Journal of Integrative Agriculture 2016, 15(5): 1145–1156

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RESEARCH ARTICLE

Vegetation changes in the agricultural-pastoral areas of northern China from 2001 to 2013

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Abstract

Climate change and human activity have resulted in increasing change of vegetation growth globally. Numerous studies have been conducted on extreme climate events and analyses of ecological environment evolution. However, such studies have placed little emphasis on vegetation change and spatial variation in this type of ecotone. Accordingly, this study analyzed the changes in vegetation type and growth using the 16-d composite MOD13A1 product with 1-km resolution and MOD12Q1 product with 1-km resolution. We used the mean, maximum, standard deviation normalized-difference vegetation index (NDVI) values, and the rate of change (ROC) of NDVI value to explain vegetation changes within the studied ecotone. Our results showed that significant vegetation type and growth changes have occurred in the study area. From 2001 to 2013, for example, with the exception of 2001, 2004 and 2009, a certain extent of grassland area was converted to cropland. Drought severity index (DSI) results indicate that there exists drought in 2001, 2004 and 2009. Such temporal changes in cropland and grassland area confirmed the ecological vulnerability of the ecotone. At the same time, vegetation varied spatially from west to east and from south to north. The mean, maximum and standard deviation NDVI values were all sorted in descending order based on differences in latitude and longitude, as follows: $NDVI_{2013}$>$NDVI_{2009}$>$NDVI_{2004}$>$NDVI_{2001}$

Keywords: vegetation growth, agricultural-pastoral area, MODIS, land cover change, temporal change, spatial variation

1. Introduction

In recent years, global climate change and human activity have affected physical and biological systems (Battisti and Naylor 2009; Karnieli *et al*. 2014), particularly in semiarid regions where exist rising temperatures, more frequent drought events and changes in precipitation regimes (John *et al*. 2009) since the 1970s (Ford and Pearce 2010). Vegetation change is one of the dominant dynamic responses of terrestrial ecosystems to climatic changes (Richardson *et al*. 2013). Therefore, numerous researchers studied the response of vegetation to climate change, they found clear evidence of ecological and climate gradients in ecotone zones (Kent *et al*. 1997; Rudel *et al*. 2005). Their findings indicated that ecological environments within ecotone zones are fragile (Attrill and Rundle 2002).

Received 21 April, 2015 Accepted 24 August, 2015
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doi: 10.1016/S2095-3119(15)61159-5

Agricultural-pastoral ecotones are defined as transitional zones between agricultural and pastoral areas (Dong *et al*. 2011) where cropland and grassland husbandry overlap both spatially and temporally. Many agricultural-pastoral areas exist in China, such as those in northern China, the semiarid ecotones of southwestern China and the oasis-desert transitional zones in arid regions of northwestern China (Zhao *et al*. 2002). Among these, agricultural-pastoral areas in northern China are the most fragile transitional zones in China. This area is a semiarid region owing to their low annual precipitation (250–500 mm). In addition, this type of region is very sensitive to the change of rainfall and temperature. In recent years, land degradation in this zone has been the largest and the longest in spatial scale compared to other ecotone areas in China. Therefore, many researchers have studied climate and land use changes in this ecotone from the 1970s onwards because of the serious desertification and deterioration of its ecological environment that have occurred (Dong *et al*. 2010).

Some researches on climate change and land cover type change have taken place in the agricultural-pastoral area of China. Gong and Han (2004) studied extreme climate events and related trends from 1956 to 2001. They found that the number of days of heavy rain, drought, and high temperatures increased during this period. Similarly, Zhang and Liu (2003) analyzed the spatial distribution of precipitation extremes in these areas and derived the same conclusions. Dong *et al*. (2007) monitored the changes in cultivated land in this ecotone using Landsat thematic mapper (TM) and multispectral scanner (MSS) remote-sensing images from 1975, 1985, 1995, 2000, and 2005. They found that the decreasing of cultivated land was primarily the result of the abandonment of cultivated land (before 2000), establishment of forest and increase in grassland (after 2000) as well as factors such as desertification and salinization. Chen *et al*. (2008) and Liu *et al*. (2011) studied land use/cover changes and found that there is a rise in temperature, a decrease in precipitation and a change of land cover type in most parts of this area.

Vegetation and its surrounding climate influence each other on timescales ranging from seconds to millions of years (Sellers *et al*. 1995; Tao *et al*. 2010, 2014). Unfortunately, only limited data is available on the response of dominant vegetation types on climate change and human activity in this ecological area, especially in the last several decades. As a consequence, we do not currently understand how changes in land cover type and agricultural and grassland boundaries correspond to climate change, how vegetation growth will be affected, and whether all vegetation types change in a similar manner, which are all important indicators of changes in the ecological environment. Furthermore, it is important for us to understand the similarities and differences in these changes along latitudinal and longitudinal gradients in this ecologically fragile region. Accordingly, the present study concentrated on monitoring and analyzing changes in vegetation growth in this region.

Specifically, we analyzed the changes in two dominant land types (cropland and grassland), and by determining changes in their boundaries since 2001, examined the relationships between vegetation growth and climate factor change. Our objectives were to report the vegetation change since 2001, and clarify the relationship of the vegetation to climate factor change in this fragile ecotone.

2. Results and discussion

2.1. Precipitation and temperature change

The amount of precipitation and temperature affect the vegetation growth seriously. So we analyzed the precipitation and temperature change before vegetation change analysis. Fig. 1-A is the moving track of precipitation centroid from 2001 to 2013, which shows that the precipitation centroid in 2001, 2004, 2009, and 2013 move to the south area with 41.07, 41.25, 40.89, and 41.17°N in latitude, respectively. This indicates that there is less precipitation in these years. And Fig. 1-B is the temperature change result in study area from 2001 to 2013, we can find that the temperature is dropped in this period.

2.2. Change in the area of vegetation

There are eight land cover types identified within the study area: forest, shrub land, grassland, wetland, cropland, urban areas, snow and ice areas, and bare land. The dominant land cover type was grassland, followed in descending order by cropland and forest. Significant changes in land cover types were found in the study area between 2001 and 2012, and there was an obvious change from grassland to cropland. Cropland was distributed in the southern (primarily in a number of counties in the central region of Gansu Province), the central (primarily in a number of counties in Liaoning Province and in the Inner Mongolia Autonomous Region) and the northern regions (Heilongjiang Province) (Fig. 2). Fig. 2 shows that the cropland area was converted to grassland in these three areas, and that the boundary of the cropland area moved into what was originally grassland. These new cropland areas created by this land cover change process were adjacent to original cropland areas and were not distributed independently.

Table 1 shows that the grassland area decreased from 562 911 to 510 240 km^2 between 2001 and 2012, and the proportion of the area decreased from 75.4 to 68.3%. Conversely, cropland mosaic area increased from 103 002 to 157 623 km^2 during this period, and its proportion of the