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The protective effects of nebkhas on an oasis

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ABSTRACT

Oases are of great importance to the sustainable development of economies and societies in desert regions. Thus, it is important to understand how many oases have survived for hundreds and even thousands of years. Oases in Northwest China include nearly all of the types found across the world. Among these oases, the Minqin Oasis, surrounded by mobile sandy deserts, is a stereotypical natural oasis that has been developed for more than 2000 years, making it ideal for a case study. Our investigation indicates that the nebkhas belt at the fringe of the Minqin Oasis, which consists of three sub-belts semi-mobile, semi-fixed and fixed nebkhas from desert to the oasis, plays a key role in its stability. The fractional speed-up ratio (δ_s) of wind generally fell within the range of −0.15 to −0.55 below the height of 0.6 m. Above the height of 0.6 m, wind velocity in the semi-mobile nebkhas was 5–27% weaker with a maximum reduction of 65% in the other two sub-belts. When wind carrying sand and dust from the desert passes through each sub-belt, its velocity is weakened by vegetation and dunes, and almost all sand and dust is deposited in the nebkha belt incrementally by grain size, ranging from coarse to fine. As such, nebkhas serve as a protection belt and ensure the existence of oases.

1. Introduction

From the perspective of integrated physical geography, an oasis is a unique geographical unit with stable water supply, fertile soil, and suitable for the growth of plants; it can provide the ideal habitats and production space for human, and is clearly different from the landscape of the surrounding desert in arid area (Shen et al., 2001). In an oasis, stable water supplies depend on river or groundwater with water table no more than 15 m; soils are derived from river alluvium and aeolian fine sediments (Kocurek and Lancaster, 1999; Beveridge et al., 2006); vegetation is mainly composed of natural plants and crops. Oases occupy a small area but bear a disproportionate amount of economic and social developmental pressure in desert regions. Due to their unique landscape and important role in agricultural production, oases have become the focus of an increasing amount of research, and important progress has been made in many fields. For example, previous literature has focused mainly on the economical use of water and soil resources in an oasis (Chen and Zhan, 1995; Zhou, 1994; Misak et al., 1997; Shen et al., 2001), with the goals of maintaining vegetation stability and water-thermal equilibrium (Bornkamm, 1986; Abd El-Ghani, 1992; Jia and Ci, 2003; Ma et al., 2003), and on the impact of environmental change on oases (Zhang and Wang, 1994; Zhao et al., 2001; Pan and Chao, 2003; Zhang et al., 2003). These studies are important for guiding the use of natural resources in oases. However, due to increasing populations in oases, especially in developing countries, water and soil resources tend to be overused, and it is difficult to implement scientific guidelines for best water and land use into agricultural practice (Shen et al., 2001). For a natural oasis at the edge or inside of a moving sand desert, a population increase puts pressure on water and soil resources, making the oasis appear to be "moving" rather than vanishing (Desai and Nelson, 2005). Previous studies have reported that nebkhas at the fringe of an oasis are the primary line of defense to prevent blown sand from invading the oasis (Sun, 1995; Gao, 2003). However, this protective function of the nebkhas has not been explained in detail. Although many reports have described the morphology of nebkhas and the airflow field over an isolated nebkha (Arens, 1996; Tengberg and Chen, 1998; Nishimori and Tanaka, 2001), few studies have been conducted on the airflow field over randomly distributed nebkhas or nebkhas at the fringe of an oasis. In the arid zone of northwestern China,

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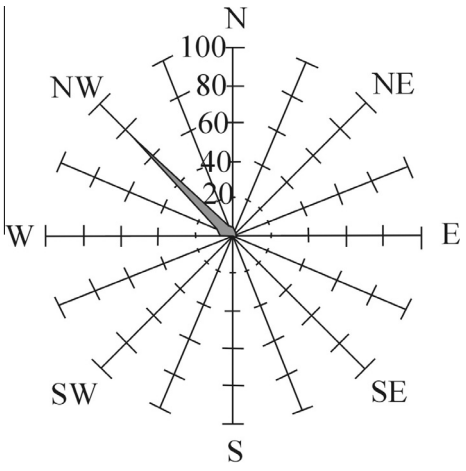

Fig. 1. Annual winds stronger than 6 m s^{-1}.

there are many different types of oases covering a total area of 86,419 km^2 (Shen et al., 2001). Thus, this region is ideal for studying the protective role of nebkhas at the fringe of an oasis.

Minqin Oasis is located downstream of the Shiyang River in the arid zone of northwest China and is surrounded by the Badan Jaran and Tengger Deserts, with a total area of 267 km^2. There used to be a large inland lake in the north and center of the Minqin Oasis (Feng, 1963), a large amount of fine sediments brought by the river and aeolian flux had deposited and formed claypan here (Shi et al., 1999). Due to climate change and irrigation consumption, the inland lake area has gradually been reduced, and finally dried up (Chen et al., 2001). Minqin Oasis is a typical developed natural oasis that has been used for more than 2000 years (Chen and Zhan, 1995). According to data from the Minqin meteorological station, the annual precipitation in the oasis is 113 mm, and the annual evaporation is 2644 mm. Minqin Oasis has persisted under conditions of increasing population (Li, 2003) and severe aridity. Is the vitality of the oasis related to the ring distribution of nebkhas of width 1–5 km at the fringe of the oasis? If so, understanding the protective role of the nebkha belt is of great importance for protecting oases in general. We chose to study the area abutted by the northwest nebkha belt of the Minqin Oasis adjacent to the Bardan Jaran Desert for two reasons First, among winds with velocities greater than 6 m s^{-1}, 97.9% blow between N and W, and 74.6% of these blow due NW (Fig. 1). The nebkha belt runs from NE to SW, which is perpendicular to the local prevailing NW wind direction. Second, the study area is the main route by which blown sand invades the Minqin Oasis and is a stereotypical region containing nebkhas including mobile dunes, semi-mobile dunes, semi-fixed dunes, and fixed dunes and cropland from desert to the oasis (Fig. 2). The objective of this study was to clarify how the nebkhas prevent the invasion of blown sand by investigating the airflow field over nebkhas and the size distribution of aeolian topsoil particles on nebkhas.

2. Methods

2.1. Investigation of nebkhas and vegetation

Nebkha morphology was investigated within an observation area falling between mobile dune and cropland (Fig. 3). According to the method proposed by Tengberg and Chen (1998), the obtained dimensions of the nebkhas include horizontal length (l) and width (w), vertical height (h), and a horizontal parameter (cl) equal to $(l + w)/2$. In addition, vegetation coverage (VC) of nebkhas was measured. For each site (1, 3, 4, 5, 6, 7 and 8), a 25 m × 25 m sample plot was selected and designated plot 1, plot 3, plot 4, plot 5, plot 6, plot 7, or plot 8, respectively. The plant species in each plot were identified, and the average height and coverage of each plant species were measured. The fixation degree of a dune is classified according to the VC, where $VC < 5\%$ for a mobile dune, $5\% < VC \leqslant 20\%$ for a semi-mobile dune, $20\% < VC \leqslant 50\%$ for a semi-fixed dune and $VC > 50\%$ for a fixed dune (Zhu, 1984). In this study, VC refers to the coverage of vertical projection by shrub branches because vegetation greening had not begun by the end of the investigation.

2.2. Wind profiling

To understand the impact of nebkhas on the wind field, we chose a section downwind from the mobile dunes inside the oasis and an observation area covered by typical Tangut Nitraria (*Nitrario tangutorum Bobr.*) nebkhas for observation. For the duration of the observation period, wind consistently originated from the NW direction. The observation section spanned from the mobile dunes to the cropland of the oasis. Site 1 was located on flat terrain within the mobile dunes and served as the reference observation site, sites 2–9 were located at tops of the dunes, and site 10 was located in the cropland inside the oasis (Fig. 3). The straight-line distance between sites 1 and 2 was 135 m. The typical Tangut

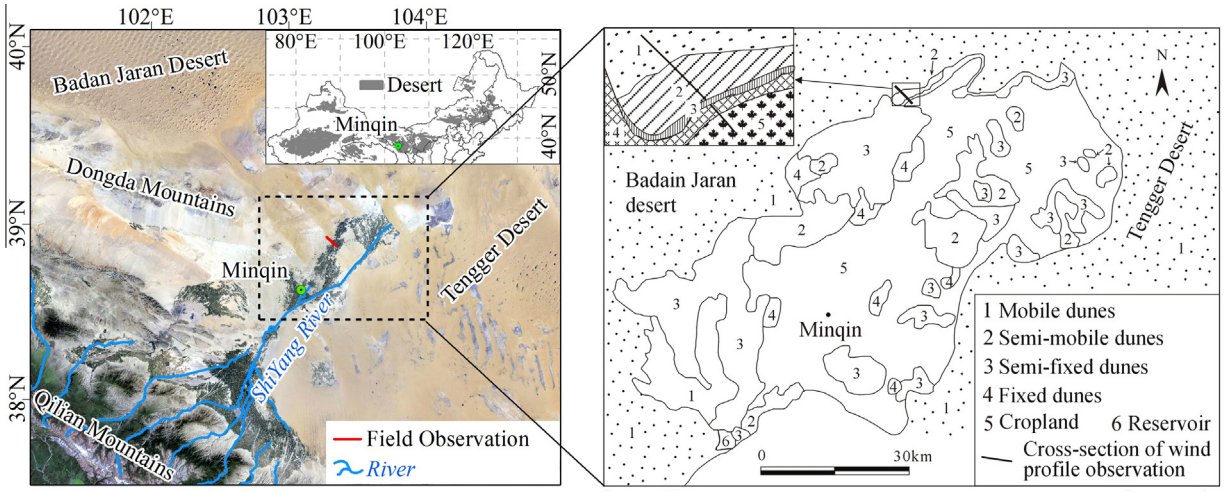

Fig. 2. The location of the Minqin Oasis and of the study area.