Evaluate the Effect of the Grain for Green Project on Vegetation Variation in Xiliugou Basin

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Abstract. Xiliugou Basin is one of the ten brooks that flow directly into the Yellow River, facing two key environmental problems: soil and water erosion and flood sediment disasters caused by storm runoff. In order to analyze the dynamic vegetation variation in Xiliugou Basin before and after Grain for Green Project (GGP), we used Normalized Difference Vegetation Index (NDVI) data to extract the series characteristics of vegetation changes from 1998 to 2010. The spatio-temporal effects of the GGP on land cover and vegetation coverage (VC) was characterized using TM/ETM+ images of 1998, 2002, 2007 and 2010. The results show that from 1998 to 2010, total VC was increasing, and areas with poor vegetation conditions declined significantly. Higher VC was for the most part spatially distributed around the river, while lower VC was present in the desert, which would be expected to have low coverage. A high spatial distribution was found in the upper reaches, while in the lower reaches it was low. Comparing the four periods, the VC distribution had substantial variation, particularly in the upper reaches. This was driven by the higher VC in grassland, which demonstrates that GGP can effectively rehabilitate ecosystems.

Keywords: Vegetation Variation; Grain for Green Project; Xiliugou Basin; Remote Sensing

1. Introduction
Vegetation is a hinge part of the ecological cycle and helps maintain the environment, including forests, shrubs, grasslands, farmland and orchards. Vegetation which is a key indicator of changes in the status of the environment also contributes to stability in the biogeochemical balance of global ecosystems [1]. Vegetation coverage (VC) which is an important property of a plant canopy refers to the vertical projection area of vegetation (including branches, stems and leaves) on the ground [2]. The hierarchical distribution of vegetation and soil which is related to VC have contribution on emissivity and temperature. The research of vegetation variation is used to master the process of surface parameterization in climate change and weather forecast [3]. As an essential index in a description of the ecological system, VC is a combination of natural environment changes and human activities [4]. A variety of VC estimation method has become the basis of regional and global climate and hydrological models, and vegetation monitoring is of great significance to the protection of ecological environment [5]. Remote sensing surveys that use vegetation indices [2] as well as a spectral mixture
analysis are two alternative methods that make important improvements to traditional methods for estimating vegetation coverage [6]. The spectral mixture analysis model was complex and contained uncertainty because it assumed the pixel as a mosaic structure. Among these methods, the vegetation indices approach is the simplest and convenient. The NDVI data from the first satellite equipped with Advanced Very High Resolution Radiometer (AVHRR) is used to evaluate seasonal change trend of vegetation. This study estimates VC using the vegetation indices method from remote sensing data.

The Grain for Green Project (GGP) is a major ecological restoration project since 1999 with the largest investment, the strongest policy, the most extensive involvement and the highest degree of public participation in China [7]. Three types of land conversion are promoted by GGP including wasteland to forest, cropland to forest and cropland to grassland. In order to promote the restoration of degraded landscapes, the focus of GGP is to plant more forests and transfer degraded wasteland and farmland to healthy manmade grassland and forests. The ecological conditions can be improved by converting farmland with a slope greater than 25 ° into forest or grassland. The project has the potential to improve the ecological environment in the upper and middle reaches of the Yellow River at the national level. Agricultural census data shows that the area of returning farmland to forest reached 28 million hectares from 1999 to 2009. It is necessary to have a extensive and far-reaching influence on the environment at the regional and national scales [8]. However, the impact of the GGP on vegetation coverage in hotspots of the Yellow River has not been well documented.

The ten brooks region which is located in the upper reaches of Yellow River belongs to the priority region for the GGP. It is caused by rainstorm runoff. In addition to floods and sediment disasters, its main problem is soil erosion. Xiliugou Basin is an important tributary of the ten-brooks. In the past, there were few studies on the vegetation variation in the Xiliugou Basin. The investigation of VC, land use and land cover is to understand the impact of GGP on vegetation change in Xiliugou Basin. The primary objectives are to: 1) use remote sensing data to investigate the characteristics of VC, land use and land cover in the Xiliugou Basin from 1998 to 2010; 2) analyze the dynamic vegetation variation before and after the Grain for Green Project.

2. Materials and Methods

2.1. Study Area

Xiliugou Basin is located in northwest of China with the longitude of 109° 24′ ~110° 00′ E and latitude of 39° 47′ ~40° 30′ N, and is a branch of the Yellow River in Ordos City, Inner Mongolia. It is one of the ten brooks that feed directly into the Yellow River. The basin originates in the Ordos Plateau, on the northern margin of the hilly and gully region in the north, through the Hobq Desert and to the Yellow River. The area is 1173 km² and its main stream is 75 km above of the Longtouguai hydrometric station. The basin has a typical arid continental monsoon climate; annual rainfall was 272 mm from 1960 to 2010, and annual evaporation was over 2,000 mm, which was 7 times greater than the precipitation. The average annual temperature is 6.1 ° C and the frost-free period is approximately 140 days. Chestnut soil and thick bone chestnut soil are the primary soil types in the watershed and the thickness of soil layer is 10 ~ 30 cm. Land-use types are mostly grassland, farmland, and sandy land.

2.2. Methods

2.2.1. Data Sources. NASA’s Landsat TM/ETM were used to ground feature identification and information extraction, and were suitable for monitoring vegetation changes. Using multi-temporal satellite images to monitor the impact of GGP on vegetation coverage, the TM and ETM data (path 127 and 128, row 032) of Ordos City were obtained on Jul. 2, 1998, Aug. 29, 2002, Aug. 3, 2007, Jul. 10, 2010. The image is taken when the vegetation is growing well, which can fully reflect the growth situation.
2.2.2. Data Processing. All the land-use, land-cover data were calculated from the statistical data. ArcGIS 10.0 and envi 4.8 image processing software are used to process and analyze remote sensing data. The original TM/ETM image is geographically sampled by nearest neighbor resampling method to the Albers projection system. Based on the 1:50,000 digital map, the geometric correction of the image was completed and 18 ground-control points were selected by ENVI 4.8 software by using the digitized map as the basic image.

2.2.3. VC Estimation. A dimidiate pixel model assumes that the spectral information of remote sensing observation pixels consists of vegetation and soil. The information S can be expressed as Sv represented by green vegetation and Ss represented by soil through remote sensing sensors [9]. The spectral information is represented by a weighted linear combination of Sv and Ss, where the weight is the proportion of vegetation area in a pixel (fc).

\[ f_c = \frac{S - S_{\text{soil}}}{S_{\text{veg}} - S_{\text{soil}}} \]  

where Ssoil and Sveg are the spectral responses from pure soil and pure vegetation pixels, respectively.

The NDVI values are derived from TM spectral data in the visible and near infrared regions of the electromagnetic spectrum. Inserting NDVI into Eq. (1), we obtain the following approximation:

\[ VC = \frac{NDVI - NDVI_{\text{min}}}{NDVI_{\text{max}} - NDVI_{\text{min}}} \]

where the subscripts max and min denote values over fully vegetated area and bare soil, respectively. The maximum and minimum values within the confidence interval range was 5% to 95%, which was determined primarily by the size of the image.

2.2.4. Land-Use and Land-Cover Change. The land-cover map was compiled from 1998 and 2010 TM/ETM images. Land-cover maps for 1998 and 2010 show nine types of land-cover with more than 80% accuracy through remote sensing interpretation. The detailed land-cover changes from 1998 to 2010 are represented by the land-cover transfer matrix.

3. Results

3.1. Temporal Variation Trends of VC
VC hierarchical results for 1998, 2002, 2007, and 2010 were analyzed using Microsoft Excel (table 1), which provided VC temporal variation information for Xiliugou Basin. As shown in Table 1, the Level 1 VC, which was the most dominant vegetation coverage in 1998, reached 512.3 km², accounting for 46.2% of the total area. Level 2 VC in 2009 was second most dominant, accounting for 29.1% of the total area. In 2002, 2007, and 2010, Level 2 VC was the most dominant, accounting for more than 34% of the total area.

| Year | Level 1 (<25% ) | Level 2 (25-45%) | Level 3 (45-60%) | Level 4 (60-75%) | Level 5 (>75%) |
|------|----------------|-----------------|-----------------|-----------------|---------------|
| 1998 | 512.28         | 323.01          | 104.12          | 58.47           | 110.32        |
| 2002 | 335.10         | 424.27          | 151.42          | 80.70           | 116.70        |
| 2007 | 326.70         | 385.39          | 175.49          | 95.26           | 125.36        |
A comparison of VC in 1998 and 2010 shows that total VC was increasing. Mean VC value increased from 0.335 to 0.468 before and after the GGP. The maximum VC variation occurred in Level 1, which fell by 349.17 km$^2$, accounting for 31.5% of the total area. Level 3 increased most, from 9.4% to 21.4%. Levels 4 and 5, which represent high coverage, both showed increasing trends of from 15.3% to 26.4%. There is thus a significant trend of rapid growth in the vegetation. This is also confirmed by the sharp reduction in extremely low coverage areas, and suggests that ecological conditions have been improving.

3.2. Spatial Variation Trends of VC

Figure 1 shows the spatial distribution of VC in 1998, prior to the GGP, and after its implementation in 2002, 2007 and 2010. The vegetation in these four years had the same spatial distribution as the integrated results obtained for 1998-2010. Relatively higher VC is observed in the southern parts of the study region in all periods. As shown in the figure, the spatial distribution in Xiliugou Basin is high in the upper reaches and low in the lower reaches. The higher VC was distributed mainly around the river, while lower VC was located in the desert, as would be expected.

3.3. VC Variation in Different Reaches

VC variation in different reaches were analyzed. In the upper reaches, 49.5% of the VC areas had medium-high coverage in 2010, while just 25.6%, 32.6%, and 37.1% of the areas had medium-high coverage in 1998, 2002 and 2007, respectively. It is thus clear that there has been a significant change in VC from 1998 to 2010 in the upper reaches. In the middle reaches, 82.2% of the vegetation areas had extremely low coverage in 1998 and 59.7% had extremely low coverage in 2010. This indicates that the VC trend is from extremely low coverage to low coverage in the middle reaches. In the lower reaches, 79.5% of the VC areas had medium-low coverage in 1998, and 64.8% had medium-low coverage in 2010. In addition, 28% of the VC areas had extremely high coverage in 2010, while just 16% had extremely high coverage in 1998. Comparing the four periods, the VC distribution experienced substantial variation, especially in the upper reaches. There was no significant VC change in the lower reaches.

3.4. Land-Cover Types Based on Remote Sensing

Land-use and land-cover maps for 1998 and 2010 are shown in figure 2. Grassland, sandy land, and cropland were the three largest land-use types in the region from 1998 to 2010. Grassland constituted 65.72%, and 66.55% of the total area, sandy land 15.11% and 13.74% of the total area in 1998 and
2010, respectively. Areas of cropland, forest, grassland and built-up land increased from 1998 to 2010. On the contrary, areas of water, sandy land and barren land decreased. Forest grew most rapidly and barren land was reduced at the fastest rate. The most notable changes in land use in the basin were a decline in water and barren land. From 1998 to 2010, moderate-coverage grassland developed rapidly. The classification results show that cropland is distributed in the south mountain areas. Sandy land is mostly distributed in the lower reaches and accounts for more than 13% of the total area. Moderate- and high-coverage grassland is concentrated in the south and near water, while low-coverage grassland is located in the north. The distribution of built-up land along the river is scattered in different areas.

![Land-use and land-cover maps of 1998 and 2010.](image)

**Figure 2.** Land-use and land-cover maps of 1998 and 2010.

### 4. Conclusions
This study analyzed spatial and temporal vegetation-coverage variation before and after the GGP, from 1998 to 2010. The results show that from 1998 to 2010, total vegetation coverage increased significantly and areas with poor vegetation conditions, such as sandy land and barren land declined. In 1998, Level 1 VC was the most dominant vegetation coverage. In 2002, 2007, and 2010, Level 2 VC was the most dominant, accounting for more than 34% of the total area. Relatively higher VC was observed in the southern parts of the study region in all periods. The spatial distribution of VC in Xiliugou Basin is high in the upper reaches and low in the lower reaches. Comparing the four periods, VC distribution varied significantly, especially in the upper reaches. There was no significant VC change in the lower reaches.

The most significant land use change is the reduction of water and barren land, and the rapid growth of moderate-coverage grassland. The shift from lower VC in sandy land, barren land, and water bodies to higher VC in grassland was the major cause for the increase in total VC from 1998 to 2010.

The GGP is thus shown to have effectively rehabilitated ecosystems. The increase in vegetation coverage has an important mitigation effect on soil erosion in the Loess Plateau. However, it is necessary to further explore the potential impact of GGP on the ecological environment.
Acknowledgments
This study was financially supported by the National Natural Science Foundation of China (Grant No. 51779099, 51979118).

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