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TEMPORAL AND SPATIAL EVOLUTION OF NDVI IN SEASONAL FREEZE-THAWING AREA OF CHINA

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Abstract

Vegetation is the most important composition part of land ecological system and is sensitive to the change of global climate. The characteristic of nearly 37a temporal and spatial evolution of NDVI in China's seasonal freezing-thawing area was studied focusing on the target of China's seasonal freeze-thawing area, utilizing methods of GIS spatial analysis and mathematical statistics and based on the dataset of AVHRR GIMMS NDVI and MODIS NDVI during 1982 to 2018. It showed that nearly 37a NDVI in China's seasonal freezing-thawing area fluctuated with an increasing trend in the range of 5.292~6.635. Besides, the coverage degree of vegetation increased dramatically. Sandy land developed from the direction of desertification to oasisization. This work provides scientific evidence for the sandy land ecological evaluation of China's seasonal freezing-thawing area and regional sustainable development.

Introduction

Vegetation which plays an important role in the aspects of energy exchanging, water cycle and climate adjustment at the land surface is a sensitive indicator for climate change (Twumasi *et al.* 2019). Normalized difference vegetation index (NVDI) is an important index for large scale vegetation coverage and productivity, whose value could characterize the activity strength of vegetation and further demonstrate the characteristics of structure and function of ecological system (Wang *et al.* 2019). Large scale and long sequence vegetation change research utilizing remote sensing technique is an important method to illustrate the change characteristic of ecological system (Vrbicanova *et al.* 2020). It has been reported that the vegetation activity at the global scope demonstrated an increasing trend (Nan *et al.* 2010). Vegetation coverage of China and its eastern area all demonstrated a change to some extent (Tucker *et al.* 1985). Vegetation coverage change which was influenced jointly by climate change and human activities was the direct result of regional ecological environmental change (Zhen *et al.* 2019). Besides, the illustration of the relationship between the temporal and spatial evolution of vegetation and climate change and human activities could provide theoretical evidence for coping with the climate change and enhancing the adaptability of ecological system. Related researches have been done. Mohammat *et al.* (2013) studied the change of NDVI in different seasons during 1982 to 2009 in Inner Asia, illustrating that the changing to green trend at regional scale stopped in the 1990s with the main reason of cold spring and dry summer. Piao and Fang (2003) studied the change of China's NDVI from 1982 to 1999 illustrating that the spring was the season whose average NDVI of China's vegetation has the most dramatic increasing trend and the fastest increasing rate. Besides, the moving up of the growth season of China's vegetation was the main approach responding to global changing. Freezing-thawing erosive area was the region with the characteristic of strong freezing-thawing as well as the corresponding freezing-thawing erosive landscape. China's seasonal freezing and thawing area is situated at the eastern border of giant sandy land at the middle latitude in Eurasian Continent which is also the eastern border of the

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desertified sandy land in China (Li and Zhou 2001). It was the typical farming-pastoral ecotone in North China, whose regional climate and human activities were with regional particularity (Zou *et al*. 2019). The present work was undertaken to study China's seasonal freezing-thawing area as the target to acquire its long time sequence NDVI data utilizing GIMMS NDVI and MODIS NDVI data. At multiple time and spatial scales, the dynamic changing trend of vegetation between the whole and the different parts of China's seasonal freezing-thawing area were calculated. Besides, the process and principle of dynamic vegetation NDVI evolution in China's seasonal freezing-thawing area was explored to clarify the temporal changing process and the impetus of China's seasonal freezing-thawing area and to provide basic data for further ecological recovering engineering as well as ecological culture establishment.

Materials and Methods

The area of China's seasonal freezing and thawing area was 423763.35 km^2 with the position of 42°30'-50°40' N, 115°30'-129°10' E including three parts of Horqin Sandy Land, Songnen Sandy Land and Hulun Buir Sandy Land.

GIMMS NDVI data adopted half-month maximum synthesized data of GIMMS NDVI provided by global inventory modeling and mapping studies (GIMMS) of National aeronautics and space administration (NASA) whose related parameters were as follow: the time sequence of 1982-2006. MODIS NDVI data adopted MOD13A2 data product from EOS/MODIS NDVI data of NASA with the time sequence of 2001-2018 (Mao *et al*. 2011, Zhou *et al*. 2014). Due to two different sensors adopted by two NDVI data, two NDVI data were dramatically different in the aspects of near red band (NIR), red band (R) and the temporal and spatial resolution rate. Thus, the consistency test should be conducted for these two data before data interpolation and fusion. Based on the resultant 8 a overlapped data from 2001 to 2006, the correlation analysis was conducted for the average maximum vegetation NDVI data during the annual growth season from April to October. The obtained correlation coefficient was 0.894 indicating the significant correlation at 0.05 confidence level, which illustrated that annual data of these two data were significantly consistent at the whole regional scale. Similarly, the consistency test was conducted for two data at the month scale to obtain correlation coefficient of 0.958, illustrating the passing at 0.01 confidence level.

In order to analyze the regional vegetation and NDVI variation characteristics of overall in time and space, the Maximum Value Composites (MVC) to obtain maximum NDVI, vegetation index reflects a certain period of time in the best state, the formula is as follows:

$$MNDVI_i = Max(NDVI_1, NDVI_2) \tag{1}$$

In equation (1), i is the serial number (i=1, 2, 3~12) of the month, and the value range is 1-12, $MNDVI_i$ representing the maximum composite value of NDVI in the ith month, $NDVI_1$, $NDVI_2$ respectively the value of NDVI in the first half and the second half of the ith month. Max represents the maximum value, and on this basis, the maximum value of annual NDVI can be calculated through the maximum value of monthly NDVI. Mean Value Method (MVM) is an index reflecting the central trend of data. Its formula is:

$$NDVI_i = \frac{1}{n}\sum_{j=1}^{n} NDVI_{ij} \tag{2}$$

In equation (2), i is the year serial number (i = 1, 2, 3~36), $NDVI_i$ represents the NDVI value of year i, n is the number of data items, j is the day serial number (j = 1, 2, 3~31), $NDVI_{ij}$ represents the NDVI value of month j of year i.

Results and Discussion

NDVI in the growth season of sandy land vegetation of China's seasonal freezing and thawing area from 1982 to 2018 was between 5.292 and 6.635 with annual average of 5.822, a dramatic increasing trend, annual average increasing rate of 0.025 and the NDVI increasing amplitude of 16.03% (Fig. 1). NDVI has continued to increase since 2002, exceeded 6.063 in 2010 and reached the maximum in 2017. During last 36 a, the minimum NDVI of northern sandy land occurred in 1988, namely 5.292, whereas the maximum NDVI of 6.635 occurred in 2017 with the changing slope of 0.0463. NDVI in the growth season from 1982 to 2018 in Horqin Sandy Land increased dramatically between 1.423 and 2.064 with annual average of 1.595, annual average increasing rate of 0.0133 and the NDVI increasing amplitude of 32-36%, NDVI reached the maximum in 2017. NDVI in the growth season of Songnen Sandy Land from 1982 to 2018 were with dramatic fluctuation and between 1.994 and 2.409 with annual average of 2.213, annual average increasing rate of 0.0027 and the NDVI increasing amplitude of 4.22%. NDVI in the growth season from 1982 to 2018 in Hulun Buir Sandy Land were with dramatic increased fluctuation and between 1.759 and 2.281 with annual average of 2.014, annual average increasing rate of 0.0093 and NDVI increasing amplitude of 17.39%.

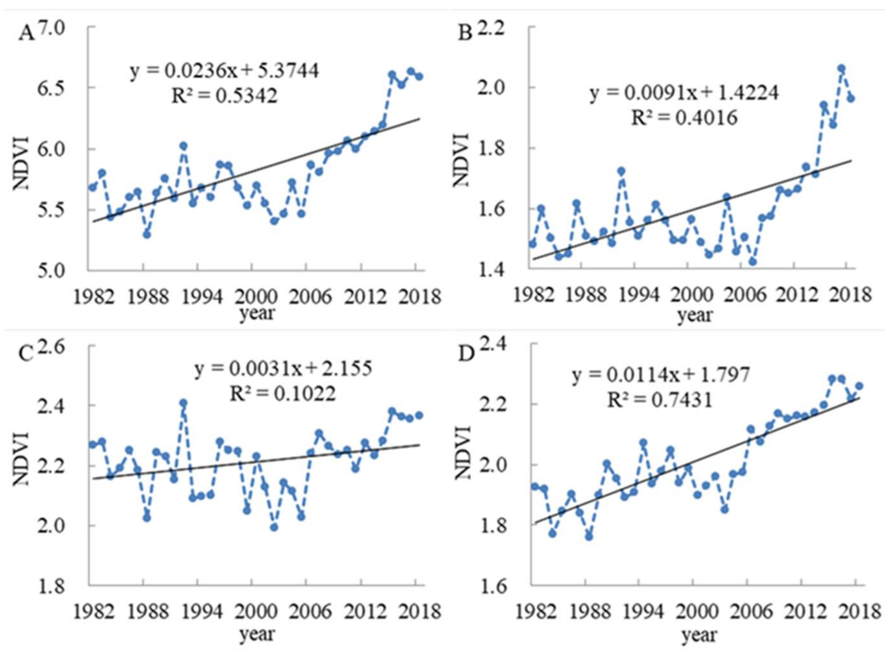

Fig. 1. Interannual variation trend of NDVI in sandy land (A: Total sand area of seasonal freezing-thawing area; B: Horqin Sandy Land; C: Songnen Sandy Land; D: Hulun Buir Sandy Land).

Vegetation NDVI of different seasons in the growth season of nearly 37a in China's seasonal freezing-thawing area all demonstrated the continuous increasing trend with different increasing rates (Fig. 2). From the calculation and the statistics of NDVI of different seasons, the average of NDVI in spring, summer and autumn were 1.415, 2.441 and 1.966, respectively. Obviously, NDVI of different seasons in the growth season of China's seasonal freezing-thawing sandy land was in a decreasing order of summer > autumn > spring. From the whole seasonal increasing trend, the

NDVI increasing trend of China’s seasonal freezing-thawing area sandy land was the most dramatic in spring. NDVI in spring in Horqin Sandy Land increased from 0.352 of 1982 to 0.454 of 2018 with annual average increasing amount of 0.0028, the increasing amplitude of 29.02% and the average of 0.313. NDVI in spring of Songnen Sandy Land increased from 0.678 of the year 1982 to 0.744 of the year 2018 with annual average increasing amount of 0.0018, the increasing amplitude of 9.73%. NDVI of Hulun Buir Sandy Land in spring increased from 0.452 of the year 1982 to 0.651 of the year 2018 with annual average increasing amount of 0.0055, the increasing amplitude of 44.11%. NDVI in summer increased from 0.837 of the year 1982 to 0.769 of the year 2018 with annual average increasing amount of 0.0019, the increasing amplitude of 8.12%. NDVI in autumn increased from 0.636 of the year 1982 to 0.839 of the year 2018 with annual average increasing amount of 0.0057, the increasing amplitude of 31.99%.

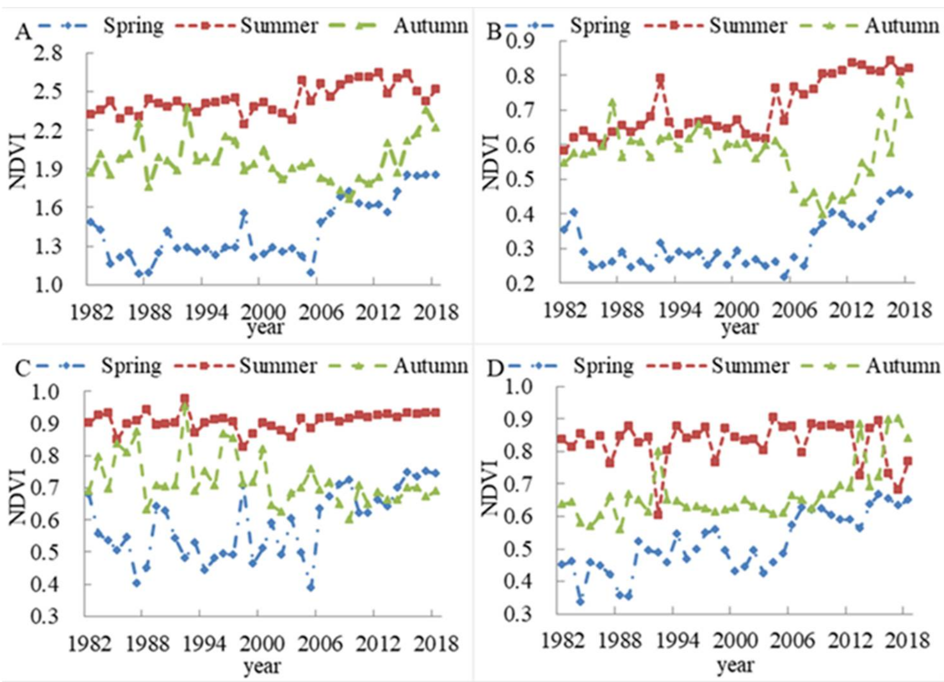

Fig. 2. Characteristics of NDVI seasonal variation in sandy land (A: Total sand area of seasonal freezing-thawing area; B: Horqin Sandy Land; C: Songnen Sandy Land; D: Hulun Buir Sandy Land).

NDVI in the growth season in Horqin Sandy Land was in a descending trend from east to west (Fig. 3). Annual NDVI averages of vegetation in the growth season in most parts and in nearly 37 years were higher than 0.25. The corresponding vegetation status was good. However, annual NDVI averages in most parts of Southwest were mainly in the range of 0.15 - 0.25 with relatively poor vegetation. Vegetation NDVI in the growth season in Songnen Sandy Land was in a descending order of east > west > the middle. The area ratio of east, west and the middle was 1: 2: 1. The annual average of vegetation NDVI in the growing season in most parts in nearly 37 years was above 0.55. The corresponding vegetation status was good. However, the annual NDVI average in the middle and south part was mainly between 0.25 and 0.35. The corresponding vegetation status was relatively poor. Vegetation NDVI in the growing season in Hulun Buir sandy land was in a descending order from east to west. The annual NDVI average in the growth season in nearly 37 years and in most parts of the area was above 0.28. The corresponding vegetation status was good. However, soil in most parts near western Hulun Lake was porous and the vegetation coverage was poor. Annual NDVI average was mostly between 0.12 and 0.26. The corresponding vegetation status was relatively poor.

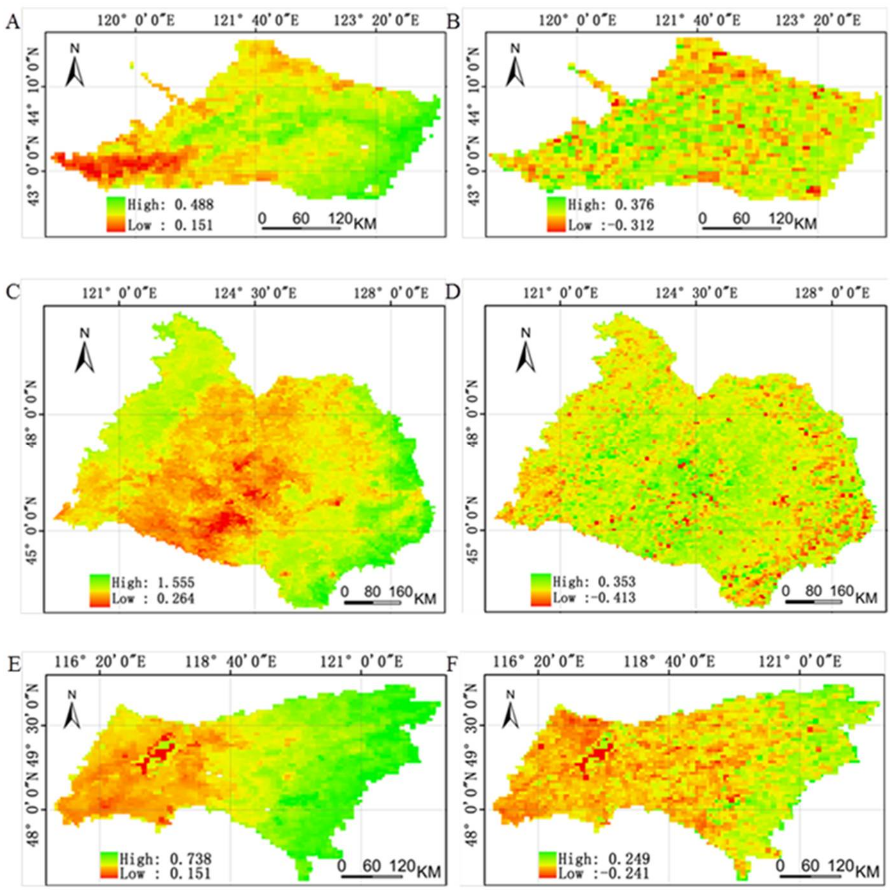

Fig. 3. Multi-year mean value and spatial distribution of NDVI in sandy land (A, B, Horqin Sandy Land; C, D, Songnen Sandy Land; E, F, Hulun Buir Sandy Land).

Vegetation NDVI in the growth season in Horqin Sandy Land demonstrated a dramatic increasing trend with the increasing values between 0.05 and 0.35 but great spatial differences, wherein the increasing amplitude of NDVI in most parts of the area was small with the variation value between 0.05 and 0.15. Vegetation NDVI in the growth season in Songnen Sandy Land demonstrated a dramatic increasing trend with the increasing value between 0.15 and 0.35, wherein the NDVI increasing amplitude of most areas was relatively small, with the variation value between 0.05 and 0.15. Vegetation NDVI in the growth season in Hulun Buir Sandy Land demonstrated a dramatic decreasing trend with the decreasing value between -0.25 and 0 and relatively great spatial variation, wherein the increasing amplitude of NDVI in northern area was large with increased value between 0.15 and 0.25.

NDVI in the vegetation growth season in China's seasonal freezing-thawing area sandy land during 1982 and 2018 demonstrated a trend of fluctuation and increasing on the whole, which was consistent with the researches of NDVI changing trend at different scales of globe, global arid area, Eurasia Continent, China and East China (Peng *et al*. 2011, Eastman *et al*. 2013). Liu *et al*. (2015) studied the temporal and spatial changing characteristic of Chinese vegetation coverage utilizing AVHRR-NDVI time sequence data of 30 years. In this work, three targets of Horqin, Songnen and Hulun Buir belonging to one natural geographic unit were chosen, further promoting the deep study of Northeastern west area. This work showed that the NDVI changing within the year in different areas demonstrated a curve of single peak with the increasing since May, the maximum in July and the decreasing at a large scale since September, which was consistent with the NDVI changing characteristic within the year obtained by Cheng *et al*. (2008). Wang *et al*. (2009) conducted quantitative analysis of vegetation coverage changing characteristic in Northeastern west area. However, considering the related research about Northeast sandy land, real time was relatively low and the accuracy was lacked to some extent. Utilizing time sequence NDVI data of nearly 37a in China's seasonal freezing-thawing sandy land, it showed that the vegetation coverage in this area demonstrated an increasing trend on the whole. Especially after 2000, due to the influence of comprehensive aspects of nature, culture and national strategies, Northeastern west area developed towards the direction of oasisization gradually. This study could further strengthen the production of agriculture and animal husbandry, develop agriculture and animal husbandry scientifically in the appropriate area and conduct strategies of transforming cropland into grassland and rotation grazing scientifically and reasonably, promoting the sustainable development in this area.

Acknowledgments

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References

Cheng Y, Xu DX and Guo N 2008. Characteristics of vegetation change in Qilian mountains in recent 20 years. Arid Zone Res. **6**: 772-777.

Eastman JR, Sangermano F, Machado EA, Rogan J and Anyamba A 2013. Global trends in seasonality of normalized difference vegetation index (NDVI), 1982-2011. Remote Sensing. **5**: 4799-4818.

Li BL and Zhou CH 2001. Sandy desertification in western Northeast China Plain in the past 10 years. J. Geograph. Sci. **11**: 307-315.

Liu XF, Zhu XF, Pan YZ, Li YZ and Zhao AZ 2015. Temporal and spatial variation characteristics of vegetation cover in China from 1982 to 2012. Acta Ecolog. Sin. **35**: 5331-5342.

Mao DH, Wang ZM, Song KS, Liu DW, Zhang B, Zhang SM, Luo L and Zhang CH 2011. NDVI change of vegetation in permafrost region of northeast China and its response to climate change and land cover change. China Environ. Sci. **31**: 283-292.

Mohammat A, Wang XH, Xu XT, Peng LQ, Yang Y, Zhang XP, Myneni RB and Piao SL 2013. Drought and spring cooling induced recent decrease in vegetation growth in Inner Asia. Agricul. Forest Meteorol. **178**: 21-30.

Nan Y, Liu ZF, Dong YH, Li XX and Ji Z 2010. The response of vegetation cover change to climate in Changbai Mountains area from 2000 to 2008. Sci. Geograph. Sin. **30**: 921-928.

Peng SS, Chen A and Xu L 2011. Recent change of vegetation growth trend in China. Environ. Res. Lett. **6**: 44027-44029.

Piao SL and Fang JY 2003. Seasonal differences in response of terrestrial vegetation activities to climate change in China from 1982 to 1999. Acta Geograph. Sin. **1**: 119-125.

Tucker CJ, Townshend JR and Goff TE 1985. African land-cover classification using satellite data. Science. **227**: 4685.

Twumasi NYD, Shao Z and Altan O 2019. Mapping built-up areas using two band ratio on landsat imagery of accra in Ghana from 1980 to 2017. Appl. Ecol. Environ. Res. **17**: 13147-13168.

Vrbicanova G, Kaisova D, Mocka M, Petrovic F and Mederly P 2020. Mapping cultural ecosystem services enables better informed nature protection and landscape management. Sustainability. **12**: 2138.

Wang GZ, Wang JP, Zou XY, Chai GQ, Wu MQ and Wang ZL 2019. Estimating the fractional cover of photosynthetic vegetation, non-photosynthetic vegetation and bare soil from MODIS data: Assessing the applicability of the NDVI-DFI model in the typical Xilingol grasslands. Inter. J. Appl. Earth Obser. Geoinfor. **76**: 154-166.

Wang ZM, Guo ZX, Song KS, Luo L, Zhang B, Liu DW, Huang N and Ren CY 2009. Response of vegetation NDVI to climate change in northeast China. Chin. J. Ecol. **28**: 1041-1048.

Zhen K, Wei JZ, Pei JY, Cheng H, Zhang XL, Huang FQ, Li FM and Ye JS 2019. Impacts of climate change and human activities on grassland vegetation variation in the Chinese Loess Plateau. Sci. Total Environ. **660**: 236-244.

Zhou W, Gang CC, Li JL, Zhang CB, Mu SJ and Sun ZG 2014. Spatiotemporal dynamics of grassland cover in China from 1982 to 2010 and its response to climate change. Acta Geograph. Sin. **69**: 15-30.

Zou J, Xie ZH, Zhan CS, Chen F, Qin PH, Hu T and Xie JB 2019. Coupling of a regional climate model with a crop development model and evaluation of the coupled model across China. Adv. Atmosph. Sci. **36**: 527-540.

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