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GIS-assisted modelling of the spatial distribution of Qinghai spruce (*Picea crassifolia*) in the Qilian Mountains, northwestern China based on biophysical parameters

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Abstract

There has been an increasing use of predictive spatial distribution of main communities or dominant species at the landscape scale for ecological restoration planning, biodiversity conservation planning and regional management decisions in the Qilian Mountains, northwest China. Understanding the spatial distribution of dominant species at the regional scale is also essential for assessing the impacts of environmental change or human effects on vegetation distribution. Based on the spatial distribution of resource variables that correlate with or control plant distribution, this study focused on the prediction of Qinghai spruce (*Picea crassifolia*) distribution at the regional scale, i.e., where the extent of the prediction was within the biogeographic range of Qinghai spruce in the upper reach of Heihe River. The development of the predictive model in the study required the integration of geographical information system (GIS) with remote sensing (RS), spatial analytic and statistical tools. First, we selected the main resource variables such as mean July temperature, water and solar radiation. These variables were spatialized as functions of elevation and horizontal coordinates or as functions of aspect and slope via a GIS. Second, the niche spaces of Qinghai spruce were determined by incorporating the spatially-distributed resource variables with the current distribution of the species, which came from remote sensing data (Landsat TM image). The niche spaces defined then were extrapolated over the study area. Third, the distribution pattern was validated by field investigations. The study showed that the scope of mean July temperature ranged from 8.5 °C to 13.5 °C, average annual precipitation from 370 mm to 660 mm, the soil moisture index from 2.3 $m^3\,m^{-1}\,year^{-1}$ to 4.5 $m^3\,m^{-1}\,year^{-1}$and the shortwave radiation for an average July day from 3.8 $mm\,m^{-2}\,day^{-1}$ to 7.8 $mm\,m^{-2}\,day^{-1}$. The elevation range belonging to Qinghai spruce in Qilian Mountains was also determined according to the mean July temperature

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space occupied by the forest. The elevation occupied by Qinghai spruce was about from 2600 m to 3400 m. We found that the density of the species has higher value from 2650 m to 3100 m based on the field investigation, and from 3100 m the density decreased with elevation increase. The basal area of Qinghai spruce had the same change as the density. That is, the suitable niche of the species ranged from 2650 m to 3100 m.

Keywords: Qinghai spruce (*Picea crassifolia*); Resource variables; Niche space; Qilian Mountains; Geographic information systems and remote sensing

1. Introduction

Due to rapid growth of human population and ever increasing human demands on natural resources, the second half of the past century witnessed the most intensive and extensive human-induced ecological deteriorations (Foster et al., 1996), especially in arid and semiarid regions (Daily, 1995). The human-induced ecological deterioration not only threatens the economic future of human population at local and regional scales through reducing biospheric productivity, but also adversely impact functional processes of energy balance and water cycles at hemispheric and global scales through destroying the natural equilibrium of land-surface and atmosphere interactions. To restore the long-disturbed ecology and understand the magnitude of human impacts for developing sustainable economy (Cernusca et al., 1996; Davis and Goetz, 1990; Dymond and Johnson, 2002; Iverson et al., 1997), the ecological potential has to be realized first. The realization depends on our ability to spatially depict the resource variables determining ecological niches or habitat (Tappeiner et al., 1998; Dymond and Johnson, 2002; Hörsch, 2003). However, our ability is often constrained by the lack of adequate data for spatially depicting the variables (Hörsch et al., 2002). Consequently, landscape-scale models have been developed in many studies to predict the potential vegetation pattern in data-lacking areas, especially in mountainous areas (Iverson et al., 1997; Bolstad et al., 1998; Ostendorf and Reynolds, 1998; Tappeiner et al., 1998; Manies and Mladenoff, 2000; Münier et al., 2001; Dymond and Johnson, 2002; Pfeffer et al., 2003). In modelling efforts, three aprroaches have been adopted. The first approach is to relate vegetation structure and/or function to environment descriptors (del Barrio et al., 1997; Ostendorf and Reynolds, 1998; Liu, 2002; Pfeffer et al., 2003). This approach is limited by the fact that the developed models are often site-dependent, i.e., a model developed in one area cannot be applied to other areas. The second approach is based on known equilibrium states between climate and vegetation (Holdridge, 1947; Neilson et al., 1992; Prentice et al., 1992). The equilibrium approach is implicitly hemispheric and global scales in nature (Brovkin et al., 1997), but it was also used to predict vegetation patterns in landscape scales (Chang et al., 1993; Wang and Xiao, 1993; Liu, 2002). The disadvantage of the approach is that vegetation is defined as an aggregate type or association (e.g., Holdridge Bioclimatic Classification) without considering individual species responses (Leemans et al., 1996; Davis et al., 1998; Goudriaan et al., 1999). The third approach focuses on defining plant species–niche (or habitat) relationships that is transferable to other scales or sites (Franklin, 1995, 1998). Plant niche or habitat includes many biophysical variables, among which air temperature, soil water and solar radiation are reported to be the most important (Busing et al., 1993; Dymond and Johnson, 2002; Larcher, 1995). This study is designed first to search for the statistical relationships between spatially-interpolated resource variables (air temperature, soil water and solar radiation) and remotely-sensed distribution of the dominant species, Qinghai Spruce, in the central part of the Qilian Mountains where human-induced ecological deterioration is minimal (Wang et al., 2001). The statistically-established relationships are then to applied to other parts of the mountains within the Heihe River Basin, where natural vegetation has been severely disturbed, to predict the potential patterns of the Qinghai Spruce distribution.

The Heihe River Basin, the second largest inland river basin in the arid region of northwestern China,