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Spatial and temporal variations of vegetation in Qinghai Province based on satellite data

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Abstract: This paper used five years (2001–2006) time series of MODIS NDVI images with a 1-km spatial resolution to produce a land cover map of Qinghai Province in China. A classification approach for different land cover types with special emphasis on vegetation, especially on sparse vegetation, was developed which synthesized Decision Tree Classification, Supervised Classification and Unsupervised Classification. The spatial distribution and dynamic change of vegetation cover in Qinghai from 2001 to 2006 were analyzed based on the land cover classification map and five grade elevation belts derived from Qinghai DEM. The result shows that vegetation cover in Qinghai in recent five years has been some improved and the area of vegetation was increased from 370,047 km^2 in 2001 to 374,576 km^2 in 2006. Meanwhile, vegetation cover ratio was increased by 0.63%. Vegetation cover ratio in high mountain belt is the largest (67.92%) among the five grade elevation belts in Qinghai Province. The second largest vegetation cover ratio is in middle mountain belt (61.80%). Next, in the order of the decreasing vegetation cover ratio, the remaining grades are extreme high mountain belt (38.98%), low mountain belt (25.55%) and flat region belt (15.46%). The area of middle density grassland in high mountain belt is the biggest (94,003 km^2), and vegetation cover ratio of dense grassland in middle mountain belt is the highest (32.62%), and the increased area of dense grassland in high mountain belt is the greatest (1280 km^2). In recent five years the conversion from sparse grass to middle density grass in high mountain belt has been the largest vegetation cover variation and the converted area is 15931 km^2.

Keywords: Qinghai; vegetation; MODIS NDVI; DEM; spatial distribution

1 Introduction

Land use/land cover is one of core problems in the field of current global environmental changes research (Chen *et al.*, 2000). Vegetation is the most important component of land

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cover (Lewis, 1998). Its variations have a significant effect on global energy cycle and biochemical circulation (Austin *et al*., 1989). Remote sensing with large-scale, synthetic, dynamic, quick characteristics has become one of the most economical and effective measures of requiring land surface vegetation cover changes (Dennison *et al*., 2003).

Topography is one of the key causes which can lead to landscape heterogeneity (Zhang *et al*., 2006). Topographical characteristics play an important role in vegetation spatial distribution (Wang *et al*., 2004). Geographical distribution of vegetation depends on temperature and precipitation (Roberts *et al*., 1997). Since Qinghai Province is a component of the Tibetan Plateau, its climate formation and distribution are mainly influenced by the Plateau (Chen *et al*., 2005). Therefore, topography in Qinghai Province with obvious plateau characteristics directly affects spatial distribution of land surface vegetation (Wei *et al*., 2004). In large scale spatial analysis, altitude is an important determinant of vegetation spatial distribution (Zhang *et al*., 1999).

This paper aims to study vegetation dynamic changes in high latitude and cold regions in China and discover geographical differentiation rule of different vegetations distributing on different altitude belts, in order to point out belt distribution characteristics of vegetation in high latitude and cold regions. Research step includes: (1) The five years (1 January 2001-31 December 2006) time series of MODIS NDVI images with a 1-km spatial resolution were applied to produce a land cover map of Qinghai Province in China by a classification approach for different land cover types with special emphasis on vegetation, especially on sparse vegetation, which synthesized Decision Tree Classification, Supervised Classification and Unsupervised Classification (Oppelt *et al*., 2004). (2) The spatial distribution and dynamic change of vegetation cover on different elevation belts in Qinghai from 2001 to 2006 were analyzed based on land cover classification map and five elevation belts derived from Qinghai DEM, and driving forces were also analyzed. The research result can provide reference for protecting ecological environment in this region. Meanwhile, we can also find out the influence from the policy of turning cropland to grassland and forest land carried out in West China on ecological environment.

2 The study area

The study area covers the whole Qinghai Province (89°35′E–103°04′E and 31°39′–39°19′N). Qinghai Province is located in the northeast of the Tibetan Plateau in West China which is adjacent to provinces of Xinjiang, Sichuan, Gansu and Tibet. The length of Qinghai Province from east to west is about 1200 km, and the width from north to south is almost 800 m (Yang *et al*., 2005).

The climate of Qinghai Province (hereafter Qinghai) is continental arid and semi-arid plateau type. The temperature from day to night changes greatly. The average temperature of January ranges from −10℃ to −16℃, and the average temperature of July varies from 8℃ to 16℃. Annual precipitation ranges from 50 mm in Qaidam Basin in the west to almost 400 mm in the southeast (Zheng *et al*., 2002).

3 Data sources and field investigation

3.1 Data sources

3.1.1 Remote sensing data

We used Asian MODIS NDVI data with a spatial resolution of 1 km from LPDAAC (Land

Process Distributed Active Archive Center, U.S.A.). Atmospheric correction, radiation correction and geometric rectification have been made for these data and metadata including data quality, attributes, etc. have been added. Annual 23 time-series images calculated from 16-day composites from 2001 to 2006 were based on these data. The 23 images were co-registered to a uniform geographical latitude/longitude projection based on WGS84 spheroid with a pixel size of 0.01 degree (Sun *et al.*, 1998).

3.1.2 DEM data

DEM data adopted in this paper were downloaded from international tropical agricultural center. The format of the data is TIFF. The spatial resolution of DEM data is 90 m. The data have been processed by quality check to eliminate all kinds of errors. The absolute vertical precision of DEM data is 16 m.

3.1.3 Vegetation map

We used 1:1,000,000 scale Chinese vegetation altas (CAS, 2001).

3.1.4 Boundary map of Qinghai

The data were downloaded from Chinese national geographical information center.

3.1.5 Qinghai TM and ETM data

The data were downloaded from the web station of the Geographical Department of Maryland University. The spatial resolution is 30 m, and projection method is latitude/longitude projection, and datum is WGS84.

3.2 Field investigation

The purpose of this study is to investigate the status quo of vegetation distribution in Qinghai. In order to ensure the actual condition of vegetation cover, field investigation of the province were conducted in July. This is because July is the month that plants in Qinghai grow most prosperously. Field observations were conducted along the borders of different land cover types. During the filed investigation, we passed through Minhe, Ledu, Pinganyi, Xining, Gonghe, Xinghai, Maqin, Dari, etc. Field research includes recording vegetation type and vegetation cover of the typical sites. And we used GPS to locate the typical site and then compared its vegetation with the corresponding remote sensing image.

4 Methods

4.1 Land cover classification of Qinghai

In this paper, land cover in Qinghai was divided into 14 classes based on the field investigation and considering various land cover classification methods, according to land cover characteristics of the Tibetan Plateau and characteristics of MODIS data (Liu *et al.*, 1998). This classification emphasized vegetation distributions, especially sparse vegetation distributions (including sparse grassland and sparse shrub).

The land cover of Qinghai was classified in the following six steps:

(1) Water body and permanent ice/snow were visually interpreted from 16-day composite images, making DEM data for a reference.

(2) Urban built-up land was visually interpreted from NDVI composite image (Red: NDVI image of June, Green: NDVI image of July, Blue: NDVI image of August), making

the city GIS layer for a reference.

(3) Threshold values were used to separate vegetation areas from non-vegetation areas. If the annual maximum NDVI was less than 0.113, the land cover which this pixel represented was non-vegetation areas. If the annual maximum NDVI was higher than 0.270, the land cover which this pixel represented was vegetation areas. Otherwise, if the annual maximum NDVI was between 0.113 and 0.270, we did not yet identify whether the land cover which this pixel represented was vegetation areas or non-vegetation areas. Because soil under vegetation would influence NDVI values of sparse vegetation.

(4) Then we adopted the following criteria to classify uncertain areas: if a pixel met the following two conditions, the land cover type which it represented was vegetation. Condition 1: the maximum NDVI occurred between June and September (annual precipitation takes place mainly during the period). Condition 2: the standard deviation of NDVI from April to October was larger than 0.180. The above threshold values were determined by comparing the annual maximum NDVI images by making high resolution TM/ETM images and the field observation data as a references.

(5) We further classified non-vegetation areas into Gobi and desert.

(6) Based on seasonal NDVI variations and reference data, vegetation areas were classified into nine vegetation classes, including sparse shrub, sparse grassland, grassland mixed with farmland, middle density grassland, dense shrub, dense grassland, needle-leaved forest, needle-leaved and broad-leaved mixed forest, and broad-leaved forest. In order to classify forest, shrub, cropland and grassland, we used supervised classification on three NDVI images. Three NDVI images come from August (peak growing season), May (beginning of growing season) and March (non-growing season), respectively. The above forest areas were then classified into needle-leaved forest and broad-leaved forest based on Chinese forest maps. Grassland mixed with farmland area was identified using Chinese farming-grazing transition belt maps.

The result of the land cover map of Qinghai in 2006 is shown in Figure 1.

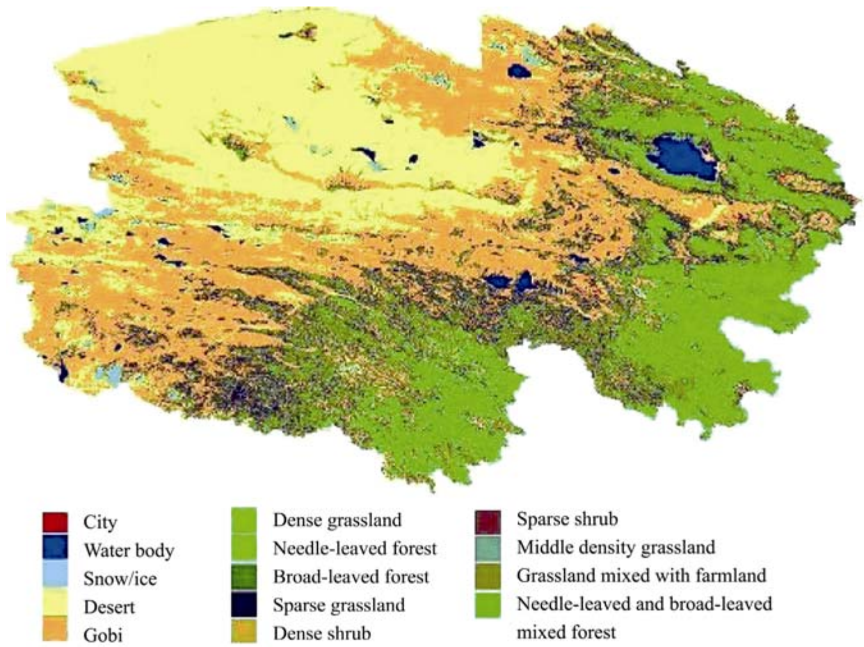

Figure 1 Land cover map of Qinghai Province in 2006

We randomly chose 3598 reference points from the classification map to assess the accuracy of the classification result. The validation data include: (a) 1:1,000,000 scale Chinese vegetation maps and land cover maps; (b) grassland sample investigation data from 1990 to 1995; and (c) TM images of Qinghai (Grossman *et al*., 1996). We used an error matrix and Kappa coefficient to validate the classification result. The overall accuracy of the classification result was 87.68%, and Kappa coefficient was 0.82. So the classification result was satisfying.

4.2 Elevation belts division of Qinghai

Based on looking up many publications (Hou, 1988; Shen *et al*., 2001; Zhang *et al*., 2001), we considered factors of sunlight, temperature, precipitation with topography, vegetation types and soil to divide the elevation of Qinghai into five belts in order to precisely analyze the vegetation distribution of Qinghai. The five elevation belts in Qinghai include:

(1) Flat region. Sea level elevation ranges from 1664 m (the lowest altitude in Qinghai) to 2800 m;

(2) Low mountain. Sea level elevation varies from 2800 m to 3300 m;

(3) Middle mountain. Sea level elevation ranges from 3300 m to 3900 m;

(4) High mountain. Sea level elevation varies from 3900 m to 4900 m;

(5) Extreme high mountain. Sea level elevation ranges from 4900 m to 6578 m (the highest altitude in Qinghai).

Figure 2 shows five grade elevation belts map of Qinghai. Among the five elevation belts the area of high mountain belt is the largest (357,776 km^2) and makes up half of the total area of Qinghai (50%). Middle mountain belt and low mountain belt are second in area extent (14%), respectively, followed by extreme high mountain belt (12%), and then flat region belt (10%). Therefore, the primary elevation of Qinghai ranges from 3900 m to 4900 m.

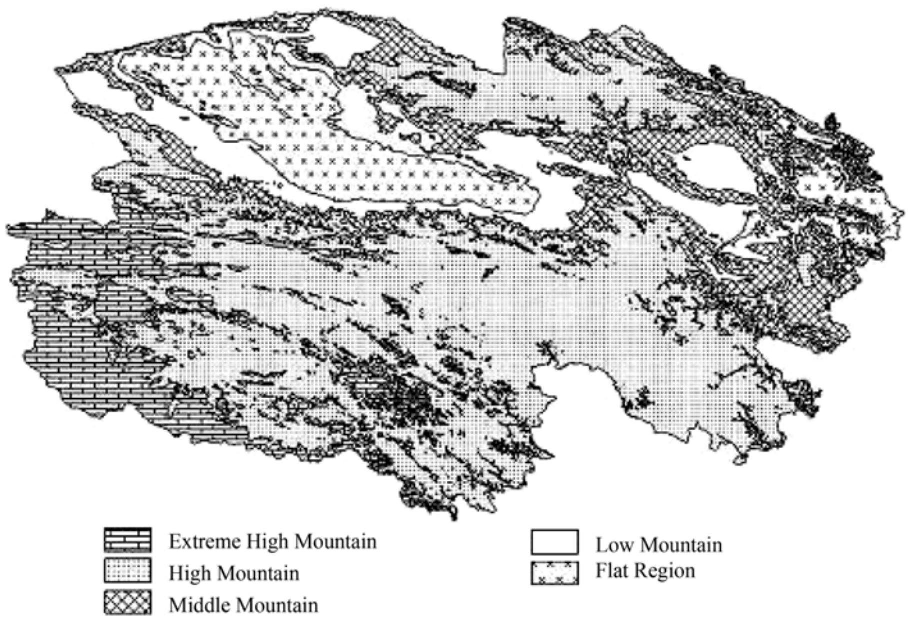

Figure 2 Five grade elevation belts of Qinghai Province

4.3 Computing spatial distribution and interannual variation of vegetation cover in different elevation belts in Qinghai

We used the above land cover classification approach to classify the yearly maximum MODIS NDVI image in 2001 and 2006 by ENVI software, respectively. And then vegetation cover maps of Qinghai in 2001 and 2006 were acquired. Thereafter, we made projection transformation, converting raster into vector, extraction of classification mask for elevation belts maps and nine kinds of vegetation spatial distribution maps of Qinghai by ArcGIS software to produce nine kinds of vegetation cover maps of each elevation belt and made corresponding statistics. Subsequently, the vegetation cover image of 2006 minus that of 2001 was the vegetation cover variation map from 2001 to 2006 in Qinghai. Then the interannual variation of vegetation cover in different elevation belts in Qinghai was computed.

5 Spatial distribution of vegetation cover in various elevation belts of Qinghai

We used ArcGIS software to make projection transformation, converting raster into vector, extraction of classification mask for elevation belts maps and vegetation spatial distribution maps of Qinghai. Nine kinds of vegetation type spatial distribution maps in various elevation belts were obtained by powerful spatial analysis of ArcGIS software. Then we made the classification statistics for each vegetation type in every elevation belt of Qinghai (Table 1).

Table 1 shows the vegetation areas of five grade elevation belts in Qinghai in 2006. On the whole, the amount of the primary vegetation type in high mountain belt, whether the single value or the total value, is higher than the other corresponding values. This phenomenon reflects that nine kinds of vegetation type in Qinghai were mainly concentrated on high mountain belt and they were suitable for the environment of high mountain belt (the elevation ranges from 3900 m to 4900 m) which was divided in this paper. That is, their biological characteristics determine that they can grow better in the alpine environment. In addition, the area of needle-leaved forest, Needle-leaved and broad-leaved mixed forest and broad-leaved forest is less than that of other vegetation types (Table 1). This shows that short shrub and grass in contrast with high forest are more suitable for high elevation regions.

Table 1 Vegetation areas of the five grade elevation belts in Qinghai Province in 2006 (km^2)

Vegetation	Flat region	Low mountain	Middle mountain	High mountain	Extreme high mountain
Sparse shrub	801	854	718	40215	10059
Sparse grassland	1100	1024	945	42718	11723
Grassland mixed with farmland	5391	7813	196	312	261
Middle density grassland	2441	5783	21849	94003	8702
Dense shrub	321	725	3295	11848	397
Dense grassland	1439	8311	32991	52150	818
Needle-leaved forest	4	107	1268	680	4
Needle-leaved and broad-leaved mixed forest	1	30	719	367	3
Broad-leaved forest	0	14	517	456	4
Total	11498	24661	62498	242749	31971

From the above statistics, vegetation cover ratio in high mountain belt is the largest (67.92%) among the five grade elevation belts in Qinghai. The second largest vegetation cover ratio is in middle mountain belt (61.80%). Next, in the order of the decreasing vegetation cover ratio, the remaining grades are extreme high mountain belt (38.98%), low mountain belt (25.55%) and flat region belt (15.46%).

5.1 Spatial distribution of vegetation in flat region belt

Flat region belt of Qinghai is mainly located in the western center of Qaidam Basin, in the eastern Huangshui River Basin and in the eastern Yellow River Basin, where the slope ranges from 3° to 5°. Desert steppe mostly covers the flat region in Minhe, Hualong and Xunhua. Grassland composition includes the arid and semi-arid grassland, of which *Stipa grandis*, *Salsola collina*, *Kalidium foliatum* and *Peganum harmala* occur frequently. The coverage of these types of grassland is low. Temperate desert steppe is widely distributed in the flat region in Xiangride, Dulan and Wulan of Qaidam Basin. There the dominant species are arid and semi-arid shrub and grassland which include *Kalidium foliatum*, *Achnatherum splendens* and *Kobresia capillifolia* (Li *et al*., 2006). Their coverage ratio is low (ranging from 20% to 30%).

Table 1 shows that the primary vegetation cover in flat region belt is grassland mixed with farmland, which covers an area of 5391 km^2 (46.89% of the total vegetation area of flat region belt). Needle-leaved and broad-leaved mixed forest has the smallest area in flat region belt (1 km^2).

5.2 Spatial distribution of vegetation in low mountain belt

Low mountain belt is distributed on low hills. Gray calcium soil low mountain and maroon clcium soil low mountain are distributed on the banks of the eastern Yellow River and Huangshui River. Brown calcium soil low mountain and grey-brown desert soil low mountain are located in Qaidam Basin. The eastern low mountain has better sunshine, and the annual precipitation ranges from 250 to 400 mm. Due to severe destroy and unreasonable usage of vegetation, considerable soil erosion occurs unfortunately. Arid grassland and meadow are distributed in the region around Qinghai Lake, Datonghe Valley, Gonghe Basin and Xinghai-Guinan Basin. The composition of arid grassland includes three to five pieces, of which *Stipa grandis*, *Agropyron cristatum* and *Poa annua* occur frequently. These herbs have high foraging value, but their production is low. The meadow is dominated by *Carex montana*, *Saussurea nimborum*, *Polygonum viviparum*, *Polygonum sphaerostachyum* and *Gentiana scabra*. The coverage of these types of grassland is high. Brown calcium soil low mountain of desert steppe is mainly located on the lower part of the eastern hills in Qaidam Basin, and the annual precipitation is scarce. The dominant forage plants in desert steppe belong to *Kalidium foliatum*, *Stipa breviflora*, with *Kobresia capillifolia* occurring as subdominants. The coverage ratio of these types of grassland ranges from 10% to 20%, and the yield is low.

Dense grassland is the most extensively distributed vegetation type with high coverage in low mountain belt which covers an area of 8311 km^2 (33.7%). Meanwhile, broad-leaved forest is the least vegetation cover type of low mountain belt with an area of 14 km^2 (0.06%) (Table 1).

5.3 Spatial distribution of vegetation in middle mountain belt

Middle mountain belt is primarily distributed on the middle part of the hills. The precipitation of middle mountain is generally higher than that of the low mountain, but with the lower temperature. The dominant plants in the east of Qinghai belong to forest and grassland. The grassland is dominated by *Carex montana*, *Polygonum viviparum*, *Saussurea nimborum*, *Poa annua*, *Potentilla anserina* and *Sanguisorba officinalis*. The coverage ratio of the grassland is high, ranging between 80% and 95%. These types of grassland with high production are better forage usage land. Deciduous broad-leaved forest and needle-leaved and broad-leaved mixed forest dominate. *Picea crassifolia* is mainly located on shaded sides of hills, and *Sabina przewalskii* is widely distributed on sunny sides of middle hills. Types of vegetation in middle mountain belt change from dense grassland and dense shrub in the east to middle density grassland, sparse grassland and sparse shrub in the west with the increase of degree of drought.

Table 1 shows that the primary vegetation cover in middle mountain belt is dense grassland, which covers an area of 32,991 km^2 (52.79% of the total vegetation area of middle mountain belt). The second most dominant vegetation cover is middle density grassland with an area of 21,849 km^2 (34.96%). Grassland mixed with farmland has the smallest area in middle mountain belt with an area of 196 km^2 (0.31%).

5.4 Spatial distribution of vegetation in high mountain belt

High mountain belt of Qinghai is mainly distributed on the upper part of Qilian Mountains and the southern Qinghai Plateau. The climate is cold, and the annual temperature averages below 0℃. Vegetations (grassland and shrub) in high mountain belt are well adapted to the cold climate and highland conditions. While the climate changes from semi-humid in the east to semi-arid and arid in the west, vegetations transit from mountain shrub and mountain meadow to alpine grassland and alpine desert steppe. Alpine deciduous broad-leaved shrub meadow is distributed only in the southeast of the southern Qinghai Plateau, eastern mountains, and shaded sides of eastern Qilian Mountains. The shrub is mainly dominated by *Dasiphora fruticosa*, *Salix oritrepha* and *Smilax scobinicaulis*. The grassland is generally dominated by *Kobresia capillifolia*, *Carex montana*, *Poa annua* and *Polygonum viviparum*. The coverage ratio of vegetation ranges from 60% to 90%. Alpine meadow is widely distributed in eastern Qilian Mountains and the central part of southern Qinghai Plateau, and *Festuca ovina*, *Kobresia capillifolia*, *Carex montana* and *Gentiana scabra* are in domination. These types of grassland with high production are one of the main pastures in Qinghai. Alpine grassland is intensively distributed in the middle Qilian Mountains and the upper part of the northwestern hills from Tuotuo River to Maduo in southern Qinghai Plateau. *Stipa purpurea* and *Agropyron pectiniforme* are dominant species, in association with *Dasiphora fruticosa*. Although the grassland with a coverage ratio ranging between 20% and 40% has a low production level, it is still one of the main pastures in Qinghai.

From Table 1, the middle coverage grassland is the most extensively distribution vegetation type of high mountain belt, which covers an area of 94,003 km^2 (38.72%). High coverage grassland comes the second with an area of 52,150 km^2, accounting for 21.48% of the vegetation area of high mountain belt. Meanwhile, grassland mixed with farmland is the least vegetation cover type of high mountain belt, which covers an area of 312 km^2 (0.13%).

5.5 Spatial distribution of vegetation in extreme high mountain belt

Extreme high mountain belt is located on the top of Qilian Mountains and high mountains of southern Qinghai Plateau, and the climate is extreme cold. Cushion plants, dominated by *Arenaria pulvinata*, *Androsace umbellata*, *Ceratoides compacta* and *Saussurea pmedusa*, are sparsely distributed on the top of high mountains.

Table 1 shows that the primary vegetation cover in extreme high mountain belt is sparse grassland, which covers an area of 11,723 km^2 (36.67%). The second most dominant vegetation cover is sparse shrub with an area of 10,059 km^2 (31.46%). Needle-leaved and broad-leaved mixed forest has the smallest area in extreme high mountain belt, which covers an area of 3 km^2 (0.01%).

6 The interannual variation of vegetation cover in different elevation belts in Qinghai

In order to acquire the variation of vegetation cover from 2001 to 2006 in Qinghai, we used a classification approach, which emphasized the spatial distribution of vegetation, to respectively process the maximum NDVI image for the whole year from 2001 to 2006, and then vegetation cover maps of Qinghai for each year were calculated out (Fang *et al*., 2001; Fang *et al*., 2003; Gao *et al*., 2000). Furthermore, we computed the variation map of vegetation cover from 2001 to 2006 in Qinghai to learn the interannual variation of vegetation cover in different elevation belts for the past five years.

According to statistics, during 2001-2006, the area of non-vegetation regions reduced by 4529 km^2; the area of sparse shrub increased by 1448 km^2; the area of sparse grassland increased by 1530 km^2; the area of grassland mixed with farmland decreased by 2214 km^2; the area of middle density grassland declined by 497 km^2; the area of dense shrub increased by 412 km^2; the area of dense grassland increased by 3021 km^2; the area of needle-leaved forest increased by 629 km^2; the area of needle-leaved and broad-leaved mixed forest increased by 268 km^2; and the area of broad-leaved forest reduced by 68 km^2. The above data reflect that obvious achievement in Qinghai has been obtained due to recent Chinese government policy of turning cropland to grassland or forest in West China. After many slope croplands are converted to grassland or forest and some mountains are banned to be cut and grazed, vegetation cover has been improved to a certain degree. In addition, more precipitation in 2006 than in 2001 in Qinghai is another main cause for vegetation cover improvement. In a word, in recent five years vegetation cover in Qinghai has been increasing from 370,047 km^2 in 2001 to 374,576 km^2 in 2006, or an increase of 0.63%.

Table 2 shows areas of conversion between nine kinds of vegetation and non-vegetation. From Table 2, the largest vegetation cover variation in Qinghai came from the conversion from grassland mixed with farmland to dense grassland and the area reached 22,213 km^2, which mainly took place in Huangshui River valley and the Yellow River basin. The second largest was the conversion from middle density grassland to sparse grassland and the area became 18904 km^2, which primarily occurred in the west of Guoluo Prefecture and Yushu Prefecture. The third derived from the conversion from middle density grassland to dense grassland and the area was 15,379 km^2, which was mostly located in the east of Guoluo Prefecture and the region around Qinghai Lake.

Table 3 shows interannual variation data of vegetation cover in different elevation belts (including flat region belt, low mountain belt, middle mountain belt, high mountain belt, and extreme high mountain belt) from 2001 to 2006.

Table 2 Transfer matrix of different vegetation from 2001 to 2006 in Qinghai Province (km^2)

Vegetation	Non-vege-tation	Sparse shrub	Sparse grass-land	Grassland mixed with farmland	Middle density grass-land	Dense shrub	Dense grass-land	Needle-leaved forest	Needle-leaved and broad-leaved mixed forest	Broad-leaved forest
Non-vegetation	–	7361	6853	13518	1306	77	467	21	6	6
Sparse shrub	5973	–	1958	4253	297	13	21	0	0	0
Sparse grassland	5640	1977	–	7297	507	20	16	1	0	1
Grassland mixed with farmland	11702	4361	7685	–	1217	791	22213	4	2	6
Middle density grassland	1248	238	18904	457	–	7436	15379	22	17	32
Dense shrub	102	11	13	651	6164	–	7177	20	12	9
Dense grassland	391	15	22	1119	12607	6158	–	1727	892	762
Needle-leaved forest	5	0	1	4	39	30	1075	–	97	68
Needle-leaved and broad-leaved mixed forest	4	0	0	4	32	22	617	80	–	53
Broad-leaved forest	21	0	0	17	71	24	745	73	54	–

Table 3 Variation areas of vegetation cover in different elevation belts from 2001 to 2006 in Qinghai Province (km^2)

Region	Non-vege-tation	Sparse shrub	Sparse grass-land	Grassland mixed with farmland	Middle density grassland	Dense shrub	Dense grass-land	Needle-leaved forest	Needle-leaved and broad-leaved mixed forest	Broad-leaved forest
Flat region	843	62	162	−686	−531	0	168	−13	−2	−3
Low mountain	1016	−144	−131	−787	−263	−167	509	7	−16	−24
Middle mountain	734	52	65	−902	−1441	−675	938	644	392	193
High mountain	−5365	1152	1109	53	953	1158	1280	−15	−103	−222
Extreme high mountain	−1555	328	323	117	737	86	−12	−2	−7	−15

7 Conclusions

Some conclusions are drawn as follows:

(1) Topography plays an important role in affecting the spatial distribution of vegetation cover. In large scale spatial analysis, altitude is a significant determinant of vegetation spa-

tial distribution. The approach which divided the whole regions of Qinghai Province into five belts contributes to the carrying out of the quantitative analysis for the spatial distribution rule of vegetation cover in Qinghai.

(2) From our results, vegetation cover ratio in high mountain belt is the largest (67.92%) among five grade elevation belts in Qinghai. The second vegetation cover ratio is in middle mountain belt (61.80%). Next, in the order of the decreasing vegetation cover ratio, the remaining grades are extreme high mountain belt (38.98%), low mountain belt (25.55%) and flat region belt (15.46%). We found that the amount of the primary vegetation type of high mountain belt was the largest compared to that of other four belts. The result shows that nine kinds of vegetation type in Qinghai are intensively distributed in high mountain belt (the elevation ranging from 3900 m to 4900 m). This is determined by the biological characteristics of vegetation in Qinghai which is suitable for the environment of high elevation. We concluded that the area of middle density grassland in high mountain belt was the largest (94,003 km^2) and vegetation cover ratio of dense grassland in middle mountain belt was the highest (32.62%). In addition, areas of needle-leaved forest, needle-leaved and broad-leaved mixed forest and broad-leaved forest were less than that of the other vegetation types in various belts of Qinghai. This shows that short shrub and grass in contrast with high forest are more adapted to high elevation regions.

(3) In recent five years vegetation cover in Qinghai has been improved with vegetation cover area increasing from 370,047 km^2 in 2001 to 374,576 km^2 in 2006 with an increase in ratio by 0.63%. Specifically speaking, the area of sparse shrub increased by 1448 km^2; the area of sparse grassland increased by 1530 km^2; the area of grassland mixed with farmland decreased by 2214 km^2; the area of middle density grassland declined by 497 km^2; the area of dense shrub increased by 412 km^2; the area of dense grassland increased by 3021 km^2; the area of needle-leaved forest increased by 629 km^2; the area of mixed needle-leaved forest with broad-leaved forest increased by 268 km^2; and the area of broad-leaved forest reduced by 68 km^2. The data reflect that obvious achievement in Qinghai has been obtained due to recent Chinese government policy of turning cropland to grassland or forest in West China. After many slope croplands are converted to grassland or forest and some mountains are banned to be cut and grazed, vegetation cover has been improved to a certain degree. In addition, more precipitation in 2006 than in 2001 in Qinghai is another main cause for vegetation cover improvement.

(4) From 2001 to 2006, the decreased area of non-vegetation region in high mountain belt is the largest (5365 km^2), while the increased area of dense grassland in high mountain belt is the greatest (1280 km^2). For the past five years, the conversion from sparse grass to middle density grass in high mountain belt has been the largest vegetation cover variation and conversion area is 15,931 km^2, which has mainly occurred in the southeastern parts of Guoluo Prefecture and pastures of Qilian Mountains in the north of Haibei Prefecture in Qinghai.

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