How Land Use Determines Vegetation: Evidence from a New England Sand Plain

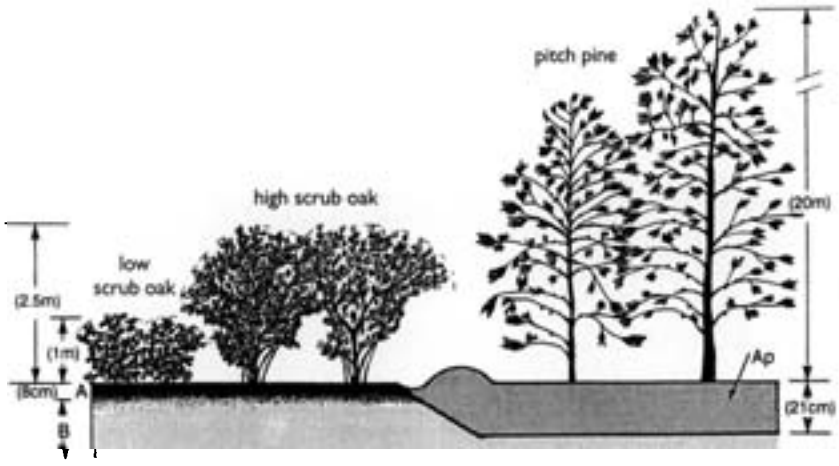
Glenn Motzkin and David R. Foster

Human activity exerts long-lasting impacts on natural ecosystems, and because today's forest composition reflects past land uses as well as natural phenomena, knowledge of land-use history and an understanding of its effects are integral to ecological study and critical for conservation planning. However, attempts to determine the relative contribution of land use vs. physical factors in controlling vegetation patterns have consistently been confounded by the strong correlation between past land use and original site conditions.

To evaluate the effects of historical land use, researchers at the Harvard Forest studied pitch pine-scrub oak communities on a broad sand plain in the Connecticut River valley of Massachusetts, a site that is unusually homogenous in topography, drainage, and soil texture. Such homogeneity enabled the researchers to detect the effects of differing land-use on the structure and composition of the vegetation. Also motivating the study was the rarity of pitch pine-scrub oak communities. They support several rare plant and animal species but have been substantially degraded by industrial, commercial, and residential development, and are therefore priorities for conservation throughout the Northeast.

The paleoecological record of the study area—1,900 acres on a flat outwash delta composed primarily of sand and gravel—suggests that pre-European fires were common, some of them, perhaps, ignited by a large regional Indian population. Like other sand plains in the region, the area was used for wood products from the eighteenth to the mid-nineteenth century. In the early nineteenth century, the Reverend Timothy Dwight, author of *Travels in New England and New York* (1821), described the Montague Plain and surrounding areas as "an extensive yellow pine plain covered with a lean, miserable soil." Nonetheless, 82 percent of it was subsequently plowed for crops before being abandoned in the early twentieth century. Agriculture had a major impact on vegetation but a relatively minor long-term effect on physical and chemical soil properties on this site. For instance, although visually striking, the difference between plowed and unplowed soil horizons is primarily one of color, the result of organic matter being redistributed within the soil by plowing.

Agricultural fields on Montague Plain were abandoned and allowed to reforest at least fifty years ago—some more than one hundred years ago—and yet the plant composition remains very different on areas that were once plowed compared to those that were never plowed. Some species are just as common today on formerly plowed areas as on unplowed sites. However, several species, most notably pitch pine *(Pinus rigida)* and gray birch *(Betula populifolia)*, are much more common on plowed sites. Of particular interest is a group of species that is characteristic of sand plain habitats and is common on unplowed portions of Montague Plain, but that has not successfully re-colonized former agricultural lands even though they were abandoned more than half a century ago. This group includes some familiar species, such as black huckleberry *(Gaylussacia baccata)*, wintergreen *(Gaultheria procumbens)*, blueberries *(Vaccinium* spp.*)*. Intensive soil and population analyses suggest that the failure of these species to re-colonize these sites does not result from plowing; instead, it appears that successful sexual reproduction is rather infrequent in these species. Their rates of vegetative spread are so slow that even one hundred years is not long enough for re-colonization.



Cross-sectional diagram across the major land-use, vegetation, and soils boundary at the Montague sand plain. An unplowed site is on the left, a plowed site on the right. Even after a century of forest growth, the soils on plowed sites exhibit a deep and light-colored A horizon, sharply separated from the underlying B horizon.

Fire has been important on the Montague Plain: high charcoal-to-pollen ratios in the paleoecological record, documentation of many large fires during this century, and field evidence of fire in 83 percent of the research plots testify to that. However, fire does not appear to be the primary determinant of vegetation patterns on Montague Plain. Rather, fire is apparently important within a pattern of species associations that is largely controlled by prior land use. For instance, pitch pine requires exposed mineral soil and open canopy conditions for successful establishment, conditions that may be met through physical disturbance such as plowing or severe fire. Because few recent fires have been severe enough to create these conditions, nearly all extant pitch pine stands are located on abandoned plowed fields. After pitch pine became established, fire contributed to its dominance on old fields.

The high frequency of extensive fires early in this century (when most stands were becoming established) probably favored pitch pine, which produces seed at a much younger age than hardwoods or white pine. Young white pine is more susceptible to fire than pitch pine and lacks the ability to resprout, an ability that is shared by pitch pine and associated hardwood species. In the absence of fire, hardwoods and especially white pine increase in number, whereas frequent light fires limit white pine and increase the understory of hardwood sprouts without disturbing the pitch pine overstory.

On unplowed sites, on the other hand, the vegetation structure varies from closed canopy hardwood-huckleberry stands to dense scrub oak thickets. We suspect that on these sites repeated cutting and burning converted formerly forested areas into shrublands: fire promotes the stability of scrub oak stands by encouraging vigorous sprouting and by removing developing tree canopies. In the absence of fire, however, hardwood trees slowly become reestablished in scrub oak stands to form an open forest canopy. Since scrub oak is intolerant of shade, this canopy eventually reduces its numbers. The continuum from scrub oak thickets to hardwood forests on unplowed sites is therefore believed to result both from fire and cutting history.

In all of these examples, a distinction remains between the vegetation of plowed sites and that of unplowed sites. We have therefore concluded that modern vegetation patterns on Montague Plain are the result of complex disturbance histories, with fire serving to modify the species assemblages that originally developed after land use was discontinued. In other words, the interactions of human, physical, and biotic factors have resulted in a remarkably heterogeneous landscape on a site with homogeneous soils.

In view of the heterogeneity of vegetation and the equally variable natural disturbance patterns in the area, conservation efforts might best focus on long-term protection of the entire landscape, rather than simply protecting the portions that currently support uncommon species. Only in this way will long-term protection of this complex, dynamic system be ensured.

Glenn Motzkin is a plant ecologist at the Harvard Forest, where David Foster is the director. Their research is reported in full in "Controlling Site to Evaluate History: Vegetation Patterns of a New England Sand Plain" by Glenn Motzkin, David Foster, Arthur Allen, Jonathan Harrod, and Richard Boone, and published in *Ecological Monographs* (1996) 66(3): 345–365.