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# Effectiveness of ecological restoration projects in Horqin Sandy Land, China based on SPOT-VGT NDVI data

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ABSTRACT

Horqin Sandy Land is a major source of sandstorms in Northern China, especially the Beijing–Tianjin–Tangshan Region. A series of ecological restoration projects including the 'Grain for Green Project', the 'Beijing and Tianjin Sandstorm Source Controlling Project', and the 'Three-North Shelterbelt Project' were implemented in this region. This study assesses the effectiveness of ecological restoration projects within Tongliao City, the main body of Horqin Sandy Land. The different treatment effects of various sand dunes were assessed and compared based on Normalized Difference Vegetation Index (NDVI) from SPOT VEGETATION Ten Daily Synthesis Archive from 1999 to 2007 and the desert distribution map of China in 2000. The results showed that: (1) the fixed and semi-fixed sand dunes were the main sand dune types, which accounted for 70% of the entire sand dune area in 2000; followed by shifting sand dunes and the semi-shifting sand dunes. (2) The ecological restoration projects resulted in improvements of different sand dune types, the improved area covered 76% of the sand dune area, mainly in the southern parts of the study area. The vegetation cover of the sand dunes in Naiman Banner, Hure Banner and the south of Horqin Left Back Banner increased significantly. While mild improvement occurred in the central sand dunes of the study area. (3) The area with degraded vegetation accounted for approximately 10% of sand dune area, mainly located in the southeast of Jarud Banner and the west of Horqin Left Middle Banner. Most of these areas showed mild and insignificant degradation except for a small area of moderate degradation. (4) The types of sand dunes in degraded status were mainly the fixed and semi-fixed sand dunes, followed by the semi-shifting sand dunes and saline-alkali land. The lower the dune fixity (e.g. shifting or semi-shifting versus semi-fixed or fixed) and the more likely to contribute to sand-storms, the greater the effectiveness of restoration projects. Finally, some implications for the sustainable development of the ecological restoration projects are discussed.



## 1. Introduction

China is facing a severe desertification problem due to a combination of physical and human factors including population pressure, climate change and reclamation (Fullen and Mitchell, 1994; Runnstrom, 2000). As one of the four largest desertification regions, Horqin Sandy Land provides a source of sand for sandstorms occurring in Northern China, especially in the Beijing–Tianjin–Tangshan Region. Formerly, Horqin region was a lush grassland, but was converted into cropland due to increasing population and food demand. In particular, the "food for the program" policy in the 1950s pushed grassland reclamation for conversion to cropland (Song and Zhang, 2006). Beginning in 1978, the "Reform and opening up" campaign, rapid economic development and increased human activities further exacerbated grassland degradation (Ren et al., 2004; Wang and Chen, 2007). The Horqin Sandy Land is facing a larger challenge than before due to climate change and population pressure (Zeng and Jiang, 2006); previous studies showed this region was undergoing significant warming and drought. Therefore, the ecosystem in Horqin Sandy Land is extremely fragile in the environment of global warming and rapid land use change (Zuo et al., 2008).

Increasing drought and intense human activities led to the aggravation of desertification. This has begun to attract governmental and citizen concerns for ecological and environmental protection of the area. Ecological engineering aiming for restoration of ecosystems is necessary in China (Mitsch et al., 1993; Mitsch and Jorgensen, 2003). Some large ecological

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restoration projects have been implemented in recent years, such as, the "Three-North Shelterbelt Project" since 1978, the "Grain for Green Project" (also called Sloping Land Conversion Program) since 1999 (Stokes et al., 2010), and the "Beijing and Tianjin sandstorm source controlling project" since 2000. However, the effectiveness of ecological restoration projects has few been evaluated (Zhang, 2006; Li et al., 2009).

As a fragile ecosystem and typical desert region in Northern China, Horqin Sandy Land has received much attention from the government and academics. The temporal and spatial changes of desertification on different scales have been investigated using field surveys and remote sensing imagery in several previous studies (Wu, 2003; Xu, 2003). Using a change detection method to examine desertification, Zhan et al. (2006) showed environmental improvement over the last 30–50 years. The ecological and environmental restoration projects have revealed preliminary success.

Desertification in the region has vacillated between degradation and improvement (Han et al., 2009). At present, the general trend is towards decreased desertification. Zhao et al. (2007) have shown that the desertification area in Horqin decreased from 5163 $km^2$ in 1987 to 4674 $km^2$ in 2000 after a large-scale restoration project. Since 2000, the trend of desertification exacerbation has been controlled and desertification area has gradually reduced, according to several studies based on moderate resolution remote sensing data (Li et al., 2006; Du et al., 2009). Despite these improvements, desertification is still a wide-spread problem resulting in non-deserted land turning to sand dune; in some regions, land reclamation still takes place and these areas will require continual monitoring.

NDVI is an effective indicator of above-ground biomass and land cover changes (Stow et al., 2007), and the slope of NDVI has been used to monitor climate and vegetation cover changes (Stow et al., 2003, 2007; Ma et al., 2007; Du and Li, 2008; Olthof et al., 2008). In this study, we use NDVI to estimate vegetation cover change for assessing the ecological restoration effectiveness.

This paper aimed to investigate the effectiveness of ecological restoration projects on desertification process in Horqin Sandy Land. The effectiveness in different sand dune types was assessed separately. We sought to answer several questions, including: What were the effects of the ecological restoration projects over last ten years? Were the effects of desertification treatment in various sand dune types consistent? Did the restoration projects have similar effects on different regions? These questions have important implications for decision makers in future ecological restoration work.

## 2. Materials and methods

### 2.1. Study area

Tongliao is located in the transitional region between the Inner Mongolia Plateau and the Northeast Plain in China, and in the middle and lower Plain of West Liaohe River. It has an area of $5.95 \times 10^4$ $km^2$ located between 119°14′–123°43′E, and 42°15′–45°59′N (Fig. 1), and contains Huolinguole City, Jarud Banner, Kailu County, Tongliao City, Horqin Left Middle Banner, Horqin Left Back Banner, Hure Banner, and Naiman Banner (Fig. 1). In China, a banner is a small administrative region similar with county. The terrain is high in the southern and northern parts, low-lying and saddle-shaped in the central part. The West Liaohe River Basin is a sandy alluvial plain located in the central portion, covering 70.7% of the total area. It belongs to a typical semi-arid continental monsoon climate. Annual mean temperature is between 0 and 6 °C, and annual average precipitation is 350–400 mm.

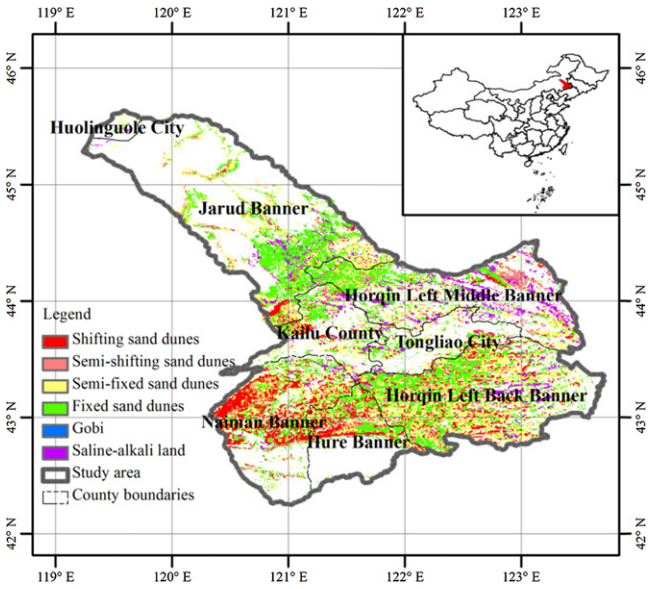


**Fig. 1.** The location of study area in China, and the spatial distribution of sandy land types according to the sand-covered desert classification map of China in 2000 with a scale of 1:100,000. There are six types of sandy lands existed there including shifting sand dunes, semi-shifting sand dunes, semi-fixed sand dunes, fixed sand dunes, gobi and saline-alkali land. (For interpretation of the references to color in this artwork, the reader is referred to the web version of the article.)

Tongliao City is the main body of Horqin Sandy Land, and almost half of the area is covered by sand dunes. Sand-covered land is mainly distributed in the north-central and south-central regions of Tongliao City, and partly in the northern regions (Fig. 1).

The main sand-covered land types include the fixed and semi-fixed sand dunes, which accounted for 35.71% and 33.40% of the entire sand dune area, respectively (see Table 1). Shifting dunes, had an area of 14.62%; the area covered by semi-shifting dunes and saline-alkali land was small. There were hardly Gobi desert areas.

### 2.2. Data

#### 2.2.1. SPOT VGT NDVI

SPOT VEGETATION 10-day Synthesis Archive (SPOT VGT-S10) products with a spatial resolution (1 km × 1 km) from 1999 to 2007 were used in the study. These data were compiled by merging 10-day segments (data strips) with a Maximum Value Compositing (MVC) method (Holben, 1986) for reducing some errors from cloud cover and large solar zenith angles (Stow et al., 2007). The data has been pre-processed by VEGETATION processing Centre of Flemish Institute for Technological Research, Vito of Belgium (Maisongrande et al., 2004). A series of processes such as atmospheric correction, radiometric correction, and geometric correction have been done to ensure data quality. SPOT VEGETATION data has been evaluated and widely used in many studies (Fraser and Li, 2002; Xiao et al., 2002; Stibig et al., 2007; Song et al., 2010).

The yearly mean normalized difference vegetation index (YMNDVI) was calculated through averaging monthly NDVI, which provides information about the vegetation condition on the land surface and the effectiveness of ecological restoration. The formula was calculated as follows,

$$YMNDVI = \frac{\sum_{i=1}^{12} MNDVI_i}{12} \quad (1)$$

where *MNDVI* means monthly maximum NDVI, which is calculated using MVC method by maximizing the three stages of data, $MNDVI = max\ (NDVI_1, NDVI_2, NDVI_3)$. $NDVI_1$, $NDVI_2$, and $NDVI_3$ are