A Striking Profile - Surveying soils Knowledge in Restoration Science

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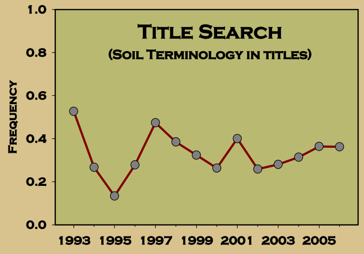
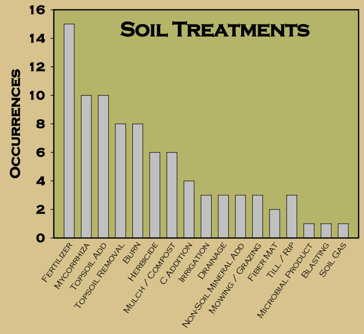
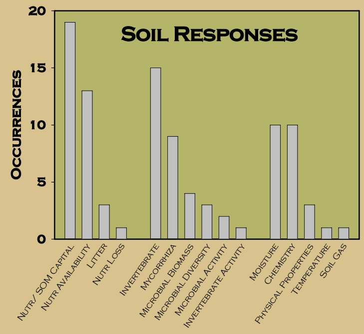
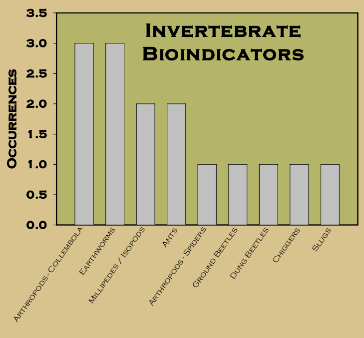
Soils knowledge occupies a central role in restoration science. If restoration represents an "acid test" for ecology, what is the pH (and relevance) of soils knowledge to restoration pursuits? To address this question, we characterized how soils information appears in peer-reviewed restoration literature. Our survey was based on manipulative experiments and case studies published in the journal *Restoration Ecology*. First, a broad overview found that specific soils terminology appeared in the titles of a third of all empirical restoration studies published in the journal. Then, to categorize how soils knowledge benefits restoration, we sorted information by restoration 1) objectives, 2) site conditions, 3) soil treatments and 4) soil responses. Our review evaluated articles from one-quarter (one issue per volume; n ~ 150 articles) of studies published since the inception of *Restoration Ecology* in 1993.



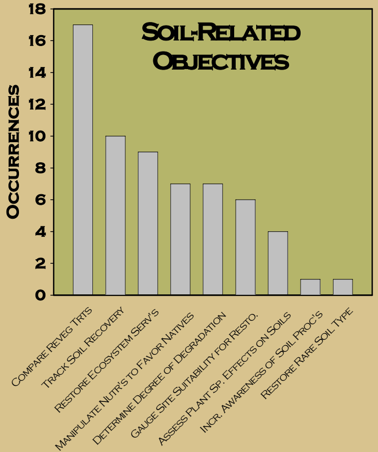






Restoration Objectives

Soil-related objectives most often targeted the influence of soil manipulations on revegetation. Assessing site degradation and tracking recovery of nutrient capital or biogeochemical processes following restoration activities were also common. Concerns regarding the challenge of achieving nutrient conditions that favor native species but preclude dominance by weedy or non-native invasive species motivated many studies. This goal characterized restoration initiating both from infertile (e.g., mine spoils) and nutrient enriched land (e.g., former agricultural fields).



Site Conditions

A variety of edaphic information was commonly included as part of pre-restoration site assessment. Candidate and reference site comparisons were a typical index of soil degradation used both to identify obstacles to restoration and to define baseline conditions for monitoring project success. The most frequent form of soil degradation was nutrient enrichment of former agricultural soils and other sites affected by nutrient loads in atmospheric deposition, runoff or groundwater.

Soil Treatments

Restoration science frequently assesses soil amendments aimed at enhancing establishment success and plant growth. Inorganic fertilizer was the most prevalent soil treatment both at the field and individual plant scales; mulch and compost types were also used to increase soil fertility. Mycorrhizal inoculation of seedlings via spore or topsoil additions was the second-most popular soil amendment. Salvage, storage and application of topsoil to field studies were typical for revegetating mine lands, road corridors and burned areas. Soil stripping and sod cutting were practiced to treat nutrient-enriched agricultural soils and eutrophied wetlands. Carbon addition, either as sawdust and sucrose, was employed to reduce plant available soil nitrogen and favor native species. Prescribed burning, herbicide application and grazing were practices that were frequently conducted prior to establishing experimental trials, but were rarely assessed experimentally; these practices are known to alter soil processes and may influence study results.

Edaphic Responses

Total soil nitrogen and organic matter stocks, followed by indices of plant nutrient availability were measured most frequently in *Restoration Ecology* articles. A wide variety of Invertebrate soil fauna were utilized as bioindicators to assess recovery of aboveground structure and habitat. In contrast, edaphic change associated with faunal activity was scarce. Response of soil chemistry, water relations, microbial activity and fungal symbionts were equally-well represented.

Digging Deeper ...

Restoration Science relies on a broad variety of soils knowledge. Most reported soil attributes responded to ecosystem changes that occurred within a few years of initiating restoration treatments; a limited number of studies documented pedogenic development (i.e. horizon formation) in response to SOM and nutrient accumulation, chemical leaching and hydrologic fluctuations that occurred over decades.

Research conclusions often invoked unmeasured soil responses to restoration treatments, climate fluctuation, historic disturbance (e.g.,herbivory, tillage) or species effects (e.g., shrub, N-fixer encroachment) to explain findings that could not be attributed to experimental treatments. Explicit consideration of previous land-use and the consequences of herbicides, fire and grazing on soil processes should lead to more effective restoration efforts.

The resolution of soil classification included in many studies (i.e., USDA Soil Taxonomy soil series) may overlook important fine-scale spatial variability. Greater detail regarding soil heterogeneity, such as that occurring along topographic gradients and across habitat boundaries, can assist in the design of restored ecosystems that closely mimic the belowground function and structure of reference areas.

Restoration Science currently presents soil knowledge in a piecemeal fashion, fragmented along disciplinary lines (e.g. nutrient, biotic, hydrologic). Researchers aiming to promote the relevance of soil science to ecosystem Restoration must highlight cases where integrated assessment of below-ground processes (e.g. spatially or disciplinarily) yielded practical knowledge that resulted in successful restoration manipulations or monitoring.