Land Cover Change in Response to Climate Variation in the Source Region of the Yangtze River (SRYR), Central Tibetan Plateau

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Abstract: The Yangtze River is China's longest river and its source region is sensitive to climate variation due to its high elevation. With the influence of global warming, the land cover change can be taken as the joint result of climatic factors. However, during the time when air temperature increased rapidly from 1975 to 2005, the relative importance of global warming to these land cover changes in Qinghai-Tibet Plateau is not well understood. To accurately assess the land cover change during 1975-2005, Landsat images and GIS techniques were used to monitor its distribution in 1975, 1990, and 2005. By overlay analysis, the dynamic patterns of land cover change were observed. The main transition patterns are the higher coverage grassland converted to lower coverage grassland (grassland degradation), grassland converted to swamped land, and the lower coverage grassland converted to sandy land (grassland desertification). The rapid increased air temperature was mostly responsible for the observed land cover change in SRYR.

1 INTRODUCTION

Monitoring the temporal land cover changes are important for sustainable development (Lambin et al., 2000) due to their close relationship with the ecosystem processes (Shi et al., 2009) such as soil erosion (Wang et al., 2014). The interactions between land cover variation and climate variation is complicated (Bonan, 2008; Pielke, 2005). Nearly 25 % of the Yangtze River's flow originates in the SRYR. This region lies at an altitude greater than 3,500 m above sea level, which makes it's fragile and susceptible to climate variations (Ren et al., 2010).

During the last fifteen years, the environmental problems of the Tibetan Plateau have been receiving more and more attention due to the impacts from global warming and increasing regional human activities (Ren et al., 2010; Fang et al., 2011; Shen et al., 2015; Arthur et al., 2008). The mean annual temperature of the Tibet Plateau increased by 2.0 °C during 1960-2010, and the ground surface temperature increased by 1.7 °C (Shen et al., 2015). The rapid climate change in this region is causing lots of environmental problems. From 1986 to 2009, the total glacier area loss was approximately 119.3 km^2 (Yao et al., 2014). Simulated results show that the area of permafrost has reduced 18,900 km^2 from 1980s to 2000s (Fang et al., 2011). Meanwhile, aeolian desertification land increased by 2,678 km^2 (Hu et al., 2012). As a result, the newly built Qinghai-Tibet Railway (completed in 2006), which runs through the SRYR undergoes serious windblown-sand damages (Zhang et al., 2012), and sand-damage–prevention measures have been used along this railway (Cheng and Xue, 2014).

Furthermore, air temperature is expected to continue increasing in the Tibetan Plateau during the next one-hundred year (Shen et al., 2002), and this will cause further more permafrost degradation (Nan et al., 2004) and aeolian desertification (Wang et al., 2002). To compare with the developed regions of China, relatively less attention has been paid to land cover change in sparsely populated Tibetan Plateau.

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Understanding the dynamic patterns of land cover evolution will provide more information for environmental management.

2 STUDY AREA

The SRYR is located in China's Qinghai Province, in the center of the Tibetan Plateau, covering an area of 1.42×10^5 km^2 as shown in Figure. 1. The altitude ranges from 3,350 to 6,519 m, with a mean altitude of 4,754 m. Many rivers originate in this region, which are Chumaer, Beilu, Tuotuo and Dangqu rivers. Bayan Har Mountains is a southern branch of the Kunlun Mountains. Glacier, lakes, swamped and sandy lands are widely distributed.

This region is characterized by chilly, high-altitude climate. The mean annual precipitation is about 350 mm, and the difference in precipitation is very obvious between dry and wet seasons.

The main vegetation includes high-cold meadow species. Soils in this region are mainly alpine steppe soils. More than 400 km of the Qinghai-Tibet railway was built across the SRYR between Kunlun and Tanggula mountains, which is called the "World's highest railway" because over 80 % of the railway is at altitudes above 4000 m, and the highest point is 5,072 m above sea level at Tanggula Mountains, and most of the railway on this sector was laid atop permafrost. The Quaternary sediments are widely distributed in this region (Wu et al., 2006), which provide abundant of materials for wind erosion (Huang et al., 1993).

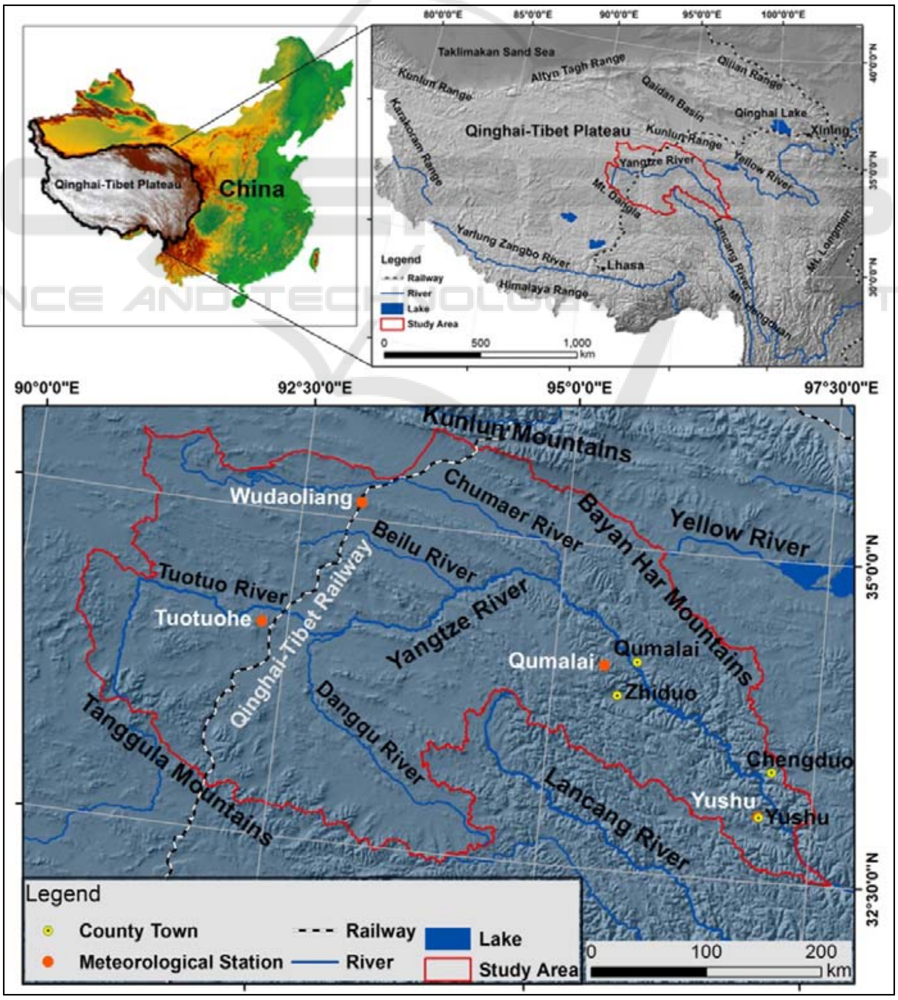

Figure 1: Location of the source region of the Yangtze River in the Tibetan Plateau.

2.1 Data Sources

Remote sensing (RS) technique and geographical information system (GIS) software were applied to get the extent of land cover at three years (1975, 1990 and 2005). The remote sensing images included Landsat multi-spectral scanner (MSS) acquired in 1975 (80-m spatial resolution); and Landsat Thematic Mapper (TM) images acquired in 1990 and 2005 (30-m spatial resolution). Images between June and October were selected, on account of vegetation is more easily recognized in this season (Ruelland et al., 2010).

2.2 Classification System for Land Cover

The classification system of Chinese Resources and Environment Database of the Chinese Academy of Sciences was adopted in this study. In this study, classification system is divided into two levels. At first level, there are six classes viz. cultivated, forest, grass, building and unused land as well as water bodies. In this study, grassland were divided into three categories (high, moderate, and low vegetation coverage) as it was the main land cover type in this region. All subcategories of water bodies, cultivated land, building land, and forest were grouped into first-level category, while, wetlands and sandy land were separated from unused land since they are particularly sensitive to climate change.

3 RESULTS

3.1 Land Cover Changes

Based on Landsat images, vector maps of land cover in 1975, 1990 and 2005 were obtained as shown in Figure. 2. It shows that grassland and unused land were the dominant land cover types in the SRYR in 2005, accounting for 58.9 and 24.4 % of the total study area, respectively. In 2005, high, moderate, and low coverage grassland accounting for 10.3, 21.4, and 27.2 %, respectively of the total study area (Table 1), and which were mainly distributed in the south of this region (Figure. 2). Unused land had consistently been the second most extensive land cover type in the three periods, which accounting for 24.4 % of the area in 2005 (Table 1). Waters bodies account for 7.2 % of the total study area in 2005, and was mainly distributed in the west of the study region. Although the distribution area of swamped and sandy lands were relatively scarce, accounting for only 4.2 and 3.7 %, respectively, the changes of which can be taken as the responses of land covers to climate change. Due to high-cold climate, only a minority of forest is distributed in the southeast of the study region, where altitude is relatively low (3000~4000 m). As a lot of places of the study area is no man's land, so the area of cultivated and building lands is only 5 and 13 km^2, respectively in the whole SRYR.

Table 1: Area and percentage of each land cover type in the SRYR (km2).

Class	1975		1990		2005	
	Area (km^2)	% of total	Area (km^2)	% of total	Area (km^2)	% of total
Cultivated land	12	0.0	12	0.0	13	0.0
Forest land	2336	1.6	2305	1.6	2280	1.6
High coverage grassland	15392	10.8	15056	10.6	14631	10.3
Moderatecoverage grassland	30822	21.7	30383	21.4	30389	21.4
Low coverage grassland	38766	27.2	38749	27.2	38752	27.2
Bodies of water	9932	7.0	10175	7.2	10280	7.2
Building land	4	0.0	6	0.0	5	0.0
Unused land	34707	24.4	34909	24.5	34783	24.4
Sandy land	4879	3.4	5117	3.6	5210	3.7
Swamped land	5450	3.8	5588	3.9	5958	4.2
Total	142299	100.0	142299	100.0	142299	100.0

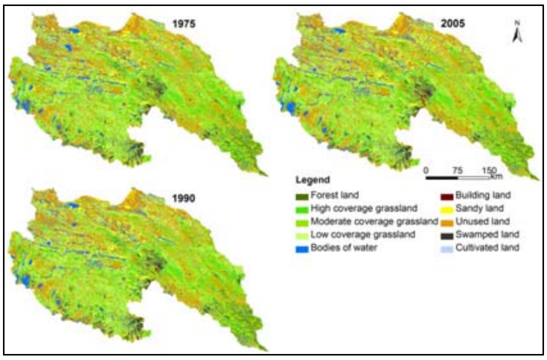

Figure 2: Land cover map of the SRYR in 1975, 1990, and 2005.

The high coverage grassland experienced the most significant decrease during 1975-1990 and 1990-2005, decreased by 336 and 425 km^2 respectively. Meanwhile, the forest also experienced a continuous declining trend during the two periods, decreased by 56 km^2 from 1975 to 2005. On the contrary, the area of water bodies, sandy and swamped lands experienced a continuous increasing trend. The area of water bodies increased by 243 km^2 from 1975 to 1990, and increased by 105 km^2 from 1990 to 2005. Sandy land increased by 238 km^2 from 1975 to 1990, and increased by 93 km^2 from 1990 to 2005. Swamped land increased by 139 km^2 from 1975 to 1990, and increased by 369 km^2 from 1990 to 2005.

In the period from 1975 to 2005, land covers in the SRYR experienced sharp changes (Figure. 3). The area of swamped, sandy lands and water bodies increased obviously, increased by 508, 331 and 348 km^2, respectively. The area of high and low coverage grassland decreased sharply, decreased by 761 and 434 km^2, respectively. Besides, the area of forest decreased by 56 km^2.

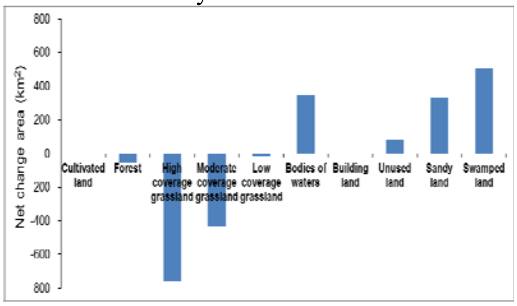

Figure 3: Net change area in each land cover type from 1975 to 2005.

3.2 Spatial Dynamic Processes of Land Cover Change

The transition matrix for LUCC from 1975 to 2005 was calculated by overlay analysis (Table 2). A total of 11,588 km^2 land cover changed during 1975-2005, accounting for 8.1 % of this region. From the LUCC transition matrix (Table 2), the main transition patterns can be clearly observed, including the transitions of moderate coverage grassland to low coverage grassland (1255 km^2), and high coverage grassland to moderate (962 km^2) and low coverage grassland (242 km^2). Besides, the transition of grassland to sandy land (362 km^2) and swamped land (698 km^2) were also obvious.

Table 2: The transition matrix of LUCC between 1975 and 2005 in the SRYR (km2).

Class	CL	FL	HCGL	MCGL	LCGL	BW	BL	UL	SL	SWL	Total Area in 2005
CL	12			1	0			0			13
FL		2266	5	6	3			0			2280
HCGL		17	13704	522	180	6		73	1	127	14631
MCGL		37	962	28105	811	36		353	6	79	30388
LCGL		6	242	1255	35787	138		1219	51	54	38751
BW		0	24	230	148	9107	0	644	101	26	10280
BL				1	1	0	3	0			5
UL		3	39	325	1570	511	1	32104	220	12	34783
SL			2	180	180	94		267	4480	7	5210
SWL		8	414	198	86	40		47	21	5143	5957
Total Area in 1975	12	2336	15391	30822	38766	9932	4	34707	4879	5450	

*CL=Cultivated land; FL=Forest land; HCGL=High coverage grassland; MCGL=Moderate coverage grassland; LCGL=Low coverage grassland; BW=Bodies of water; BL=Building land; UL=Unused land; SL=Sandy land; SWL=Swamped land.

In detail, during 1975-2005, the loss in high coverage grassland was mainly converted to low coverage grassland, moderate coverage grassland, and swamped land, conversion area were 242, 962, and 414 km^2, respectively. The gain of high coverage grassland was also mainly converted from low and moderate coverage grassland to swamped land, the conversion area was 522, 180, and 127 km^2, respectively, but the gain areas were all less than the loss areas, which resulted in a general decreasing tendency of high coverage grassland. The gain and loss area of swamped land was 814 km^2 and 306 km^2, respectively, and which mostly converted with grassland. The gain of sandy land was primarily converted from unused land, moderate and low coverage grassland, the area was 267, 180, and 180 km^2, respectively. In addition, the decrease of forest land was mainly converted to high and moderate coverage grassland, and swamped land.

4 DISCUSSION

The change of vegetation is the result of drought in the shallow soil of the habitat, and which is greatly controlled by temperature and precipitation (You et al., 2014). Although some study points out that overgrazing will cause the degradation of alpine ecosystems by ruining vegetation coverage (Song et al., 2009; Wang et al., 2008), climate warming is taken as the most close driving factors of grassland degradation in the Tibetan Plateau (Wang et al., 2006; Shen et al., 2011; Gao et al., 2014). So we analyzed changes in the temperature and precipitation in the SRYR based on meteorological data from 1975 to 2005 (Hu et al., 2012).

The climate in the SRYR got warmer and wetter between 1975 and 2005. During this period, the mean annual precipitation increased at a rate of 21 mm per decade. The increase of precipitation would helpful for vegetation growth and increase soil moisture, and would thereby get rid of of grassland degradation and desertification, even resulted in the extension of swamped land. In the meantime, the annual temperature increased at a rate of 0.47 °C per decade, and the increase rate accelerated in the last 15 years (at rate of 0.71 °C per decade). The air temperature increase rate are much greater than the global increase rate (0.03 to 0.06 °C per decade) (Folland et al., 2002).

Increasing temperature has been taken as the key climatic factor responsible for land degradation (Gao et al., 2014) and aeolian desertification Tibetan Plateau (Xue et al., 2009). In the SRYR, permafrost has reduced and unstable permafrost has increased due to temperature increase since 1980s (Fang et al., 2011). Permafrost plays an crucial role in maintaining the alpine vegetation in the Tibetan Plateau (Yang et al., 2004), but the degradation of vegetation can enhance the effects of climate change (Wang et al. 2012) . This barrier also leads to soil organic matter accumulation (Wang et al. 2006). Aeolian desertification in the SRYR always occurs with the degradation of vegetation which protects the underlying sediments from wind blowing. Therefore, these factors which damaged the vegetation cover are likely to lead to aeolian desertification. So, it is concluded that the increase of air temperature was the key factor responsible for the eco-environmental degradation in the SRYR.

5 CONCLUSIONS

This study conducted in the center of sparsely populated Tibetan Plateau advocates that multi-temporal satellite images play a vital role in quantifying spatial and temporal variations of land cover which is otherwise not possible to attempt through conventional mapping. The results showed grassland and unused land were the main land cover types in the SRYR, accounting for 58.9 and 24.4 % of the total study area in 2005, respectively. A total of 11,588 km^2 （8.1 % of the total study area）land cover changed during 1975-2005. Land cover change was mainly characterized by grassland degradation, sandy and swamped lands expansion. As the mean annual temperature increased and the increasing rate accelerated during1990-2005, resulted in grassland degradation and sandy land increase. Air temperature rise, combined with the dry, cold, and windy climate of the SRYR appear to be the driving forces of the land cover changes.

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