CHAPTER 4

DESERTIFICATION IN AN ARID SHRUBLAND IN THE SOUTHWESTERN UNITED STATES:

Process Modelling and Validation

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1. Abstract

In the Mojave Desert of the southwestern U.S. human destruction of soil crusts and removal of vegetation have led to progressive, expanding degradation of adjacent arid shrublands. Aeolian mobilisation of dust, sand and litter triggered by anthropogenic disturbance contributes to the destruction of islands of fertility in adjacent areas by killing shrubs through burial and abrasion. This interrupts nutrient-accumulation processes and allows the loss of soil resources by abiotic transport. Thus the processes of degradation spread across the landscape driven largely by abiotic processes.

Soil chemical analyses and remote sensing observations presented here are designed to test a model hypothesis of degradation of arid shrublands. Nutrient and non-nutrient chemical species in the soil act as tracers of material transport and provide clues as to the nature of progressive anthropogenic degradation in arid shrublands. Remote sensing yields information about short- and long-term effects on the landscape as well as important constraints on the magnitude of degradation. Field, chemical and remote sensing observations argue for an extension of recent definitions and models of desertification to include the loss of islands of fertility in established shrublands. This extended model places arid shrublands in a continuum of physical and ecological processes and ecosystems that links semiarid grasslands with Sahara-like hyperarid barren lands.

2. Introduction

The Earth's expanding population is pressing into previously sparsely-inhabited regions. As a result the world's drylands, comprising nearly a third of the total land surface, are coming under increasing land use pressures. Despite their low vegetative productivity, these lands are not barren. Rather, they consist of fragile ecosystems vulnerable to anthropogenic disturbance in which degradation is often irremediable on human timescales. Any successful management plan or attempt at remediation must be firmly rooted in an understanding of natural arid zone processes and the way in which they are perturbed by human activities.

Observations in the deserts of the southwestern U.S. and elsewhere indicate that human

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destruction of soil crusts and removal of vegetation lead to a progressive, expanding degradation (Campbell 1972; Bowden *et al.* 1974; Wilshire 1980; Fryrear 1981; Hyers and Marcus 1981; Khalaf and Al-Ajmi 1993; Spitzer 1993; Ray 1995; Bach 1998). Indirect disturbance of arid lands adjacent to areas of direct disturbance can extend far beyond those initially disturbed. Severe financial and societal consequences can result including property damage, increased health and safety hazards, and decreased agricultural productivity (Clements *et al.* 1963; Bowden *et al.* 1974; Fryrear 1981; Hyers and Marcus 1981; Leathers 1981; Bach 1998).

The purpose of this study is to present soil chemical analyses and remote sensing observations which are designed to test the model hypothesis presented here. Chemical species are used to trace material transport from two severely disturbed sites in the American Southwest, and to probe the loss of N and P through dust emission. Remote sensing data provide temporal and spatial information about the extent of indirect land degradation. An integrative landscape process model of arid shrubland degradation is developed in which aeolian transport of material is the primary mechanism of degradation of arid shrublands.

3. Model Hypothesis and Approach

The model hypothesis to be tested explains the progressive devegetation of areas adjacent to sites of direct disturbance and destruction of islands of fertility in these areas. The inferred sequence can be visualised as:

(1) mobilisation by wind of dust and plant litter, depleting the soils of nutrients in areas of direct disturbance;
(2) mechanical damage to and burial of plants by saltating sand in adjacent downwind areas;
(3) reduction of vegetation cover in adjacent areas, leading to an expanding area in which wind removes dust and litter material, depleting the soils of nutrients;
(4) dune formation in adjacent areas, which decreases near-surface water availability for young plants, increases temperature and albedo, and buries ecologically important cryptobiotic crust and other bacterial communities, and
(5) reduction of effective soil moisture and depletion of soil nutrients in areas of direct and indirect disturbance.

According to the model hypothesis, aeolian mobilisation of dust, sand and litter triggered by anthropogenic disturbance contributes to the destruction of islands of fertility by killing shrubs through burial and abrasion. Sand blown from areas of direct disturbance may cover areas downwind several times the size of the initial disturbance. This interrupts nutrient accumulation processes and allows the loss of soil resources by abiotic transport processes. The resulting reduction of vegetation cover, in turn, increases runoff and wind transport, reduces latent heat flux through evapotranspiration, and results in increased surface temperatures. These feedbacks can result in continuing reduction of vegetation cover and