivated land and developed land, and a part of this cultivated land was subsequently converted into developed land (Figure 3). In contrast to the earlier period, only 2000 ha of cultivated land was converted into grassland (1504 ha) and forestland (321 ha), indicating that large changes in land use may have been partially controlled. This was likely due to local governments restricting reclamation of grassland and strengthening protection and restoration efforts.

From 2000 to 2012, the most obvious transformation occurred in grassland, cultivated land and developed land. The area of grassland and cultivated land converted into developed land was much greater than in the earlier periods. Much of the cultivated land was converted into grassland, similar to the last period; a fraction of cultivated land and grassland was converted into water body due to the construction of the Sangna reservoir and other water conservancy projects such as small reservoir construction and small watershed comprehensive management.

Discussion

Effects of climate change, logging and population growth on land-use change

Over a long period, both natural and human factors drive changes in land use. It has become relatively warmer and drier in this region in recent decades (Zhang et al. 2007). Such change results in a reduction in wetland area. Human activity was undoubtedly the primary driving factor in land-use change in this study area over the past few decades.

Since 1958, forest harvesting has been the major revenue source within Shangri-La County. Forest harvesting has increased soil erosion, which negatively affects the water supply to wetlands. In 1998, the implementation of the Natural Forest Protection Project has played an important role in protecting forests and wetlands. However, the ongoing need for large amounts of timber results in continued expansion of surrounding deforestation.

Figure 3. Matrix of land-use/land cover type changes (the horizontal axis represents land-use types in the base period and the histogram represents the amount of area converted from the land-use types in the base period to various land-use types in the last period).

Not surprisingly, human population density sharply increased in the study area, directly parallel to the loss of forestland and grassland from 1974 to 2012. From 1992 to 2011, the population increased from 31,791 to 85,634. Population growth leads to expansion of cultivated land and residential areas, often at the expense of grassland as this land type is most easily brought into cultivation.

Challenges for wetland conservation in Jiantang

Forest and wetland ecosystems in Jiantang have been continuously degraded by excessive logging and other human activities, primarily due to population growth and socio-economic development (Zhang et al. 2007). Since 1974, due largely to human activities, the forests surrounding the region's wetlands have diminished each year, and much of the grassland is either now cultivated or developed, with the most obvious change occurring in the Napahai area. Of the three lakes, Napa Lake is the closest to the county town and was one the first areas to be developed. The water area has decreased, and human activities now occur within the wetland centres.

The effects of tourism development on wetlands are becoming more obvious. Infrastructure construction (e.g. roads, viewing platforms, airports), trampling and environmental pollution put increasing pressure on wetland protection efforts (Bi et al. 2004; Chen & Yang 2004; Wang et al. 2004; Zhang et al. 2009; Yao 2011). Previously, it was thought that a well-planned tourism industry would create local job opportunities and alleviate

ecological pressure by utilising resources in a more sustainable fashion. However, this present study suggests that such use can also damage the ecosystem. Developed land is needed for hotels, restaurants and other tourism-related services, and cultivated land is further utilised to produce forest-related products for purchase; in both cases, deforestation becomes inevitable in the immediate areas surrounding the wetlands. Preserving forest and grassland cover outside the three lakes areas in Jiantang is critically important as these wetlands are no longer large enough to be self-sustaining (Zhao & Jia 2008). Deforestation and grassland lost around these wetlands areas not only reduces or damages important habitat, but also creates barriers between wetlands areas and their surrounding habitats.

The existing tourism industry in Jiantang, if not well-regulated, will eventually lead to significant decline in the region's natural occurring wetland ecosystems.

Conclusions

Land use has changed significantly in Jiantang from 1974 to 2012. Grassland has decreased continuously within this region. A total of 4378 ha of forestland have been lost over the past 38 years. In contrast, cultivated and especially developed land increased in this region. As a result, the wetland ecosystems of Jiantang have become fragmented.

A booming tourism industry and the subsequent dramatic expansion of developed land in Jiantang now

threatens the integrity of the region's wetland ecosystems. The Napahai wetlands were the first in this region to be developed and are thus experiencing more negative effects (relative to the Bitahai and Shudulake wetlands). It is important to better control the development of the region's tourism industry if these wetland ecosystems are to be preserved. Conservation measures such as creation of large-area, multi-use forest buffers and corridors around and within each wetland, limiting tourist access to the most sensitive ecosystems and last the development and implementation of sustainable land management policies should be considered.

Acknowledgements

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References

- Bi Y, Wang J, Wang P, Chen H, Nian B, Xi W, Li S. 2004. Analysis on threat factor of plateau wetland in Shangri-La. *Environ Prot.* 6:26–30. Chinese.
- Brander LM, Florax RJGM, Vermaat JE. 2006. The empirics of wetland valuation: a comprehensive summary and a meta-analysis of the literature. *Environ Resour Econ.* 33:223–250. doi:10.1007/s10640-005-3104-4
- Chen B, Yang G. 2004. Quantitative study of the impact of tourist trampling on ecotourism scenic region. *Scientia Geographica Sinica.* 24:371–375. Chinese.
- Dai LM, Wang Y, Lewis BJ, Xu D, Zhou L, Gu XP, Jiang LH. 2012. The trend of land-use sustainability around the Changbai mountain biosphere reserve in northeastern China: 1977–2007. *Int J Sust Dev World Ecol.* 19:369–377. doi:10.1080/13504509.2012.675599
- de Freitas MWD, Santos JORD, Alves DS. 2013. Land-use and land-cover change processes in the upper Uruguay Basin: linking environmental and socioeconomic variables. *Landscape Ecol.* 28:311–327. doi:10.1007/s10980-012-9838-9
- Gao Z, Cao X, Gao W. 2013. The spatio-temporal responses of the carbon cycle to climate and land use/land cover changes between 1981–2000 in China. *Front Earth Sci.* 7:92–102. doi:10.1007/s11707-012-0335-x
- Gren I, Folke C, Turner K, Batemen I. 1994. Primary and secondary values of wetland ecosystems. *Environ Resour Econ.* 4:55–74. doi:10.1007/BF00691932
- Howard-Williams C. 1985. Cycling and retention of nitrogen and phosphorus in wetlands: a theoretical and applied perspective. *Freshwater Biol.* 15:391–431. doi:10.1111/j.1365-2427.1985.tb00212.x
- Hudson PF, Colditz RR, Aguilar-Robledo M. 2006. Spatial relations between floodplain environments and land use—land cover of a large lowland tropical river valley: Pánuco Basin, México. *Environ Manage.* 38:487–503. doi:10.1007/s00267-003-0157-4
- Jensen JR. 2004. Introductory digital image processing: a remote sensing perspective. Upper Saddle River (NJ): Prentice Hall.
- Ju Y, Zhuo J, Liu B, Long C. 2013. Eating from the wild: diversity of wild edible plants used by Tibetans in Shangri-La region, Yunnan, China. *J Ethnobiol Ethnomed.* 9:28. doi:10.1186/1746-4269-9-28
- Kaffashi S, Shamsudin MN, Radam A, Rahim KA, Yacob MR. 2013. We are willing to pay to support wetland conservation: local users' perspective. *Int J Sust Dev World Ecol.* 20:325–335. doi:10.1080/13504509.2013.800612
- Lambin EF, Geist H. 2006. Land-use and land-cover change. Berlin: Springer.
- Lang RL, Shao GF, Pijanowski BC, Farnsworth RL. 2008. Optimizing unsupervised classifications of remotely sensed imagery with a data-assisted labeling approach. *Comput Geosci.* 34:1877–1885. doi:10.1016/j.cageo.2007.10.011
- Li W, Tan R, Wang J, Du F, Yang Y. 2013. Effects of anthropogenic disturbance on richness-dependent stability in Napahai plateau wetland. *Chin Sci Bull.* 58:4120–4125.
- Li Y, Long C, Kato K, Yang C, Sato K. 2011. Indigenous knowledge and traditional conservation of hulless barley (*Hordeum vulgare*) germplasm resources in the Tibetan communities of Shangri-La, Yunnan, SW China. *Genet Resour Crop Evol.* 58:645–655. doi:10.1007/s10722-010-9604-2
- Lin HL, Feng QSH, Liang TG, Ren JZ. 2013. Modelling global-scale potential grassland changes in spatio-temporal patterns to global climate change. *Int J Sust Dev World Ecol.* 20:83–96. doi:10.1080/13504509.2012.749815
- Lindgren DT. 1985. Land use/land cover: inventory and change. Land use planning and remote sensing. Dordrecht: Springer; p. 101–115.
- Liu Y, Constable A. 2010. ESD and lifelong learning: a case study of the Shangri-La institute's current engagement with the Bazhu community in Diqing, China. *Int Rev Educ.* 56:271–285. doi:10.1007/s11159-010-9164-x
- Liu Y, Dao Z, Yang C, Liu Y, Long C. 2009. Medicinal plants used by Tibetans in Shangri-La, Yunnan, China. *J Ethnobiol Ethnomed.* 5:15. doi:10.1186/1746-4269-5-15
- Malaviya S, Munsli M, Oinam G, Joshi PK. 2010. Landscape approach for quantifying land use land cover change (1972–2006) and habitat diversity in a mining area in central India (Bokaro, Jharkhand). *Environ Monit Assess.* 170:215–229. doi:10.1007/s10661-009-1227-8
- Mitsch WJ, Gosselink JG. 2007. Wetlands. Hoboken (NJ): Wiley.
- Muangthong S, Clemente RS, Babel MS, Gallardo W, Weesakul S. 2012. Assessment of wetland ecosystem health in lower Songkhram, Thailand. *Int J Sust Dev World Ecol.* 19:238–246. doi:10.1080/13504509.2011.620643
- Naik DR, Bosukonda S, Mrutyunjayareddy K. 2011. Reservoir impact assessment on land use/land cover and infrastructure—a case study on Polavaram project. *J Indian Soc Remote Sens.* 39:271–278. doi:10.1007/s12524-011-0086-2
- Rooney RC, Bayley SE, Creed IF, Wilson MJ. 2012. The accuracy of land cover-based wetland assessments is influenced by landscape extent. *Landscape Ecol.* 27:1321–1335. doi:10.1007/s10980-012-9784-6
- Sairinen R. 2004. Assessing social impacts of urban land use plans: from theory to practice. *Boreal Environ Res.* 9: 509–517.
- Shao GF, Wu JG. 2008. On the accuracy of landscape pattern analysis using remote sensing data. *Landscape Ecol.* 23:505–511. doi:10.1007/s10980-008-9215-x
- Shao GF, Wu W, Wu G, Zhou XH, Wu JG. 2003. An explicit index for assessing the accuracy of cover-class areas. *Photogram Eng Remote Sens.* 69: 907–914.
- Shi LY, Cui SH, Yin K. 2010. The impact of land use/cover change on ecosystem service in Xiamen. *Acta Geographica Sinica.* 65:708–714.
- Torbick NM, Qi J, Roloff GJ, Stevenson RJ. 2006. Investigating impacts of land-use land cover change on wetlands in the Muskegon river watershed, Michigan, USA. *Wetlands.* 26:1103–1113. doi:10.1672/0277-5212(2006)26[1103:IIOLLC]2.0.CO;2
- Wang J, Wang P, Lu F, Yang G. 2004. Impact of tourist activities on the environment in Bitahai lake wetland ecotourism scenic spot. *Prog Geog.* 23:101–108. Chinese.

- Woodward RT, Wui Y. 2001. The economic value of wetland services: a meta-analysis. *Ecol Econ.* 37:257–270. doi:[10.1016/S0921-8009\(00\)00276-7](https://doi.org/10.1016/S0921-8009(00)00276-7)
- Xie Z, Liu J, Ma Z, Duan X, Cui Y. 2012. Effect of surrounding land-use change on the wetland landscape pattern of a natural protected area in Tianjin, China, Thailand. *Int J Sust Dev World Ecol.* 19:16–24. doi:[10.1080/13504509.2011.583697](https://doi.org/10.1080/13504509.2011.583697)
- Yao P. 2011. The influence of tourism development on the ecological environment of Shangri-La in Diqing. *J Sichuan Higher Inst Cuisine.* 3:32–34. Chinese.
- Zhang K, Tian K, Lv XG, Luo S, Li JY, Li NY. 2009. Impacts of tourism on water storage and regulation of meadow soil in Napahai lakeshore wetlands. *Adv Water Sci.* 20:800–805. Chinese.
- Zhang M, Wang K, Chen H, Liu H, Yue Y, Zhang W. 2010. Impacts of land use and land cover changes upon organic productivity values in Karst ecosystems: a case study of northwest Guangxi, China. *Front Earth Sci China.* 4:3–13. doi:[10.1007/s11707-010-0005-9](https://doi.org/10.1007/s11707-010-0005-9)
- Zhang Q, Ma Y, Liu WJ, Li HM. 2007. Regional land use dynamics of plateau wetlands in the northwest of Yunnan Province, China. *J Mountain Sci.* 25:265–273.
- Zhao JZ, Jia HY. 2008. Strategies for the sustainable development of Lugu Lake region. *Int J Sust Dev World Ecol.* 15:71–79. doi:[10.1080/13504500809469771](https://doi.org/10.1080/13504500809469771)