Monitoring and Evaluation of Grassland Desertification in Litang County Using Multi-temporal Remote Sensing Images

DAN Shang-ming[1, 2], XU Hui-xi[3], DAN Bo[4], HE Fei[5], SHI Cheng-cang[6], REN Guo-ye[6]

1.Key Laboratory of Atmosphere Sounding, China Meteorological Administration, Chengdu 610225, P.R.China;
2.Sichuan Province Agrimeteorological Center, Chengdu 610072, P.R.China;
3. Institute of Engineering Surveying, Sichuan College of Architectural Technology, Deyang 618000, P.R.China;
4.Sichuan Provincial Meteorological Observatory, Chengdu 610072, P.R.China;
5.Chengdu University of Information Technology, Chengdu 610225, P.R.China.
6.Institute of Remote Sensing Application, Sichuan Academy Agricultural Sciences, Chengdu 610066,P.R.China;
1.danscqx@163.com , 4.danhoulin@163.com

Abstract: Using four Landsat TM & ETM+ images which obtained in 1989, 1994, 2000 and 2005, the normalized difference vegetation index (NDVI) was calculated on the basis of the geometry correction, radiometric calibration and atmosphere correction, and the assimilation of the NDVI images was made by establishing the least squares equation of linear regression, and extracted the vegetation coverage from the NDVI and converted it into the desertification index (DI) based on the binary model, the classifiable research was made on the desertification of grassland about 103 km^2 near the Litang county. The result demonstrates that: (1) Desertification in Litang County has been deteriorating in the past 16 years (1989-2005). The 1st stage (1989-1994) saw decreased desertification area, the 2nd stage (1994-2000) observed radical deterioration, and the 3rd stage (2000-2005) witnessed slack in this regard. (2) Tendency of desertification has nothing to do with precipitation and wind speed. (3) Human activities e.g. overload over grassland and disorder explorations etc are considered the main causes in exacerbating desertification. (4) Expansion desertification area slowed down during the 3rd stage (2000-2005), which ecological restoration projects in China have brought about marked effects.

Keywords: Landsat; Multi-temporal RS images; Litang County; Grassland desertification; Driving force

1 Introduction to the study area

Litang County, on the southeast verge of a transversal mountain range east of the Qinghai-Tibet Plateau, is located in the west of Sichuan Province and in the southern hinterland of Garze Tibetan Autonomous Prefecture. In recent years, little work and few reports contributed to grassland desertification in hinterland of West Sichuan Plateau, besides Ren Guo-ye et al [1] and Ren An-cai et al [2] adopting two remote sensing images marked out the grave degree of grassland desertification and temporal-spatial characteristics in Litang.This paper monitored and evaluated tendency of grassland desertification in Litang County from 1989~2005, adopting four periods of Landsat satellite remote sensing images.

The study area was spotted somewhere close to the county between 29º54.2´～30º0.3´ N and 100º14.4´～100º20.1´ E, covering area of 103 km^2. The region feature is hill-type plateau with altitude of 3900～4500m, belonging to the category of high-altitude meadow grassland and swamp meadow grassland. Litang City, located northwest of ROIs, is 4,014m above sea level. The NO.318 state road crosses through the city, while the NO.217 provincial road is connected to the NO.318 state road from southeast to northwest. The Wuliang River goes through in the southwest. Save for river, road, and township in ROIs, large amounts of light coloured desertification plaques are obviously visible (Figure1.).

2 Data and methodology

2.1 Remote sensing data and pretreatment

According to comprehensive consideration, this research adopted four periods of Landsat satellite remote sensing images. Its spatial resolution is 30 meter, and its quantity is good. Metadata of images is in Table 1.

This research work was financial supported by Key Laboratory of Atmosphere Sounding, China Meteorological Administration (No.KLAS200703) and the key project of Sichuan Environmental Protection Bureau (No.2008HBY002), P.R.China.

978-1-935068-01-3

Firstly, make radiometric calibration for images in four periods according to the equation in the reference [3]. Then make atmospheric correction for them according to COST model in the reference [4].Taking the remote sensing images obtained in 2005 with nice quality and clear objects as its base image, calibrate images of another three time phases (1989, 1994, 2000) onto the base image by means of polynomial. Control points were about 35～40 points of identical object displaying small spatial dimension, obvious characteristic, easy identification, and even distribution. Root-Mean-Square Error (RMS) of control points obtained in 1989, 1994, and 2000 were 0.9, 0.67, and 0.68 pixel respectively in calibrating onto image obtained in 2005.

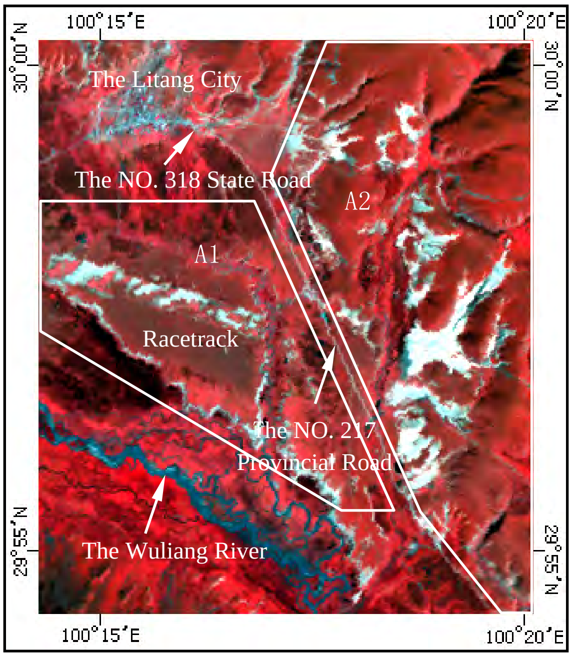

Figure 1. Research range and Regions of Interest (A1 & A2)

Table 1. Metadata of images

NO.	Satellite	Sensor	Date
1	Landsat4	TM	1989-01-25
2	Landsat5	TM	1994-01-15
3	Landsat7	ETM+	2000-10-06
4	Landsat5	TM	2005-10-12

2.2 NDVI Calculation & assimilation

Using: $NDVI= (NIR-RED)/ (NIR+RED)$ （1）

In the above equation, NIR represents near infrared band, RED represents red band, i.e. band 4 and band 3 of TM/ETM+ sensor respectively.

Methods to assimilate data are the following: Taking the image obtained in 2000 with comparatively big NDVI dynamic scope as its main image, NDVI images of other time phases were respectively corrected as follows: (1) Identifying the corresponding spots without basic change of geographical object in both the primary and secondary images through visual interpretation and man-machine interaction and gaining a number of sample data sets x and y (data scattered between NDVI high and low values areas);(2)Adopting the least squares equation to gain linear regression parameters a and b [5]; (3) Calculating assimilation via the following equation:

$$y=ax+b \qquad (2)$$

In the above equations, x and y respectively stand for the NDVI before and after assimilation.

2.3 Calculating vegetation coverage

f_c, i.e. vegetation coverage of mixed pixels in remote sensing images can be gained as follows [6]:

$$f_c=(NDVI-NDVI_{soil})/(NDVI_{veg}-NDVI_{soil}) \qquad (3)$$

In the above equation, $NDVI_{soil}$ and $NDVI_{veg}$ respectively stand for remote sensing pixel under none vegetation and full vegetation coverage. Typical image pixel approach was adopted to determine $NDVI_{soil}$: Firstly, find a fairly large desertification plaque in the image, inside of which there are image pixel without vegetation and water distribution, and then detect the pixel with Minimum NDVI inside of the plaque. After doing experiments again and again, the value of $NDVI_{soil}$ is 0.010583.Regarded maximum of NDVI in 2000 as $NDVI_{veg}$ and gaining 0.9.

2.4 Desertifi cation classification & calculating area

DI (Desertification Index) acted as an indicator [7] of assessing classification of desertification in Litang County:

$$DI=1-f_c \qquad (4)$$

Desertification falls into five categories. They are described in Table 2.Drawing on results of Chen Bao-rui et al [7] and Wang Tao et al [8] of calculation results about Litang, critical value of desertification can be determined, and the areas of different category were gained according to pixels of different category.

Table 2. Classification of desertification extent

NO.	Desertification extent	Classification criterion	State description
1	Serious desertification	DI＞86%	Signifies the extremely grave stage of desertification in the latter stage as the primitive land surface was completely destructed.
2	Severe desertification	76%<DI≤86%	Denotes the intense development stage of desertification as primitive landscape.
3	Moderate desertification	66%<DI≤76%	Stands for obvious degradation of grassland, in a development stage of desertification is basically destructed.
4	Mild desertification	46%<DI≤66%	Represents the preliminary stage of desertification as the vast majority of land surfaces conserve primitive grassland.
5	Non-desertification	DI≤46%	Surface maintains the status of native grassland.

In order to mitigate errors of geographical object (such as river, river shoal) and man-made constructions (township and road) in judging desertification grassland and analyzing tendency, two ROIs, i.e. A1 and A2 (Figure 1.) were established by visual interpretation and man-machine interaction to gain area each category within ROIs, and then obtain percentage of desertification area in the total area studied. A1 and A2 account for 56.7% of the total area studied. Desertification grassland outside of A1 and A2 was barely up to 1% of the total desertification area. As a result, misinterpretation of desertification outside of ROIs caused little error.

3 Research results

3.1 Desertification situation

Area and proportion of different grades of grassland desertification in research area showed in Table 3.

During 16 years (1989 to 2005), the area of serious desertification (DI＞0.86), above severe desertification (DI＞0.76), above moderate desertification (DI＞0.66), and above moderate desertification (DI＞0.46) increased 97.4hm^2; 174.5hm^2, 147.0hm^2 and 52.2hm^2 respectively, and area increase proportion is 161.8%, 66.3%, 26.3% and 3.68%. There is a clear feature that the more serious the degree of desertification is, the greater area increase rate is.Various types of desertification area in 1989 accounted for 0.58%, 2.67%, 5.42% and 13.75% of the study area respectively, and that in 1989 accounted for 1.53%, 4.36%, 6.84% and 14.26%.

3.2 Analysis of tendency of desertification

Divided into three phases to calculate the rate of desertification area of R (%) and annual rate of increase of Rn (%/a), and calculation results shown in Table 4. In the first phase (1989～1994), all types of desertification significantly reduced. The area of serious desertification(DI＞0.86), above severe desertification(DI＞0.76), above moderate desertification(DI＞0.66), and above moderate desertification(DI＞0.46) decreased 32.56%, 27.94%,18.67% and 16.43% respectively, and annual increasing rate was -7.58%、-6.34%、-4.05% and -3.52% respectively. In the second phase(1994～2000), desertification situation sharply downturn.The area of serious desertification(DI＞0.86), above severe desertification(DI＞0.76), above moderate desertification(DI＞0.66), and above moderate desertification(DI＞0.46) increased 4.10%,9.78%,8.83% and 11.44% respectively, and annual increasing rate was 24.53%,12.84%,6.10% and 1.80% respectively. In the third phase(2000～2005), the area of serious desertification(DI＞0.86), above severe desertification(DI＞0.76), above moderate desertification(DI＞0.66), and above moderate desertification (DI＞0.46) increased 4.10%, 9.78%,8.83% and 11.44% respectively, and annual increasing rate was 0.81%, 1.88%,1.71% and 2.19% respectively. During 16 years

Table 3. The desertification area of grassland and its proportion in different grades

No.	Desertification extent	DI	1989 Area (hm^2)	1989 Proportion (%)	1994 Area (hm^2)	1994 Proportion (%)	2000 Area (hm^2)	2000 Proportion (%)	2005 Area (hm^2)	2005 Proportion (%)
1	Serious desertification	＞0.86	60.2	0.58	40.6	0.39	151.4	1.47	157.6	1.53
2	Above severe desertification	＞0.76	275.6	2.67	198.6	1.92	410.0	3.97	450.1	4.36
3	Above moderate desertification	＞0.66	559.3	5.42	454.9	4.40	649.0	6.29	706.3	6.84
4	Above mild desertification	＞0.46	1419.2	13.75	1186.0	11.49	1320.3	12.80	1471.4	14.26

 978-1-935068-01-3 © 2009 SciRes.

Table 4. The increased rate (R) and the annual increased rate (Rn) of the desertification area in different stages, and meteorological data

NO.	Items	1989～1994		1994～2000		2000～2005		1989～2005	
		R (%)	Rn(%/a)	R (%)	Rn(%/a)	R (%)	Rn(%/a)	R (%)	Rn(%/a)
1	Serious desertification	-32.56	-7.58	272.91	24.53	4.10	0.81	161.79	6.20
2	Above severe desertification	-27.94	-6.34	106.44	12.84	9.78	1.88	63.32	3.11
3	Above moderate desertification	-18.67	-4.05	42.67	6.10	8.83	1.71	26.28	1.47
4	Above mild desertification	-16.43	-3.52	11.32	1.80	11．44	2.19	3.68	0.23
5	Precipitation (mm)	750.5～792.9		792.9～843.8		843.8～886.2		750.5～886.2	
6	Wind speed (ms^{-1})	2.053～1.915		1.915～1.750		1.750～1.612		2.053～1.612	
7	Temperature (℃)	3.12～3.40		3.40～3.73		3.73～4.01		3.12～4.01	

(1989 to 2005), the area increasing rate was 6.20%, 3.11%, 1.47% and 0.23%.

4 Analysis and evaluation of driving force

4.1 Background trends in climate

Make linear regression for meteorological data during 20 years (1984 to 2005), and then obtain precipitation (P), wind speed (W) and temperature (T) of the regression equation as the following:

$$P=8.4814x-16119 \quad (R^2=0.1863) \tag{5}$$

$$W=-0.0275x+56.751 \quad (R^2=0.5848) \tag{6}$$

$$T=0.0558x-107.87 \quad (R^2=0.2732) \tag{7}$$

Where x represents a particular year during the study period. Above equations showed that precipitation and temperature trend was increasing and wind speed trend was decreasing. Among them, the correlation coefficient of wind speed was the highest, $R^2=0.5848$.According to equation 5 to 7, calculated precipitation, wind speed and temperature changes in the three stages. Calculation results are in Table 4.From 1989 to 2005, precipitation increased 135.7mm, wind speed decreased $0.44ms^{-2}$, and temperature increased 0.893℃.

4.2 Human activities

Desertification was mainly occurred in (1) race course (the triangle area in A1, Figure 1.) and its surrounding area; (2) desertification spots in cluster east of the NO.217 provincial road ; (3) some areas east of the city. Desertification distributes in the places where human activities focus on.

Human activities are as follows: (1) overload over grassland[1]: as many as 1.033 million sheep were herded in Litang in 1982, still there was room for feeding extra 105,000 sheep in that year as the area was capable of rearing 1.138 million sheep in capacity. As of 2005, the number of sheep reared in local surged up to 2.5 million, an increase of 142% and an annual increase of 3.92% respectively. Theoretically speaking, the overload rate expanded to 119.6%. The number of cattle was too many for the area to afford rearing – the primary cause; (2) disorder exploration: the local grassland is abundant in numerous natural plants e.g. Chinese caterpillar fungus, fritillary bulb, tricholoma matsutake, monkey-head mushroom, and black fungus, attracting a raft of outsiders to exploit it, in a disorderly way, due to its excellent quality, non pollution, and pharmaceutical value, and damaging topsoil to result in desertification; (3) grassland desertification as a result of social events e.g. horse race in every summer; and (4) damage by wild rat: ineffective measures in eradicating rats caused its rampancy, even worse the local folks hunt eagle and fox etc (natural enemy of rat), mainly contributing grassland degradation.

4.3 Analysis & assessment

Desertification in Litang County has been deteriorating in the past 16 years. The 1st stage saw decreased desertification area, the 2nd stage observed radical deterioration, and the 3rd stage witnessed slack in this regard.

Compared with the 2nd stage, the annual increasing rate of serious desertification (DI＞0.86) decreased from 24.53% to 0.81%, that of above severe desertification (DI ＞0.76) decreased from 12.84% to 1.88%, and that of above moderate desertification (DI＞0.66) decreased from 6.10% to 1.71% in the 3rd stage.The reason was that Litang County was listed as one of pilot counties in the “national project of returning grazing land to grassland” in 2003.Further implementation of the project slackened desertification and grassland was gradually recovered.

Increased precipitation and wind speed decreases (see Table 4) should help to reduce the trend of desertification, however, desertification worsened during research period. This showed there is no clear correlation between desertification and precipitation and wind speed, and they were not the driving factor of desertification.

As far as temperature is concerned, On the one hand increase in temperature aggravates drought and exacerbates desertification. On the other hand the region is subject to the frigid climate; increase in temperature with advantageous rainfall may give a push to the growth of plants and restrain desertification. Accordingly, further experiments and evidence are needed to verify if temperature drives desertification in local.

Research results think that human activities are a major factor that caused desertification.

As far as influence that the use of satellite remote sensing data gives on comparability is concerned, this research thinks that the area of desertification in winter (January) of 1989 and 1994 may be slightly exaggerated, compared with that in the autumn (October) of 2000 和 2005.If deducting this exaggerated factor, the research result can not affect the trend of grassland desertification, and May slightly increase the severity of desertification trend.

5 Conclusions

Desertification in Litang County has been deteriorating in the past 16 years (1989-2005). The 1st stage (1989-1994) saw decreased desertification area, the 2nd stage (1994-2000) observed radical deterioration, and the 3rd stage (2000-2005) witnessed slack in this regard.

Tendency of desertification has nothing to do with climate factors e.g. precipitation and wind speed, but it is in proportion to change of temperature. However further work needs to be done in delving into driving forces of temperature towards desertification.

Human activities e.g. overload over grassland and disorder explorations etc are considered the main causes in exacerbating desertification. Expansion desertification area slowed down during the 3rd stage (2000-2005), which ecological restoration projects in China have brought about marked effects.

References

[1] Ren Guo-ye,Shi Cheng-cang,Dan Shang-ming, et al. Preliminary study of remote sensing monitoring on Litang grassland's desertification of north-western plateau in Sichuan[J].Southwest China Journal Of Agricultural Sciences,2007,20(1):170-171. (in Chinese)

[2] Ren An-cai, Ren Guo-ye, Deng Liang-ji, et al. Temporal and spatial distribution of Litang rangeland's desertification on North-western plateau of Sichuan using TM image[J]. Southwest China Journal Of Agricultural Sciences,2008,21(2):425-428. (in Chinese)

[3] Chi Hong-kang,Zhou Guang-sheng,Xu Zhen-zhu, et al. Apparent Reflectance And Its Applications In Vegetation Remote Sensing[J].Acta Phytoecologica Sinica,2005,29(1):74-80. (in Chinese)

[4] Li Yu-huan,Wang Jing,Lv Chun-yan, et al. Retrieve of Earth Reflection Base On The Remote Sensing Data of TM/ETM[J].Journal of Shandong Agricultural University,2005,36(4):545-551. (in Chinese)

[5] Ding Li-xia,Zhou Bin, Wang Ren-chao.Comparison of Five Relative Radiometric Normalization Techniques For Remote Sensing Monitoring[J].Journal of Zhejiang University,2005,31(3):269-276. (in Chinese)

[6] Liu Guang-feng,Wu Bo, Fan Wen-yi, et al. Extraction of Vegetation Coverage in Desertification Regions Based on the Dimidiate Pixel Model --A Case Study in Maowusu Sandland[J].Research of Soil And Water Conservation,2007,14(2):268-271. (in Chinese)

[7] Chen Bao-rui,Xin Xiao-ping,Zhu Yu-xia, et al. Change and Analysis of Annual Desertification and Climate Factors in Inner Mongolia Using MODIS Data[J].Remote Sensing Information,2007:39-44. (in Chinese)

[8] Wang Tao,Wu Wei,Wang Xi-zhang.Remote Sensing Monitoring And Assessing Sandy Desertification: An Example From The Sandy Desertification Region of Northern China[J].Quaternary Sciences,1998(2):108-118. (in Chinese)

978-1-935068-01-3 © 2009 SciRes.