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Factors affecting sand dune mobility on the Navajo Nation, Arizona, U.S.A.

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Introduction

The interaction among natural and invasive vegetation species, dune mobility, and changes in soil moisture conditions are currently under examination on the 71,000 km^2 Navajo Nation. Sand-dune deposits that cover one-third of this area are being assessed for potential sand dune mobility by combining surficial mapping with data gathered on rainfall, temperature, and vegetation cover and its characteristics. Meteorological data are used to calculate the ratio of precipitation to potential evapotranspiration (P/PE) that has been shown to be a critical factor controlling dune mobility, because of its direct link to the amount of stabilizing vegetation (Lancaster and Helm, 2000; Muhs and Holliday, 1995; Muhs and Maat, 1993). Thresholds in P/PE for changes in dune mobility are based on observations by Muhs and Holiday (1995), with transitions from mostly stable to mostly active at P/PE = 0.315, and from mostly active to fully active at P/PE = 0.125. This study has classified Navajo Nation dune fields as active or stabilized, and the degree of dune mobility has been compared to local conditions of calculated P/PE. New findings in this study generally corroborate previous work, but suggest that certain vegetation species may alter these thresholds and exert an overriding influence on dune mobility.

Discussion and Results

Calculated annual values of P/PE of data, from 40 meteorological stations within and adjacent to the Navajo Nation, exhibit a wide range of values that reflect distinct local variations in climate as well as temporal variations in soil moisture. Based on these calculations, and the known climatic variability of the past 50 years, sand dunes on the Navajo Nation exist under meteorological conditions that promote the entire spectrum of dune mobility, from mostly stable, mostly active, to fully active during periods of drought. Arid regions within the Navajo Nation have consistently low P/PE, with median values for areas such as Monument Valley as low as 0.145, indicating that dunes in these areas are “normally” on the threshold of becoming fully active. (P/PE values for drought years in these regions are typically from 0.07 to 0.10, well below the threshold of 0.125 for fully active dunes.) In contrast, Betatakin, in the western Navajo uplands has a median P/PE of 0.487, indicating that this region typically has enough moisture for dunes to remain fully stable.

Work to date has shown that areas with active and largely active sand dunes generally have a P/PE < 0.3, corroborating work of Muhs and Holliday (1995). However, dunes that are covered with native vegetation and stable are also found in these areas despite low soil moisture. In addition, mostly active dunes in the areas of moderate P/PE (0.25-0.35) are closely associated with Russian Thistle (tumbleweed), an invasive annual that requires minimal moisture to germinate. Active to mostly active dunes associated with this type of vegetation have been mapped in areas that differ significantly in calculated soil moisture across the Navajo Nation. The relation of dune mobility to vegetation may be altered due to the presence of this invasive plant, which is an annual designed to detach and blow away during dry, windy periods.

An examination of temporal variation in P/PE for areas on the Navajo Nation indicate a trend of decreasing soil moisture balance starting in 1988, with P/PE ratios in the eastern Navajo Nation that are below 0.3 for the first time in 50 years. These data suggest a change to warmer and drier conditions for the southern Colorado Plateau, beginning in 1988 and continuing to the present. Interviews with elderly Navajo residents who live in areas with active dunes near Tuba City and Chinle, Arizona, indicate that dunes in these areas have become more active in recent years. Dunes at a local home site in the Tuba City area have become mobile in the last five years, covering corrals and collapsing a house. Significant changes in sand migration were observed during two drought years: 1996 and 1999. However, an earlier, more significant dry period in 1988-1990 did not result in similar changes in mobility. Possible explanations for increased dune activity in years of less significant drought are 1) recent drought years are part a continuation of drier conditions, whereas the earliest significant drought years (1988-1990) were preceded by wetter conditions, and 2) the recent addition of Russian Thistle at the Tuba City site may have contributed to the rapid change in dune mobility during dry periods. Because Russian Thistle invades areas that are disturbed by human activities, land use factors may compound changes in dune stability that occur as a result of climatic variation and alter the ability of these areas to become stabilized by native vegetation during periods of increased moisture.

References

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