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RS-BASED MONITORING OF NDVI SPATIAL VARIATIONS: A CASE STUDY OF TYPICAL GRASSLANDS ON MONGOLIAN PLATEAU

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The Mongolian plateau is a relatively isolated territory with arid and semiarid conditions and vast steppe spaces. Ecological changes in the steppe ecosystems affect the environment of northeastern Inner Mongolia in China, and eastern Mongolia. The article analyzes the spatio-temporal distributions of the vegetation cover and plant communities (at the level of facies) based on the Landsat and MODIS13Q1 remote sensing data of Sino-Mongolian transects at typical steppes of the Mongolian plateau in 2002, 2009 and 2016 and with the use of 3S technology. The research results indicate a general tendency to degradation of the vegetation cover macrostructure; herewith, a more serious degradation is observed on the transect of Inner Mongolia in China in comparison with the territory of Mongolia. Differences in plant communities are presumably explained by different methods of cattle grazing.
Keywords: Mongolian plateau; true steppe; vegetation cover; Sino-Mongolian transect; comparative analysis.

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Introduction

Remote sensing (RS) has become an indispensable technique for monitoring vegetation change, which is the latest source of data for vegetation measurement [Benewinde et al., 2018]. It monitors the reflection characteristics of green vegetation through spectral information [Tucker, 1979; Gould, 2000], and calculates the normalized difference vegetation index (NDVI) based on the visible and near-infrared functions of satellite sensors. It can easily and accurately monitor the spatiotemporal characteristics of vegetation [Fensholt et al., 2012], and is capable of long-term continuous monitoring of vegetation in local regions and wide areas [Kogan, 1995; Liu et al., 1996; Rhee et al., 2010]. NDVI is the most extensively used vegetation index for arid and semi-arid regions [Pettorelli et al., 2005], which can represent the photosynthetic biomass, carbon sequestration, plant water stress and biodiversity [Nagendra et al., 2013]. Although the NDVI data from RS satellites are inferior to the field monitored data [Yang et al., 2015], they provide valid reference for the time series and wide area monitoring, which also reflect changes in the plant biomass. Since the early 1990s, NDVI has become one of the major indicators in ecosystem assessment worldwide [Wang et al., 2015]. The ratio between red and near-infrared bands, which is derived from the NDVI reflectivity, is highly effective and can help monitor the natural vegetation changes and human activities [Carlson et al., 1997]. Most studies have measured different spatiotemporal and grassland types [Linya Ma et al., 2014]; estimated the soil carbon stocks; observed the biodiversity of various species and biomes at different scales; and predicted the spectral reflectance enhancement of non-plants and the spectral content features of vegetation. During the grazing effect survey, the impact of grazing on grassland vegetation index and the extent of land degradation can be monitored. Located in the inner Asia, the Mongolian Plateau includes all of Mongolia, the Republic of Buryatia in Southern Russia, and the Inner Mongolia Autonomous Region of China, which covers an area of 3.1 million km^2 .The plateau is divided into landscape types such as alpine grasslands, meadow grasslands, high-cold grasslands, typical grasslands and desert grasslands according to vegetation, geographical features and geographical distribution, of which the typical grasslands have a most wide distribution [Yunjie Wei et al., 2009; Batunacun et al., 2015]. This paper chooses the typical grasslands in Mongolian Plateau for study. The area is dominated by grasses like Stipa krylovii, Leymus chinensis, Artemisia frigida, Cleistogenes squarrosa and Potentilla acaulis. Its major soil type is chestnut soil, and climate type mid-temperate arid/semi-arid continental. In recent years, the ecological environment of typical grassland transects in the Mongolian Plateau hasundergone varying changes due to natural factors and unreasonable human activities. For instance, natural environment is deteriorating, water resources are scarce, soil erosion is severe, and most of all, grassland degradation is intensifying, and desertification is still occurring [Yunfeng Hu et al., 2015]. Besides, grazing method differs between China and Mongolia for the typical grasslands, and the ecological environment has also deteriorated to varying degrees [Guilian Dan, 2009]. Thus, it is of far-reaching significance for proposing rational development and utilization, strict protection, eco-environmental protection and regional sustainable development in different regions. Research of typical grasslands in Mongolian Plateau started earlier abroad. In the 1950s, Russian scholars carried out preliminary description and investigation on the community growth habitats and plant traits of grassland vegetation for animal husbandry [Enqi Wu, 2017]. In the 1970s, researches were conducted in the fields of biochemistry, histology, cytology and plant growth [Yunatov, 1954; Miroshnichenko, 1971; Kalinina, 1974]. Since the 1970s, Mongolia has systematically studied grassland degradation, changes in grassland plant growth, plant classification, plant identification, plant distribution, development of ecological history and plant morphological features [Banzragch, 1970; Ligaa, 1972; Maniabazar, 1973; Dashnyam, 1974; Ulziikhutu, 1989; Tserendash, 1996; Bayasgalan, 2003; Dash et al., 2004; Khalbaaet et al., 2004; Sars et al., 2008; Tuvshintogtokh et al., 2010]. The main researches on typical grasslands in China are around the classification, spatial distribution and variation, coverage, biodiversity and degradation of vegetation; the monitoring analyses of plant pollens, grassland community types and desertification plants by means of 3S technology, plant dynamic model, chemical experimentation and assessment model; as well as the overall study of vegetation status and dynamic variation [Hongru Ha, 2005; Shuqing Sun, 2011; Lixin Wang, 2012; Qingqing Li et al., 2013]. Despite extensive studies on the vegetation coverage of typical grasslands on Mongolia Plateau, the RS micro-features of vegetation coverage by different grazing methods have never been studied. Hence, in-depth analysis of the RS micro-feature variation of typical grasslands on Mongolia Plateau from the perspective of regional and vegetation growth season scales is of great significance for understanding the effects of different grazing methods on vegetation coverage, and for guiding the grazing style, eco-environment protection and eco-environment monitoring in the area.

Setting

2.1 Overview of the Study Area

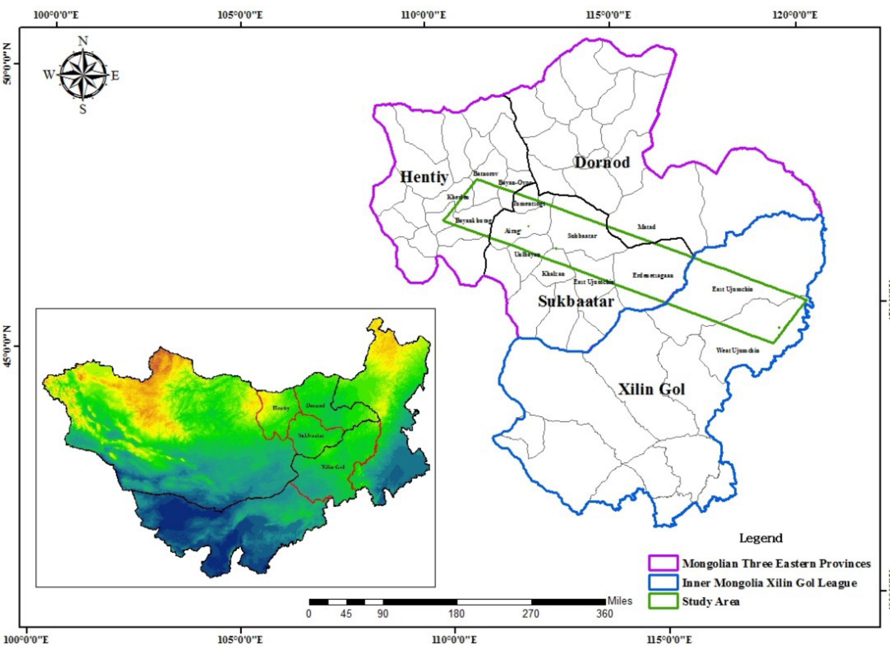


Fig. 1. Schematic of the Sino-Mongolian transects

In this study, typical grassland transects from the Saiwendur Village, Bayanhua Town, Weat Ujimqin Banner, Xilinhot City, Inner Mongolia Autonomous Region, China to the Öndörkhaan City, Khentii Province, Mongolia were chosen as the study area, which were located in the typical grasslands of the Mongolian Plateau. The transects cross Inner Mongolia's Xilingol League East, West Ujimqin Banners and Mongolia's Sukhbaatar, Dornod and Khentii Provinces. Their longitudes and latitudes are: 118°14'32.64»E, 44°32'30.08»N (South), 119°13'25.31»E, 45°13'09.35»N (East), 110°13'34.08»E, 47°13'58.02»N (West), 111°08'51.25»E, 47°56'20.13»N (North). The study area is 108.76 km^2 in width, 1688.39 km^2 in length, and 69850.01 km^2 in total area (Fig. 1). Its southeastern part is dominated by plains and low hills, which is located in the western side of Greater Khingan Mountains. The central part is dominated by plains, with flat terrain. In its northwestern part, there are Khentii Mountains, Kherlen River, Onon River and Wulezhazhu River Valley, with a highest altitude of 1461 m. The average annual temperature ranges from -0.2 °C to 3.5 °C, where the average minimum temperature in January is -20 °C, and the average maximum temperature in July is 21 °C. Besides, the annual precipitation ranges from 107.1 mm to 362.3 mm [Zhang et al., 2009].

2.2 Data Sources and Methodology

2.2.1 Data sources

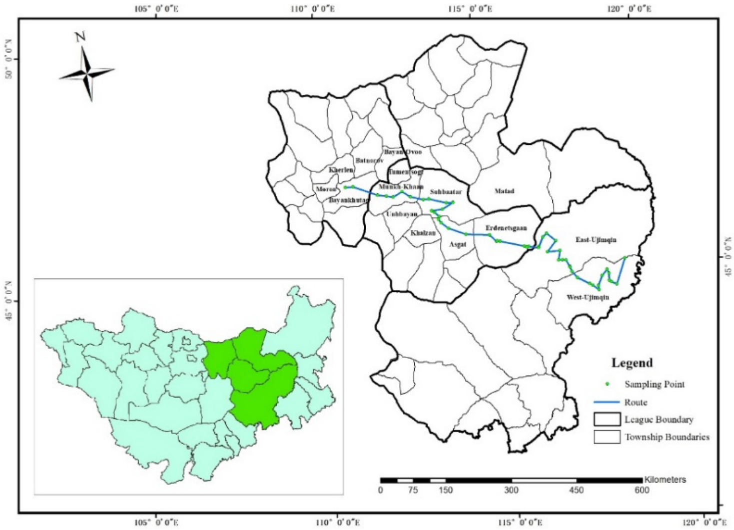
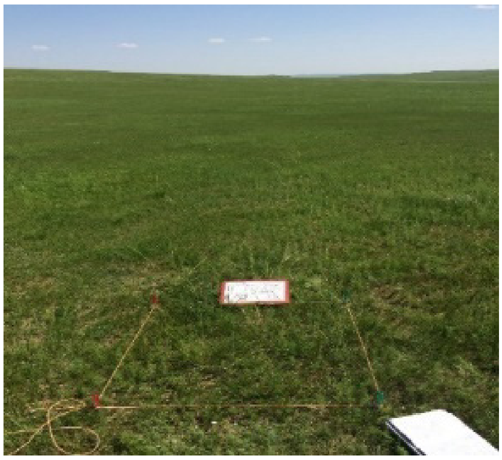


Fig. 2. Sampling points and survey routes

The RS data of this study were selected based on the temperature, precipitation anomalies and image quality for years with normal temperatures, precipitations and equal time intervals. Eligible Landsat images with a 30 m spatial resolution from April to September of 2002, 2009 and 2016 were downloaded from the USGS website (https://www.usgs.gov/) and the NASA MODIS website (https://modis.nasa.gov/), as well as the MODIS13Q1 products (h25v04 and h26v04) at a 16-day interval with a 250 m spatial resolution of corresponding years. Meanwhile, we conducted comprehensive scientific field investigations on the Sino-Mongolian transects in the study area southeast from the northwestward in 2015, 2016 and 2017 (see Figs. 1–2). A comprehensive survey was conducted on the transects around issues such as land cover, grassland plant communities and pastoralist livelihoods. Vegetation samples were collected mainly from flat open sites, where human activities were less, and vegetation types and coverage were distinct. A total of 54 sampling points were set in the study transects, including 27 points in the Inner Mongolia and 27 points in the Mongolia. The spatial distribution patterns and differentiation trends of plant species on the Sino-Mongolian transects were summarized, which provide basic facts and data support for the later verification of vegetation coverage, RS retrieval, etc. (Figs. 2–4).

A



B

Figs. 3–4. Vegetation sample plots A, B

2.2.2 Data processing

Envi 5.2 software was used to perform 432 band combination of TM RS images [Anxin Mei et al., 2001], while the remaining images for years 2002 and 2009 were rectified geometrically based on the 2016 RS images [Guozhen Lu, 1995]. Projection conversion was carried out in Arcgis 10.2 software while taking into account the size, shape and geographical location of the study area. The Albers equal-area conic projection was adopted [Lun Wu, 2001]. Mosaicking was performed again in Envi5.2 with the georeferenced images, and the study area was clipped with the mask in Arcgis 10.2 software [Shubin Deng, 2010]. During processing of NDVI data, the MODIS reprojection tools (MRT) were utilized for projection, format conversion and splicing of the downloaded data to derive the NDVI values. Meanwhile, the mean NDVIs of images in the three periods of each year were calculated via the unit statistics feature. Afterwards, the NDVI raster image data were transformed into the floating point types of -1~1 using the Raster Calculator to extract the study area by mask. Based on the MODIS NDVI, the vegetation coverages in the Sino-Mongolian transects in 2002, 2009 and 2016 were calculated by employing the dimidiate pixel model [Miaomiao Li et al., 2004]. On the basis of the above data, the overall status of vegetation coverage in 2016 was analyzed for the study area, as well as the quantitative variations of vegetation coverage [Xueling Zhang, 2009]. Finally, two linear vegetation coverage transects (six line vector data in total) with the same topographical features and north-south length (30 km) were selected from the 2002, 2009 and 2016 three period images of Sino-Mongolian transects on the Mongolian Plateau. Based on the Landsat images and MODIS NDVIs, the linear NDVI values were calculated using Envi5.2 software, and comparative analysis was made on the linear vegetation coverage under different grazing conditions for the Sino-Mongolian transects based on the three-period data.

2.2.3 Data verification

To ensure the accuracy of the vegetation coverage estimation model, verification was carried out using the field survey data obtained in 2015, 2016 and 2017. Linear regression analysis was performed on the estimated and measured data [Sun Ming et al., 2012]. As shown in Figs. 5–6, thirty-three points have the predicted values greater than the measurements, while eight points have the predicted values less than the measurements. The correlation coefficient between actually measured vegetation coverage and that estimated by dimidiate pixel model was 0.953**; the determination coefficient was 0.91; the root-mean-square error was 0.0093; the relative error was 6.30%; and the model accuracy 93.70%. These indicate overall high accuracy of the dimidiate pixel model for estimating the vegetation coverage in the Sino-Mongolian transects, which is suitable for the vegetation coverage estimation of typical grassland transects.

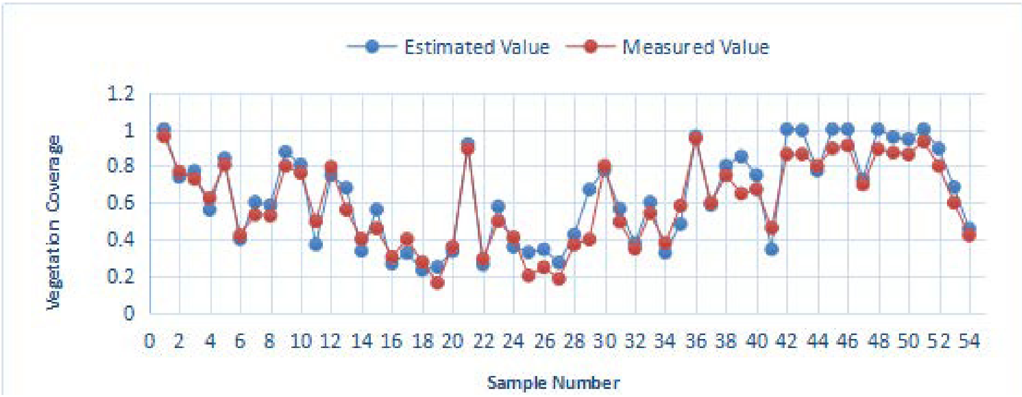


Fig. 5. Trends of vegetation measurements and estimations

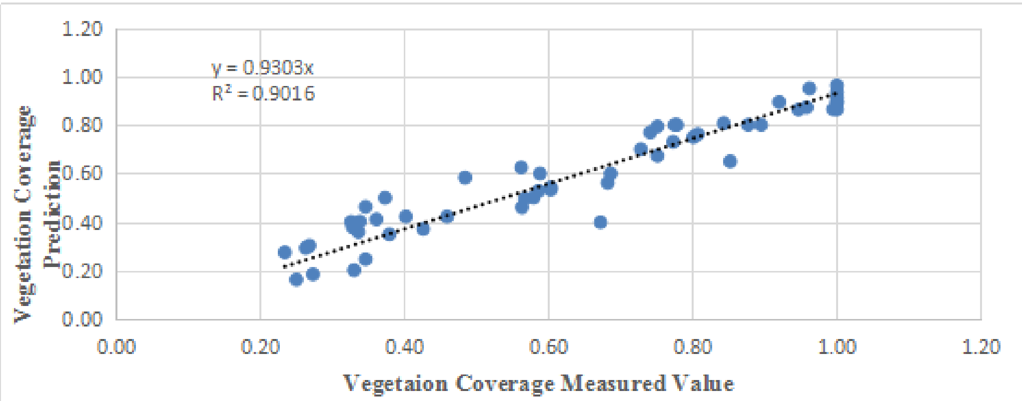


Fig. 6. Linear regression model of vegetation measurements and estimations

2.2.4 Information extraction

The dimidiate pixel model was utilized to calculate the vegetation coverage in the Sino-Mongolian transects in 2002, 2009 and 2016 based on the MODIS NDVI. According to the actual vegetation coverage in the study area and the relevant provisions on regional vegetation coverage grades in the Technical Regulations for Grassland Resources Survey, the vegetation coverage in the Sino-Mongolian transects was classified into five grades [Shumao Guo, 2009] as follows:

· Grade 1: High vegetation coverage, dense forest lands and shrubs, high grassland yield, and coverage greater than 60%.

· Grade 2: Moderate to high vegetation coverage, moderate to high grassland yield, and coverage ranging from 30% to 60%.

· Grade 3: Moderate to low vegetation coverage, moderate to low grassland yield, marsh grasslands, and vegetation coverage ranging from 15% to 30%.

· Grade 4: Scattered vegetation, with mild degradation, and severe erosion, vegetation coverage ranging from 5% to 15%.

· Grade 5: Moderate to severe desertification lands, regions with bare rock, bare soil and low residential density and grassland yield, vegetation coverage less than 5%.

Results

3.1 Macro-analysis of typical grassland vegetation on the Mongolian Plateau

In this paper, NDVI values were extracted using MODIS data for the status analysis of Sino-Mongolian transects on the Mongolian Plateau's typical grasslands, which was an effective way of grasping the spatiotemporal patterns of vegetation quality changes. To better understand the current vegetation coverage status in the study transects, we classified the vegetation coverage into five grades according to the specific conditions.

Table 1

Statistics and percentages of various grades of vegetation coverage
in Sino-Mongolian transects in 2016

Grades	Mongolian transect		Inner-Mongolian transect	
	Area (km^2)	percentages of the total area (%)	Area (km^2)	percentages of the total area (%)
Grade 1	32544.37	69.82	7631.72	32.85
Grade 2	11904.85	25.54	8590.34	36.97
Grade 3	1581.93	3.39	4457.01	19.18
Grade 4	389.40	0.84	1346.92	5.80
Grade 5	193.62	0.42	1208.37	5.20

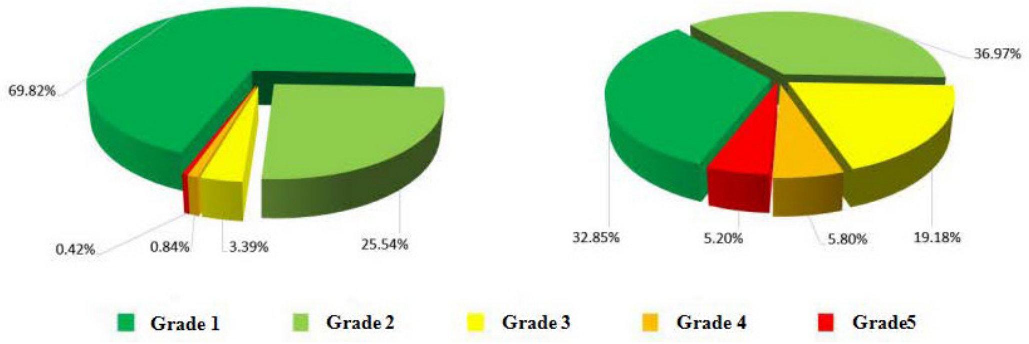


Fig. 7. Proportions of different grades of vegetation coverage in Sino-Mongolian transects in 2016

As shown in Fig. 8, the spatial distribution characteristics of various coverage grades in Sino-Mongolian transects in 2016 were: Mongolian transects: The Grade 1 vegetation was distributed mainly in Barun Urt to Öndörkhaan cities; the Grade 2 vegetation was distributed mainly in Erdenchangan Sumu; the Grade 3 vegetation was distributed mainly in Mongolia's Erdenchangan Sumu and Bichigt Port vicinity; and the Grades 4, 5 vegetations were distributed mainly in the northern part of Erdenchangan Sumu. Inner Mongolian transects: The Grade 1 vegetation was distributed mainly in the West Ujimqin Banner; the Grade 2 vegetation was distributed mainly in China's East Ujimqin Banner and slightly in West Ujimqin Banner; the Grade 3 vegetation was distributed mainly in the East Ujimqin Banner's Baolag Sumu, Uente Sumu, Uengen Sumu, Eji lake Sumu, Hubqingaobi Sumu, Sama Sumu and Uliastai Town, as well as West Ujimqin Banner's Bayin Hushe Sumu; and the Grades 4, 5 vegetations were distributed mostly around the East Ujimqin Banner's Uragaygobi and Hubqingobi, mainly in Uengen Sumu, Uliastai Town, AlatanHili Sumu and Hubqingaobi Sumu.

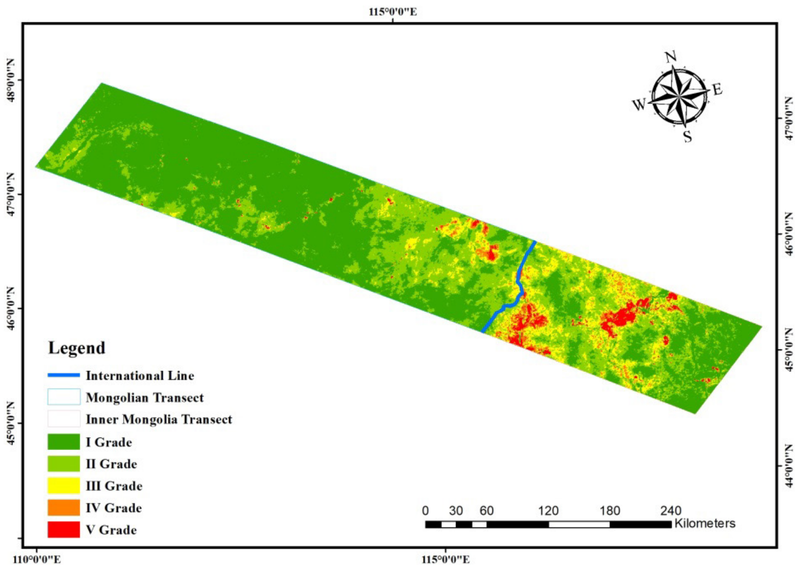


Fig. 8. Distributions of various grades of vegetation coverage in Sino-Mongolian transects in 2016

3.2 Micro-analysis of typical grassland vegetation on the Mongolian Plateau

The Sino-Mongolian transects on the Mongolian Plateau's typical grasslands share similar natural conditions, topography and vegetation characteristics, as well as the same language culture and humane history. Currently, Mongolia adopts a traditional four-season nomadic grazing, with free camp site selection, moving distance, number of migrations, etc., and fundamentally fixed camps in winter. The number of migrations per year is at least 2–3 times, which can be up to 8 times. Small numbers of pastoralists settle near Sumu for grazing. There are few clipping pastures in the Mongolian pastoral areas, which can be used moderately for grazing after grass trimming in autumn. Vegetation area has decreased slightly, showing varying degrees of degradation. Since 1996, China's Inner Mongolia has implemented sedentary and rotational grazing. The traditional nomadic grazing has basically disappeared, and sedentary grazing and enclosure are mainstreams nowadays, except for the two-season rotational grazing still adopted in some areas [Cairui Fan, 2017]. The settlements suffer gradually reduced vegetation coverage and severely degraded vegetation due to grazing throughout four seasons. Tow linear vegetation coverage transects (six linear transects in total) with the same topographical features and the same length (30 km) were selected from the 2002, 2009 and 2016 three-period images of the Sino-Mongolian transects, and subjected to the comparative analysis based on the 432 bands of TM RS images. The Mongolian linear vegetation coverage transect has longitude and latitude of: (south) 115°02'16.94» E, 46°08'33.95» N, (north) 114°41'32.40» E, 46°15'36.75» N; and the Inner Mongolian linear vegetation coverage transect has longitude and latitude of: (south) 118°16'33.85» E, 45°01'48.40» N, (north) 117°56'33.53» E, 45°09'19.07» N. Comparative analysis was made on the RS micro-features of vegetation coverage.

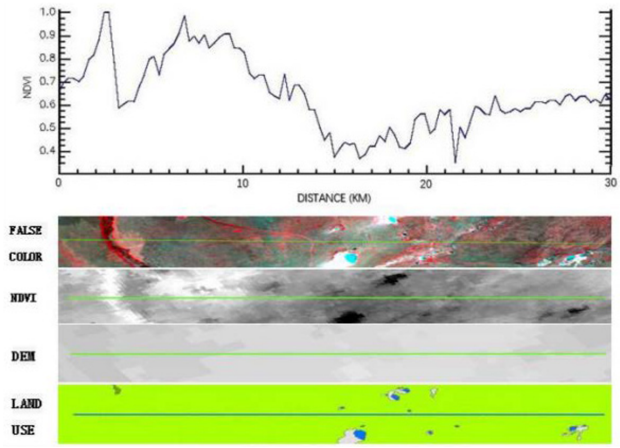


Fig. 9. Comparison of linear vegetation coverage in Mongolian transect in 2002

From Figs. 9 and 10, it can be seen that the vegetation coverage of transects in China and Mongolia have varying features in 2002, showing differences in the two model line segments. For the Mongolian transect, the vegetation coverage reaches 1.0 in an area between 2-3 km. This area exhibits large fluctuations since it is a wetland with high vegetation coverage. At an area from 4 to 5 km, the vegetation coverage decreases rapidly. In the TM RS images, this area is white red in color, with a vegetation coverage of 0.5897. Slow fluctuations are observed in an area between 5– 30 km, and the vegetation coverage reaches 1.0 at 7 km. For this area, the maximum vegetation coverage is 1.0, while the minimum vegetation coverage is 0.3702. On the whole, the average fluctuation of the Mongolian transect is not very large, and the high-to-low frequency is normal.

The Inner Mongolian transect fluctuates the most between 9–11 km and between 15–18 km. The vegetation coverage decreases significantly, and some anthropogenic factors exist in these areas. The smallest vegetation coverage is found at 10.2 km, with a value of 0.5516. It can be seen from the two figures that the Inner Mongolian transect has a larger frequency than the Mongolian. In 2002, the climate differed between China and Mongolia, with the precipitation in the Inner Mongolian transect larger than the Mongolian, so the coverage of vegetation in Inner Mongolia was higher. However, the frequency of fluctuations in China's Inner Mongolia was worse than the Mongolia.

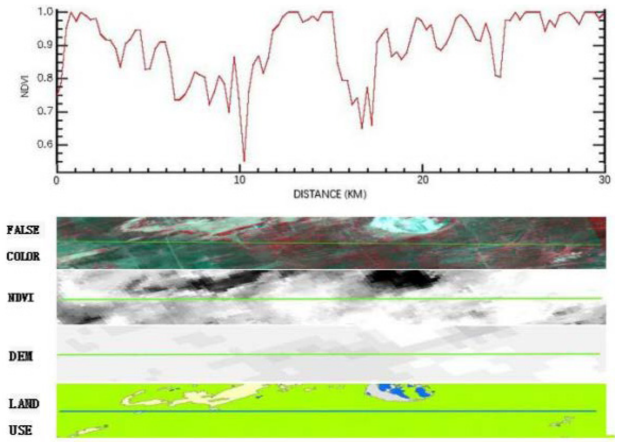


Fig. 10. Comparison of linear vegetation coverage in Inner Mongolian transect in 2002

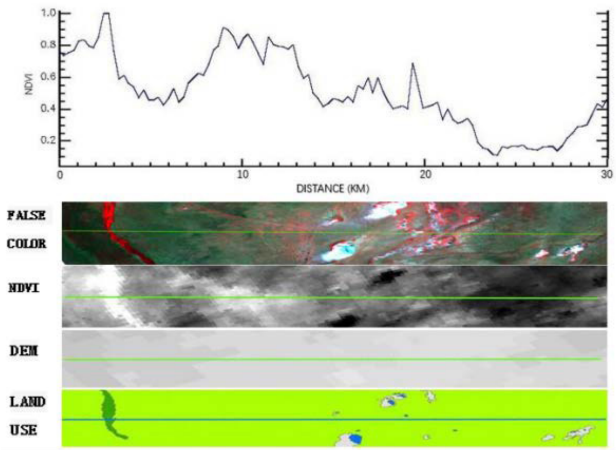


Fig. 11. Comparison of linear vegetation coverage in Mongolian transect in 2009

It can be seen from Figs. 11 and 12 that the grassland vegetation varies markedly between the Mongolian and China's Inner Mongolian transects in 2009 due to different systems and intensities of grazing. Mongolia also exhibits the highest vegetation coverage in an area between 2–3 km. This area is deepest red on the images, which is the most vegetated area as well, with a coverage of 1.0. The vegetation coverage is fairly high in an area from 8 to 14 km, while rather low at 24 to 28 km, with a minimum of 0.1093. Overall, the frequency of fluctuations in the Mongolian transect is relatively stable.

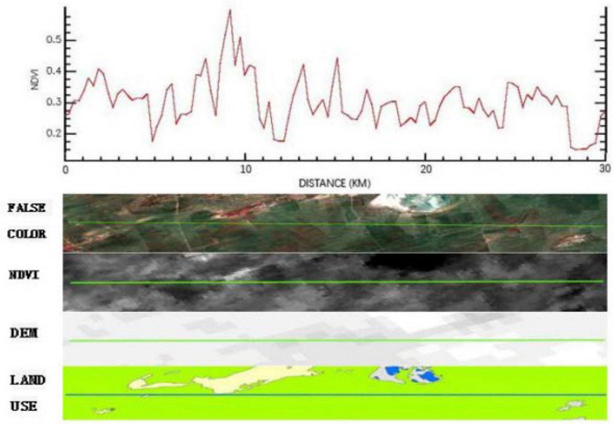


Fig. 12. Comparison of linear vegetation coverage in China's Inner Mongolian transect in 2009

Since January 1, 2003, China's Inner Mongolia has implemented the Measures of the General office of the People's Government of the Inner Mongolia Autonomous Region on the Management of Grazing Withdrawal Pilot Project for «fence enclosure, grazing prohibition (rotational grazing), captive breeding, and contraction to households». As a result, fence enclosure increased evidently in the Inner Mongolian transect in 2009. It can be seen from the RS images that the pastures have varying degrees of fence enclosure and grazing styles, such as sedentary grazing and fence enclosure, or two-season rotational grazing and four-season settlement grazing. The overall vegetation coverage in the Mongolian transect is lower than the Inner Mongolian, with the maximum value being 0.5979 and the minimum value being 0.1492. The linear vegetation coverage data of the Inner Mongolia transect model fluctuates largely overall, showing frequency instability.

From Figs. 13 and 14, it can be seen that the vegetation coverage of the Mongolian transect decreases markedly in an area between 2–3 km in 2016, with a value of 0.2740, which is lower than that in 2002 and 2009. As a consequence, the vegetation fluctuations in some areas are unstable, and the frequency also changes with coverage. The vegetation coverage is 0.6388 at maximum, and 0.2410 at minimum. Nevertheless, the overall average frequency is relatively stable, which runs low to high. The main reasons are Mongolia's climate drought and vegetation degradation in 2016, which caused the drying up of rivers and lakes and decline of precipitation.

For the Inner Mongolian transect of China, the vegetation coverage is the highest in an area from 15 to 16.5 km, with a value of 1.0. This area is red on the RS images and densely vegetated. Hence, the deeper the red on the RS images, the higher the vegetation coverage, while the whiter color on the images indicates lower vegetation coverage. The maximum vegetation coverage in this area is 1.0, whereas the minimum 0.2186. In summary, the magnitude of vegetation coverage directly affects the amplitude of fluctuations, as well as the variation of frequency to varying degrees. In 2016, the fluctuation frequency of China's Inner Mongolian transect was more unstable than the Mongolian, mainly because of severe human interference.

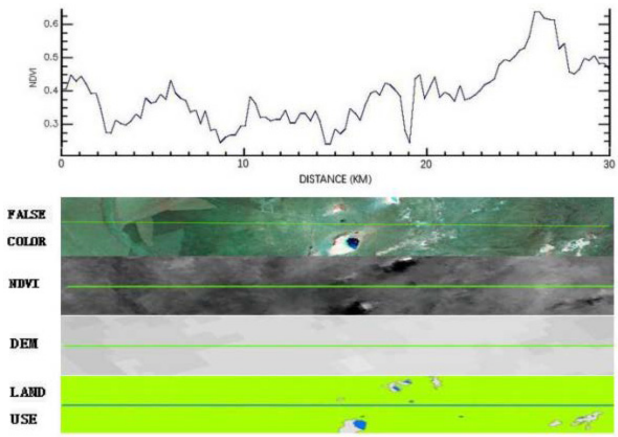


Fig. 13. Comparison of linear vegetation coverage in Mongolian transect in 2016

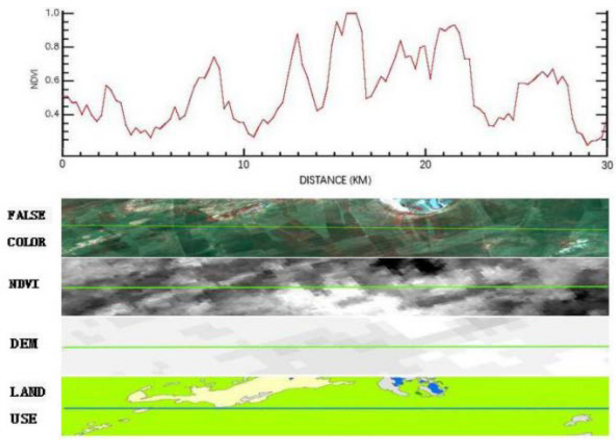


Fig. 14. Comparison of linear vegetation coverage
in China's Inner Mongolian transect in 2016

The primary factor responsible for vegetation coverage variation in the Sino-Mongolian transects in the past 15 years is the interference of grazing methods. Grazing is a continuous process of human interference. Different grazing conditions have different effects and changes on the development and pattern of vegetation coverage. Meanwhile, varying grazing intensities also produce different stages of succession. The grassland vegetation coverage changes with grazing intensity, and overgrazing has caused the degradation of such coverage. In this study, the deeper the red on the RS images, the higher the vegetation coverage, while the whiter color on the images indicates lower vegetation coverage. As Mongolia adopts the traditional nomadic grazing, the frequency of vegetation coverage fluctuations is stable there. In Inner Mongolia, grazing methods are fence enclosure, sedentary grazing, two-season rotational grazing and four-season settlement grazing, so the frequency of vegetation coverage fluctuations is highly unstable. In summary, Mongolia's traditional free choice grazing has no significant harm to the grassland vegetation, while Inner Mongolia's enclosure grazing is quite harmful to grassland plants, which has eventually led to the landscape fragmentation and somewhat affected the vegetation landscape.

Discussions and conclusions

4.1 Discussions

The overall classification of vegetation coverage in this paper conforms to the anthropogenic/natural factors and rules. However, since the data used are the mean NDVIs synthesized from 16-day values of July and August, the vegetation coverage calculations differ somewhat from the actual values. Sampling points are increased additionally in the study area to expand the research from points to planes, and the layouts of vegetation sampling points are further increased under different grazing systems. The representativeness of sampling points within the Sino-Mongolian vegetation coverage comparison areas supplements the authenticity of linear vegetation coverage in the transects. Given the scarce studies on the vegetation characteristics of Sino-Mongolian boundary transects on the Mongolian Plateau, the present study provides theoretical and practical bases for the eco-environment improvement, protection, rational vegetation utilization of typical grasslands; and for the sustainable development of local animal husbandry. In the future work, we will carry out a comprehensive landscape ecology research based on the topographical, soil, vegetation, climatic and hydrological characteristics. The vegetation coverage, community characteristics and changes are important trends reflecting grassland degradation. Seasonality causes significantly different vegetation coverage under different grazing methods, which cannot fully reflect the difference in overall vegetation degradation as well. Therefore, a more systematic analysis is needed for the study area in the future research.

4.2 Conclusions

In this paper, Sino-Mongolian transects on the Mongolian Plateau's typical grasslands are chosen for study. A vegetation coverage classification system is established on the basis of summarizing the methods for vegetation coverage monitoring at home and abroad. Further detailed analysis is carried out on the vegetation coverage based on the three-period Landsat and MODIS13Q1 data for the years 2002, 2009 and 2016 in combination with the field measured data using 3S technology, and the current status of vegetation coverage in the Sino-Mongolian transects is investigated. Finally, the RS micro-features of vegetation coverage in the two countries under various grazing conditions are studied. The following conclusions are drawn:

The Sino-Mongolian transects on the Mongolian Plateau's typical grasslands have an overall area of 69,848.53 km^2, of which the Mongolian transects cover 46,614.17 km^2, and the Inner Mongolian transects cover 23,234.36 km^2. For Mongolian transects, Grade

1 vegetation occupies the largest area, with a value of 32,544.37 km^2, accounting for 69.82% of the entire Mongolian transects. Meanwhile, the Grades 2, 3, 4 and 5 vegetation areas are: 11,904.85 km^2, 1,581.93 km^2, 389.40 km^2 and 193.62 km^2, respectively. The Grade 1 vegetation is distributed mainly in Barun Urt to Öndörkhaan cities; the Grade 2 vegetation is distributed mainly in Erdenchangan Sumu; the Grade 3 vegetation is distributed mainly in Erdenchangan Sumu and Bichigt Port vicinity; and the Grades 4, 5 vegetations are distributed mainly in the northern part of Erdenchangan Sumu. As for Inner Mongolian transects, Grade 2 vegetation occupies the largest area of 8,590.34 km2, accounting for 36.97% of the entire Inner Mongolian transects. Meanwhile, the Grades 1, 3, 4 and 5 vegetation areas are: 7,631.72 km^2, 4,457.01 km^2, 1,346.92 km^2 and 1,208.37 km^2, respectively. The Grade 1 vegetation is distributed mainly in the West Ujimqin Banner; the Grade 2 vegetation is distributed mainly in East Ujimqin Banner and slightly in West Ujimqin Banner; the Grade 3 vegetation was distributed mainly in the East Ujimqin Banner's Baolag Sumu, Uente Sumu, Uengen Sumu, Eji lake Sumu, Hubqingaobi Sumu, Sama Sumu and Uliastai Town, as well as West Ujimqin Banner's Bayin Hushe Sumu; and the Grades 4, 5 vegetations were distributed mostly around the East Ujimqin Banner's Uragaygobi and Hubqingobi, mainly in Uengen Sumu, Uliastai Town, AlatanHili Sumu and Hubqingaobi Sumu.

Grazing style is the primary factor affecting the vegetation coverage for China and Mongolia. Grazing is a continuous process of human interference. The development and pattern of vegetation coverage are affected and changed by the grazing condition to varying degrees. Meanwhile, varying grazing intensities also result in different stages of succession. The grassland vegetation coverage changes with grazing intensity, and overgrazing causes the degradation of such coverage. In this study, the deeper the red on the RS images, the higher the vegetation coverage, while the whiter color on the images indicates lower vegetation coverage.

Mongolia adopts traditional nomadic grazing, where the vegetation coverage is highest in an area between 2–3 km in 2002 and 2009. This area is deep red on the images. In 2016, the vegetation coverage decreased markedly, showing an overall reduction. The main reasons are climate drought and vegetation degradation in 2016, which caused the drying up of rivers and lakes, as well as decline of precipitation. Nevertheless, the overall fluctuation frequency of vegetation coverage in Mongolia was relatively stable from 2002 to 2016. In Inner Mongolia, grazing methods are mainly fence enclosure, sedentary grazing, two-season rotational grazing and four-season settlement grazing. In 2002, the fluctuations were greatest in areas between 9-11 km and between 15–18 km. The vegetation coverage decreased, and some anthropogenic factors were present in these areas. There was less fenced enclosure in 2002, with unstable fluctuating frequency. Since January 1, 2003, Inner Mongolia has implemented the establishment of «fence enclosure, grazing prohibition (rotational grazing), captive breeding, and contraction to households». As a result, fence enclosure increased evidently in 2009, and as shown in the RS images, the pastures had varying degrees of fence enclosures. The fluctuations were greatest in 2016, with unstable frequency. Therefore, the overall fluctuation frequency of vegetation coverage in China's Mongolian transects was highly unstable from 2002 to 2016. In conclusion, Mongolia's traditional free choice grazing has no major harm to the grassland vegetation, while Inner Mongolia's enclosure grazing has a significant landscape fragmenting effect and can impact the vegetation landscape to some extent.

The effects of natural factors on the vegetation coverage in Sino-Mongolian transects are irrespective of administrative division. Nevertheless, the vegetation coverage shows some differences under different grazing methods and anthropogenic stresses. Humans not only cause reduction of vegetation through activities like urbanization, overgrazing and excessive deforestation, but also promote the vegetation growth through policies such as the Three-North Shelter Forest Program, the Grazing Withdrawal Project and the Rotational Grazing System. For the Sino-Mongolian transects on the Mongolian Plateau's typical grasslands, the leading factor is climatic in the Mongolian territory, whereas is anthropogenic in the Chinese territory.

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ДИСТАНЦИОННЫЙ МОНИТОРИНГ ВАРИАЦИЙ ВЕГЕТАЦИОННОГО ИНДЕКСА NDVI В ИССЛЕДОВАНИИ СТЕПЕЙ МОНГОЛЬСКОГО ПЛАТО

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Монгольское плато является относительно изолированной территорией с аридными и семиаридными условиями и представляет собой обширные степные пространства. Экологические изменения в степных экосистемах оказывают влияние на окружающую среду северо-восточной Внутренней Монголии КНР, а также восточной Монголии. В статье приводится анализ пространственно-временного распределения растительного покрова и растительных сообществ (на уровне фаций), основанный на данных дистанционного зондирования Landsat и MODIS13Q1 китайско-монгольских трансектов на типичных степях Монгольского плато в 2002, 2009 и 2016 гг. с использованием технологии 3S. Результаты исследования показывают общую тенденцию деградации макроструктур растительного покрова, при этом по сравнению с территорией Монголии в трансекте Внутренней Монголии КНР наблюдается более серьезная деградация. Различия в растительных сообществах предположительно объясняются разными методами выпаса скота.
Ключевые слова: Монгольское плато; настоящая степь; растительный покров; китайско-монгольский трансект; сравнительный анализ.