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RESEARCH ARTICLE

Peatland area change in the southern Altay Mountains over the last twenty years based on GIS and RS analysis

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Abstract Analyses results of total peatland area changes in the southern Altay Mountain region over the past 20 years are discussed in this paper. These analyses were based on remote sensing (RS) and geographical information system (GIS) studies. Possible control methods are evaluated by comparing these results to other regional records and climate data. The area of the peatland zones was calculated by overlaying a peatland layer of Landsat TM (Thematic Map) image constructed by using supervised classification with a layer of slope based on a digital elevation model (DEM). The results show that slope layer is crucial to improving the accuracy of peatland extracted from TM images. The peatland area of the Altay Mountains increased from 931.5 km^2 in 1990 to 977.7 km^2 in 2010. This trend is consistent with the climate change in this region, due in part to increasing temperatures and precipitation, suggesting possible climate controls on peatland expansion. The increase in the peatland area in the Altay Mountains over the last 20 years has been influenced by the westerlies. Alternatively, changes in the largest highland peatland area of the Zoige Basin, located in the eastern Tibetan Plateau have been influenced by the intensity of the Asian summer monsoons. In addition to increased temperatures, decreased precipitation in the Zoige Basin and increased precipitation in the Altay Mountains, due to varied patterns of atmospheric circulation, are the probable causes for driving the change differences in these two peatland areas.

Keywords RS image, DEM image, GIS analysis, peatland area change, the Altay Mountains

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1 Introduction

Peatlands represent the largest carbon (C) reservoirs in the biosphere, particularly those in the northern regions, and in recent years, have been shown to be important players in the global carbon (C) cycle. Peatlands are common ecosystems in the cool and humid climates of the Northern Hemisphere (Gignac and Vitt, 1994; Ruppel et al., 2013). According to the IPCC Fourth Assessment Report on climate change, during the past century, global temperatures have increased by 0.74°C (Solomon et al., 2007). If warming is associated with drying due to increased evaporation, as stated in IPCC report, Xinjiang could be seriously threatened (Fu et al., 2013). The Altay Mountain range in Central Asia experiences the greater contrasts in climate than any other continent in the world (Lydolph, 1977), resulting in extremely cold winters and hot summers. Due to the prevailing stable Siberian High, cold and dry arctic air masses are predominate in winter; in summer, humid air masses from the Atlantic Ocean and recycled moisture are the main sources of precipitation (Schwikowski et al., 2009). The southern Altay Mountains show a warming and wetting trend based on recent instrumental climate data, and are thus of interest with respect to their responses to these climate conditions. Due to the importance of peatlands in the global carbon budget, there is growing interest with respect to their feedback effect on global atmospheric warming (van Bellen et al., 2011). Understanding the responses of these C-rich ecosystems may be useful in projections of the trends in peatland C content in the future. In the meantime, the peatlands are also important for water storage, especially in the arid regions (Holden, 2005). Analysis of data collected from peatland areas is key to better understand both the peatland ecosystem and water storage. In the 1980s, some studies investigated peatland distribution and initiation, mostly for peat mining and peat resources (e.g., Cai, 1981). The southern Altay Mountains in arid northwestern China contain a great deal of sparsely distributed peatlands. However, basic information of the total area of the peatlands is still lacking.

In this paper, the change in the total area of the peatlands in the southern Altay Mountains was evaluated using remote sensing (RS) and geographical information system (GIS) analyses. Factors influencing these changes are evaluated by comparing these data to climate data and regional records.

2 Study region

The Altay region (86°E–89°E, 46.5°N–49°N) is situated in northwestern China (Fig. 1). The altitude of the Altay mountainous region is > 3,000 m. The climate is typically influenced by the westerly atmospheric circulation. The mean annual temperature in the southern Altay Mountains ranges from –3.6°C to 1.8°C. The annual precipitation increases with altitude from 200 mm to 600 mm. The wetlands cover ca. 2,341 km^2, which is 9% of the total area of the southern Altay Mountains. Peatlands distribute sparsely in the small basins across the Altay Mountains.

3 Data sources and methods

The data include field measuring data, 1 ∶ 200,000 topographic maps, 1 ∶ 1,000,000 administrative boundary maps, Landsat4 and Landsat5 TM images, and a digital elevation model (DEM). Seven Landsat TM images used in this study were acquired by the American Landsat4 and Landsat5 satellite[1)] with 30 m resolution. These seven images were acquired during two periods, 1989–1991 and

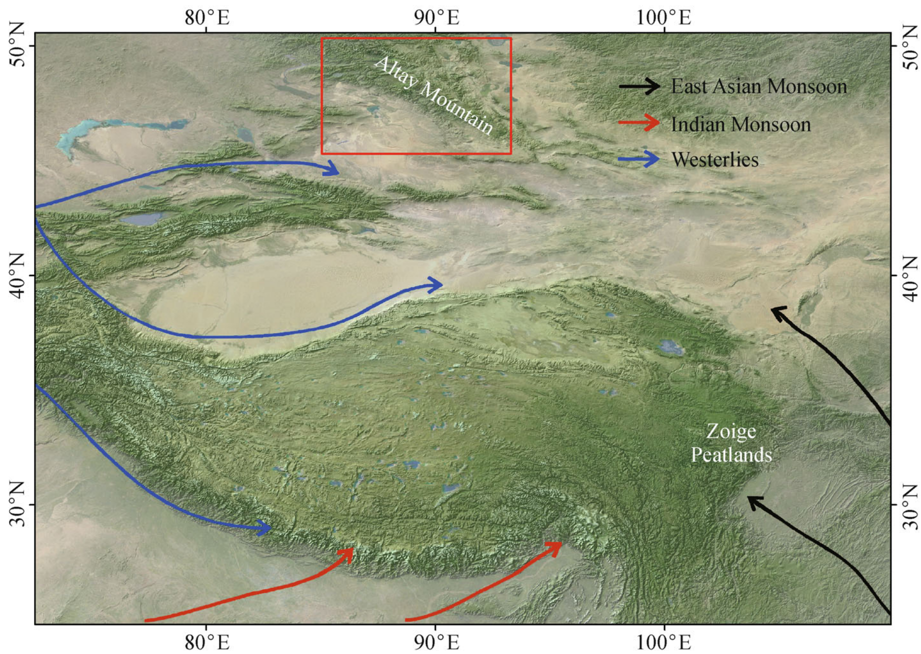

Fig. 1 Satellite image showing the location of the study region, the southern Altay Mountains, and the airflows controlling the regional climate.

Table 1 Orbit information about TM images in the Altay Mountain region used for the peatland area calculation

Image#	Path	Row	Satellite
1	142	27	Landsat4
2	143	26	Landsat4
3	143	27	Landsat4
4	144	26	Landsat4
5	141	27	Landsat5
6	142	27	Landsat5
7	143	26	Landsat5

1) http://glovis.usgs.gov/

2006–2010. Details regarding these images are given in Table 1. Most of these images have less than 10% cloud cover and were collected during the summer seasons (June to September). The peatlands can be clearly identified from the satellite images during this season (Sheng et al., 2004). The DEM of the Altay Mountains was derived from the International Scientific Data Service Platform, with 30 m resolution[1)].

The data processing platform included ArcGIS 9.3 and Erdas 9.2. Methods of data processing are listed below:

1) The 1 : 200,000 topographic map was first scanned into a grid and a new ground control point (GCP) document was created. Then the images were corrected with the multinomial method to produce the geographically coordinated digital topographic map.

2) TM images from multiple bands were combined and a false color composite image was chosen from bands 7, 4, and 2. The false color composite picture was capable of displaying a great deal of information and highlighting the differences in various image features (Min et al., 2008). This mitigated the problem of single-view images (bands, noise, band registration, radiation enhancement, contrast stretching, etc.).

3) The geometric precision of the remote sensing images was corrected with the 1 : 200,000 topographic map. First, the obvious points in the map were selected, and then corresponding points were located in the TM image. These served as ground control points. Second, these GCPs were optimized, and the pixel coordination was transformed using the polynomial correction method. Finally, the pixel brightness values were resampled with cubic convolution. The spatial sampling resolution was 30 m/pixel.

4) The remote sensing images were supervised classified based on the method of Maximum Likelihood Supervised Classification in order to extract a peatland layer. Training samples for supervised classifications were selected based on known control points of peatland that had been obtained by field survey. The kappa statistics of these two period supervised classifications were calculated: The kappa index was equal to 0.7514 in 1990 and 0.6454 in 2010. The different categories were decomposed and merged by visual interpretation. The slope angle layer was calculated by DEM images as an ancillary layer, assuming that peatland would develop in areas where slope was $< 5°$ (Gong et al., 2006; Niu and Gong, 2009). The supervised classified image layer and the slope layer were overlaid. After extracting the peatland in this way, results were reanalyzed based on NDVI. Schumann et al. (2008) stated that NDVI of peatland areas should be within the range of [–0.042, 0.25]; the present results were distributed in this range, indicating high accuracy.

5) The simulation map was cut according to the 1 : 1,000,000 administrative boundaries vectogram, and then the final area of peatland was obtained. The peatland area of the past 20 years was calculated using spatial analysis tools.

The monthly gridded instrumental climate data ($30' \times 30'$ grids) during the period of 1970–2008 were obtained from Udel[2)] and covered the entire research region.

4 Results and discussion

The results were based on RS images and ArcGIS analysis. They showed that the total peatland area increased from about 931.5 km^2 in the early 1990s to 977.7 km^2 in 2010 (Fig. 2). During the same time, the peatlands area increased mainly in the northwestern part of the Altay Mountains, while showing some decreased trend in the southeastern part.

The peatlands cannot be identified clearly using a simple supervised classification or any other simple automatic classification system. Slope layer is crucial to improving the detectability of topographic features, which are related to the development of peatlands (Sheng et al., 2004). However, there are still some areas in the peatlands layer that have been difficult to process, so a visual identification was used. Our results show that the combination of using supervised classified and slope layer is ideal for peatland area extraction, as indicated by field checking[3)].

The climate data show that both the temperature and precipitation have increased over the last 40 years (Fig. 3). Variations in temperature and precipitation were calculated based on the trend line by fitting the trend for this period (1972–2008). Between 1972 and 2008, annual temperature increased by 1.48°C and precipitation by 37.68 mm. This increase in temperature affected the peatlands by increasing the production of organic material as well as decomposition rate, which would provide potential cause for increase in total peatland area in the Altay Mountain region. Furthermore, many researchers have found that the response of vegetation lagged behind climate change for several years (Braswell et al., 1997; Los et al., 2001; Piao et al., 2003; Wang et al., 2003). Thus, increases in precipitation and temperature could have long time effects on the vegetation in peatland areas. In addition, the glacial areas shrunk from 452.53 km^2 in 1989 to 304.88 km^2 in 2011, due mostly to the increase in summer temperature (Wang, 2012). The melting of the glaciers may have contributed to the water source in the basin, allowing them to expand. The increased temperature and precipitation caused an increase in the general peatland area. The glacier melting lead to the local differences, in that smaller glaciers were more sensitive to climate change, especially from

1) http://datamirror.csdb.cn/admin/productdemMain.jsp
2) http://climate.geog.udel.edu/~climate
3) http://www.wetwonder.org/en/

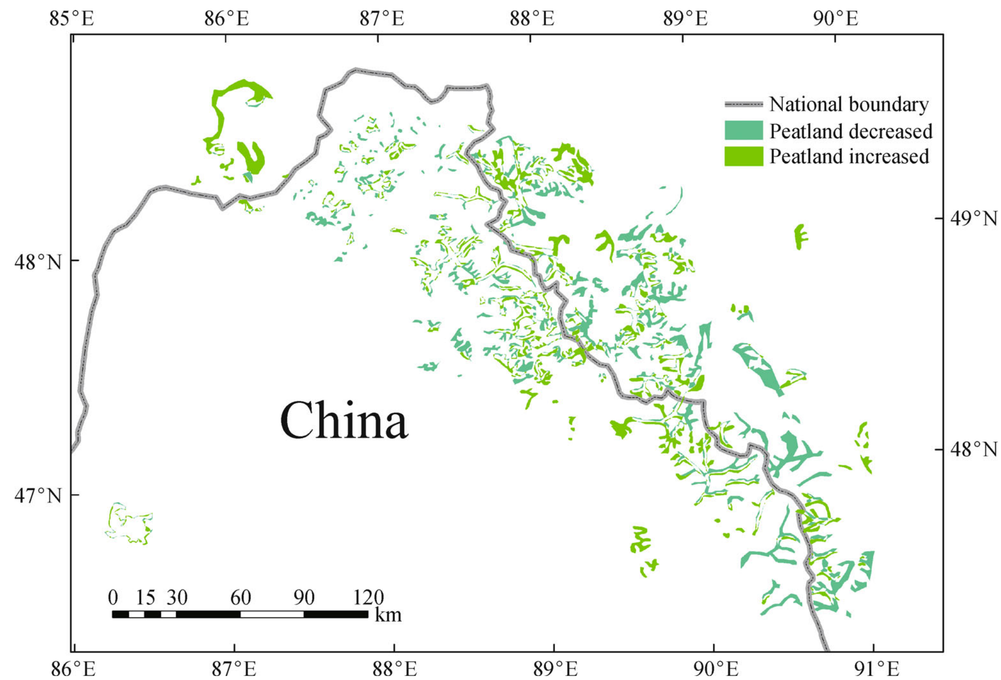

Fig. 2 The distribution of the peatlands in the southern Altay Mountains.

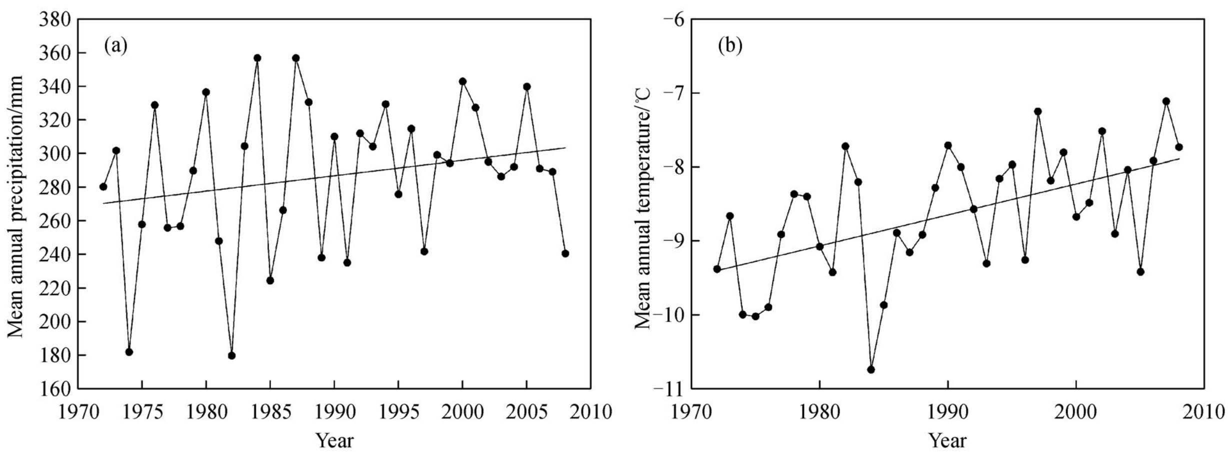

Fig. 3 Climate data during 1970–2010 in the southern Altay Mountain region. (a) Mean annual precipitation (mm); (b) Mean annual temperature (°C).

1989 to 2011, while the Altay Mountain glacier showed little change in fluctuation after 1987 (Wang, 2012). This trend showed these relatively warmer and wetter climate conditions could be beneficial for peatland initiation, as warm temperatures increase production (e.g., Beilman et al., 2009), while wet hydrology can minimize C released through decomposition (e.g., Moore and Knowles, 1989; Klein et al., 2013).

The increase in total peatland area in the Altay Mountains over the past 20 years, which was influenced by the westerlies, shows a trend opposite that of the largest highland peatland, the Zoige Basin, on the eastern Tibetan Plateau (Yong et al., 2003; Wang et al., 2005; Yao et al., 2011; Hu et al., 2012; Li et al., 2012; Xie et al., 2012). The Zoige Basin peatlands are influenced by the Asian summer monsoons, resulting in a decrease from 4,143 km^2 to 3,588 km^2 from 1990 to 2009 (Yao et al., 2011). In addition to increased temperature, decreased precipitation in the Zoige Basin and increased precipitation in the Altay Mountains, accompanied by varied atmospheric circulation patterns, are the probable causes for driving the change differences in total peatland area. A recent report on the regional differences of glacial retreat change in western China suggests the similar mechanism. Yao et al.

(2012) report on the glacial status over the past 30 years by investigating the glacial retreat of 82 glaciers, area reduction of 7,090 glaciers, and mass-balance change of 15 glaciers. The Himalayas (excluding the Karakorum) in the monsoon region is characterized by the greatest reduction in glacial length and area and the most negative mass balance, while the eastern Pamir in the westerly region is characterized by the least glacial retreat, area reduction, and positive mass balance. Because of global warming, the main driving forces behind these regional differences are probably decreasing precipitation in the Himalayas and increasing precipitation in the eastern Pamir.

5 Conclusions

The combination of using supervised classified and slope layer is ideal for peatland area extraction. The 20 years of remote sensing images data set and a corresponding climate data set from 1998 to 2010 were used to analyze peatlands area change and their relationship to climate. The results indicate that the peatlands area in northern Altay Mountain increased from 1990 to 2010. This trend showed these relatively warmer and wetter climate conditions could be beneficial for peatland initiation, as warm temperatures increase production, while wet hydrology can minimize C released through decomposition.

Under global warming, comparing to the largest high-land peatland in the Zoige Basin, the main driving forces are probably decreasing precipitation in the Himalayas and increasing precipitation in the eastern Pamir. In some regions, warming temperatures might also cause peatland hydrology to become drier, which could increase decomposition of organic matter in these regions. Therefore, additional studies of both peatland hydrology and C accumulation rates are needed from vegetated drained peatlands in other northern regions.

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