Doctoral Dissertation

Remote Sensing Based Monitoring for Land Degradation in Inner Mongolian Grassland
(Summary)

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The Inner Mongolia grassland comprises more than 20% of China's total grassland area, which made this region as the largest animal husbandry base in China. However, land degradation also occurred here, mainly due to the effects from human behaviors and climate change, threatening daily lives of the local residents.

The main objective of this study is to evaluate the grassland degradation in Inner Mongolia on both quantity and quality levels using the remote sensing based methods. The dissertation has been divided into seven chapters. Chapter 1 clarifies the background and the objectives of the present study. Chapter 2, 3, and 4 study the grassland degradation dynamics on quantity level during different study periods. Chapter 5 applies nonlinear and non-stationary method for degradation trend analysis. Chapter 6 evaluates the grassland degradation on quality level. Chapter 7 makes general discussion of the whole dissertation. More detailed information are displayed below.

In Chapter 2, a time series of NDVI data from 1983 to 2013, derived from the advanced very high-resolution radiometer Vegetation Health Product (AVHRR-VHP), was applied to detect linear trends, seasonal phenology transition dates, and growing seasons to assess the dynamics of the vegetation growth and phenology in the Inner Mongolia Autonomous Region in China. Overall, Inner Mongolia became warmer and drier during the study period. A significant increasing cumulative NDVI trend was found for 30.30% of the total vegetation covered area, and 21.21% of the area exhibited a significant decreasing trend. The degraded area was primarily located in the northeastern meadow and typical steppe regions. The restored area was mainly in the western desert steppe. The forest grew at a normal rate during these years. However, a severe drought during 1993–2003 was detected, when approximately 27.56% of the total vegetation covered area experienced a significant decreasing NDVI trend. The length of the growing season (LOS) in 1983–2013 shortened because of the delay of the start of the growing season (SOS) and the advance of the end of the growing season (EOS). However, this trend reversed in the more recent decade (2003–2013). The phenology was closely associated with climate change, especially precipitation. Moreover, the LOS was strongly correlated with the spring precipitation. The variability of the vegetation responses to climate change was also assessed, indicating that most of the vegetation types had recently recovered and that the restored areas had a varied spatial distribution.

In Chapter 3, changes in land use types and biomass prediction based on satellite images were evaluated using time-series data obtained from Terra MODIS images during 2002-2012. The biomass samples had been collected in three sites (meadow, typical and desert steppe) with time interval of two weeks in growing season (May to September) in 2011. And the corresponding 16-day composite vegetation indices (VIs) of normalized difference vegetation index (NDVI) extracted from MODQ13 product used to regress with biomass data. The best results obtained in Linear-NDVI model with the highest coefficient of determination (R^2) and lowest root mean square error (RMSE). Overall, the vegetation covered area increased in this decade whereas the barren land decreased. The most obvious land use change was detected around the western desert steppe in Inner Mongolia Autonomous Region (IMAR), suggesting that the vegetation recovery improved in the low vegetation covered steppes.

In Chapter 4, the trends in vegetation cover and phenology dynamics in the Inner Mongolia grassland was evaluated to understand vegetation responses over the last decade, by applying a normalized difference vegetation index (NDVI) time series obtained by the Terra Moderate Resolution Imaging Spectroradiometer (MODIS)during 2002–2014. The results showed that the cumulative annual NDVI increased to over 77.10% in the permanent grassland region (2002–2014). The mean value of the total change showed that the start of season (SOS) date and the peak vegetation productivity date of the season (POS) had advanced by 5.79 and 2.43 days respectively. The end of season (EOS) was delayed by 5.07 days. These changes lengthened the season by 10.86 days. Our results also confirmed that grassland changes are closely related to spring precipitation and increasing temperature at the early growing period because of the global warming. Overall, productivity in the Inner Mongolia Autonomous Region tends to increase, but in some grassland areas with grazing, land degradation is ongoing.

In Chapter 5, a nonlinear and non-stationary method, empirical mode decomposition (EMD) was employed to detect the cumulative NDVI trend in 23 meteorological stations. Comparing to the regular linear analysis method, the results obtained the trends with lower significance, revealing that the EMD method are still needed to be modified to catch the vegetation change in semiarid and arid region.

In Chapter 6, the potential of band depth approaches using partial least squares (PLS) regression to estimate herbage biomass and the concentrations of nitrogen (N) and phosphorus (P) was investigated in the Inner Mongolia grassland. Field hyperspectral measurements and plant sampling were conducted in desert and typical steppes with different fertilizer levels. The PLS analyses of typical steppe, desert steppe and combined datasets were based on canopy reflectance and first derivative reflectance (FDR) at wavelengths of 400–1000 nm, with consideration of six band depth features extracted from the red absorption region (580–740 nm). The predictive accuracy of the standard full-spectrum PLS (FS-PLS) was compared with that of the iterative stepwise elimination PLS (ISE-PLS) via the cross-validated coefficient of determination (R^2) and the ratio of prediction to standard deviation (RPD). In most of the datasets, the ISE-PLS provided better predictive results than the FS-PLS. The final models used band depth features to estimate herbage biomass (R^2 = 0.624–0.952, RPD = 1.506–4.539) and pasture N (R^2 = 0.437–0.888, RPD = 1.331–2.869) and reflectance and FDR to estimate pasture P (R^2 =

0.686–0.815, RPD = 1.754–2.267). The models could accurately estimate most of the grass parameters (RPD > 1.5), with the exception of pasture N concentrations in the desert steppe dataset due to a range of variation that was too small. The band depth approach with ISE-PLS improved the predictive ability of the method for estimating herbage biomass and the nutrient contents of grasses in sparse grasslands.

Last chapter makes general discussions about the achievements corresponding to the objectives in the current study and the limitation of the experiments. Improvement which will be conducted in the future was also been explained in this part.