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Formation of Soil-Vegetation Patterns

Marcel Meinders and Nico van Breemen

Abstract

Vegetation patterns often resemble the pattern of the geological substratum. In some cases, however, correlations between soils and vegetation in patterned distributions appear to have developed in an initial homogeneous landscape. Here, soil-vegetation feedback processes appear to be responsible for the development of such patterns. In this paper, we discuss various systems and their feedbacks that may lead to formation of patterns. In semi-arid systems, soil-water-vegetation feedbacks might lead to Turing-like self-organized pattern formation, as indicated by previously published models. In other cases of patterned soil-vegetation systems, feedback mechanisms may be involved that locally enhance growth of one species and inhibit that of other species. These interactions do not fulfill the criteria of Turing for pattern formation. However, such strong competitive interactions may lead to patterned vegetation as is shown by a study of a competitive model including spreading of the species. This pattern is not due to self-organization but depends on the initial boundary conditions.

Introduction

Many plant species are confined to sites with more or less particular soil properties. This reflects a better ability of such species to cope with certain adverse soil conditions, or to better use available soil resources, than competing species in the vicinity. As a result, spatial soil heterogeneity is almost invariably associated with differences in vegetation cover. Such heterogeneity is in fact the basis of most soil surveys using aerial photographs or other remotely sensed data. Usually, the observed vegetation pattern resembles the pattern of the geological substratum. An example is given in Figure 11.1, where sparsely vegetated sandy point bar deposits alternate with more densely vegetated clayey depressions in a recent floodplain, bordered by high forest on higher land with older, better-drained soils.

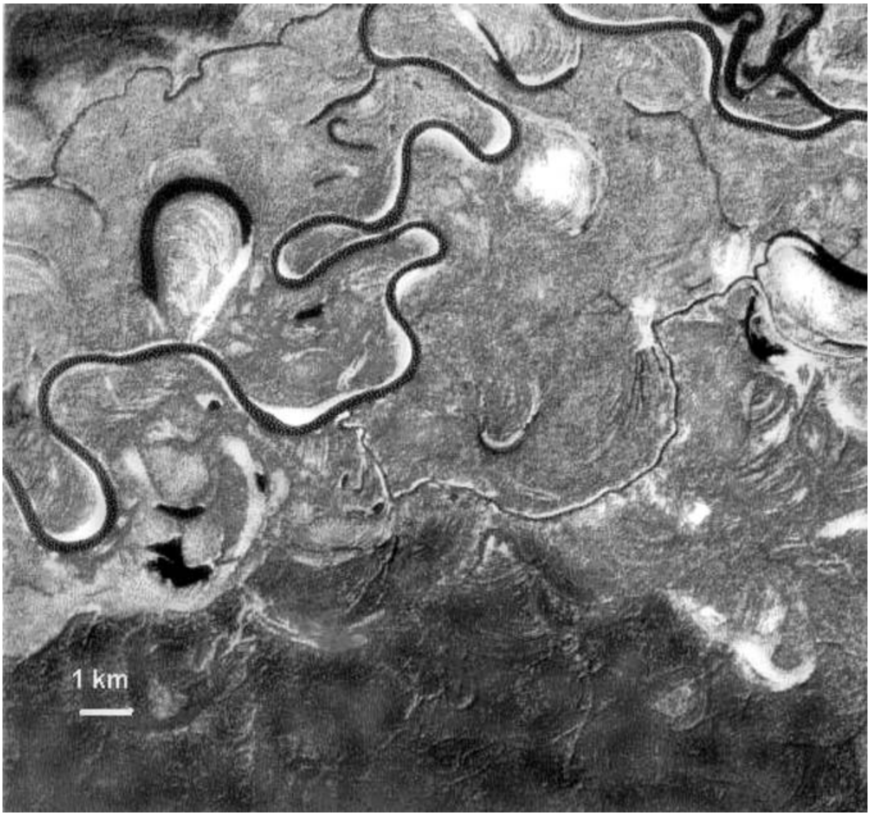

FIGURE 11.1. Satellite image from a river floodplain in Amazonia, Brazil (courtesy W.G. Sombroek, personal communication). Different grey scales show variable soil and hydrological conditions, as reflected by differences in plant cover under pristine conditions. In the active floodplain, sparsely vegetated sandy point bar deposits (light grey) alternate with more clayey filled depressions with a more luxuriant vegetation (medium grey) and open oxbow lakes (black). The high forest on either side of the active floodplain (dark grey) grows on older, better drained soils. Such patterns in plant cover that mirror underlying soil differences due to geological processes have traditionally been used in soil survey. Courtesy W. G. Sombruek.

Sometimes, however, heterogeneity in vegetation cover does not, or only partially, reflects differences in soil parent material (Figure 11.2). In such cases, ecosystem processes within an initially more or less homogenous landscape must have been responsible for the observed patterns. In this paper, we will investigate the hypothesis that soil-vegetation feedback processes can be responsible for such pattern formation.

This hypothesis builds on the well-known phenomenon that soil properties influence vegetation growth, and vegetation and associated soil-dwelling biota influence many chemical and physical soil properties (Hole