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Understanding the dynamic coupling between vegetation cover and climatic factors in a semiarid region—a case study of Inner Mongolia, China

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ABSTRACT

Vegetation is sensitive to changes in the ecological environment in arid and semiarid regions, so information on the dynamics of vegetation cover changes can provide important information for ecological environmental protection and early warning of ecosystem degradation. With the SPOT/VEGETATION normalised difference vegetation index dataset of the typical semiarid land in Inner Mongolia (IM) during 1998–2008, this study applied an integrated statistical method combing asymmetric Gaussian filtering, seasonal Kendall test, R/S analysis, correlation analysis and regression analysis, to investigate the impact of climatic factors on trends in vegetation cover. The main findings are as follows: (1) Over the 1998–2008 period, the vegetation coverage is relatively stable in IM, with only 24.5% of the total area exhibiting a significant variation in cover. The spatial distribution of the vegetation cover change has the following regional characteristics: in the northeast forest region, the vegetation cover is stable; in the middle steppe region, significant changes are observed and in the southwest desert region, the vegetation exhibits significant degradation. (2) Normalised difference vegetation index time series in most regions of IM reveal a vegetation change trend. In the high vegetation covered regions, the change trend will be reversed, whereas in the low vegetation covered regions, the original change trend will be preserved. (3) Analysis of correlation coefficients and stepwise linear regression reveals relationships between vegetation change and climatic factors. Temperature and precipitation have a direct influence on vegetation change, acting as the main climatic driving forces for the regional vegetation evolution. Copyright © 2012 John Wiley & Sons, Ltd.

KEY WORDS semiarid land; vegetation coverage; NDVI; climatic factors; seasonal Kendall test; R/S analysis; stepwise regression

INTRODUCTION

Vegetation is the main part of the terrestrial ecosystem and is considered as a sensitive indicator for environmental change as it reflects land cover change to a certain extent (Beerling *et al*., 1997; Mata-González *et al*., 2011). As one of the core issues for land use/land cover change (LUCC), related studies concerning vegetation-cover change have been important for research into global change (Matthews *et al*., 2004; Pettorelli *et al*., 2005; Strengers *et al*., 2010). Furthermore, an understanding of the structure, function and relevant processes of regional vegetation cover from quantitative, spatial, temporal and multi-scale perspectives is vital in assessing vegetation dynamics (Wu and Hobbs, 2002; Aragao *et al*., 2005; Strengers *et al*., 2010). Moreover, scientists have recognised the value of evaluating spatial ecosystem patterns and temporal processes using data archives. In the past 20 years, with the development of Earth observation technology and the long-term data accumulation, researchers have the ability to analyse and discuss the vegetation coverage intensively.

Among the surface parameters extracted from the remote sensing data, the normalised difference vegetation index (NDVI) is an extensively used indicator for vegetation condition (Tucker *et al*., 2005; Beck *et al*., 2006; Brown *et al*., 2006), which is calculated as the formula NDVI = (infrared red)/(infrared + red), where infrared and red are the reflectance in the near-infrared and red electromagnetic spectrums of objects on the earth surface, respectively. NDVI is closely related to vegetation cover, phytomass, leaf area index and net primary productivity and can reflect the cover information objectively over large spatial and temporal scales. It is a particularly suitable index for evaluating the condition of vegetation growth and the spatial distribution of vegetation density (Beerling *et al*., 1997; Thuiller *et al*., 2005). By analysing the NDVI time series, it is possible to estimate inter-annual vegetation evolution trends for various vegetation attributes such as phonological changes (Moody and Johnson, 2001; Stockli and Vidale, 2004), and incorporate this information into models of climate, hydrology, net primary production and biogeochemical cycling (Yu *et al*., 2003). Currently, there are many methods for analysing NDVI time series, such as principal component analysis (Eastman and Fulk, 1993), Fourier analysis (Azzali and Menenti, 2000; Jakubauskas *et al*., 2002), wavelet decomposition (Alhamad *et al*., 2007; Martínez and Gilabert, 2009; Yang *et al*., 2011), Mann–Kendall (MK) test (Julien and

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