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# Ecological engineering principles in a restoration curriculum

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ABSTRACT

University restoration ecology courses are predominantly offered in departments of biology, forestry, ecology, landscape architecture, and environmental science, and may enroll students who do not have a strong math or engineering background. Three restoration courses at the University of Washington have been strengthened by adding elements of ecological engineering to their lectures and problem sections. Restoration implies the management of natural resources, and there are a number of restoration problems for which better solutions are achieved when the restorer has a good grasp of numerical and engineering methods We have incorporated team activity, problem solving, estimating, and project management elements into three senior level restoration courses that present complex problems to students. The use of ecological engineering methods has given greater authenticity to the classes, and has sparked real student interest in the use of such methods to solve problems in a discipline that has traditionally been more focused on the biology and ecology of ecosystems.



## 1. Introduction

"Ecosystem restoration, as it is currently practiced throughout the world, is done by practitioners who have little experience in design, and by engineers who do not appreciate the capabilities of ecosystems to self-design" (Mitsch, 2014) In his 2014 article, William Mitsch examined large restoration projects that had not all been successes. He concluded that "for ecological restoration to become more accepted and predictable, the fields of ecological engineering and ecosystem restoration need to be better integrated and more transdisciplinary in universities." In this paper we present an account of an attempt to reach this goal by incorporating math and engineering ideas and methods into an established restoration program.

Students who study restoration are often from a natural sciences background and engineering students generally are confronted by few curricular opportunities beyond engineering courses. The Society for Ecological Restoration website (http://www.ser.org) lists 40 academic restoration programs in the United States that are offered at colleges and universities. Of those 40, the programs at SUNY-College of Environmental Science and Forestry and the Biological Systems Engineering program at the University of Nebraska feature both a variety of restoration ecology and ecological engineering courses and allow some flexibility in selecting electives from either field. At the University of Washington we have tried to create a restoration option that encourages restoration students to develop math and engineering skills, and allows engineering students to immerse themselves in problems of natural ecosystem management. The restoration ecology curriculum at the University of Washington is realized as a 25 credit undergraduate minor and a 25 credit graduate certificate. Most students in the masters of environmental horticulture (MEH) program consider themselves "restoration students" and exceed the certificate requirements. Most of the students who pursue the undergraduate minor are matriculated in the environmental science or environmental studies degree programs.

The portfolio of restoration ecology courses at the University of Washington has been growing in size and popularity since an "introduction to restoration" course was initiated in 1993. In response to increasing student interest in restoration, a hands-on, academic year-long capstone course was started in 1999 and remains exceptionally popular with students and the local community. Capstone classes are culminating courses that build upon the course work that graduating seniors have been exposed to during their academic careers (Todd et al., 1995) and can attract students with many different backgrounds. The restoration capstone course attracted (and continues to attract) an academically diverse set of well-motivated students, but the faculty observed a lack of basic math, science and problem-solving skills in many of them even as these students persisted and finished the course. In response, a course called restoration design was introduced in 2007 and restoration problem-solving was introduced in 2012. The new courses were designed so that math, engineering methods and conceptual problem-solving and design were used to achieve solu-

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tions to typical restoration or landscape management problems. The courses are offered in the Environmental Science and Resource Management (ESRM) program of the School of Environmental and Forest Sciences (SEFS), hence the courses have an ESRM prefix.

In addition to the introduction, problem-solving, design, and capstone courses, the portfolio of restoration ecology courses includes plant propagation, native plant production, biological invasions, and restoration in North American ecosystems. Courses in statistics, ecophysiology, hydrology, fire ecology, plant identification and other fields support the restoration specialization.

## 2. Desirable skills for restoration designers and practitioners

It has been asserted that ecological restoration is not a single scientific or applied discipline. It is a practice that requires not only the application of a number of different skillsets, but often necessitates the assembly of a team of well-trained specialists (Clewell et al., 2005). For this reason, successful restoration requires the restorer to master a number of skills or to have the ability to communicate with a team of specialists. Some of the more important areas of expertise that a practitioner might need to be familiar with are listed below. We have tried to give students an exposure to problems that must be solved in these areas. To do this we present them with numerical and conceptual problems that are critical for successful restoration in different kinds of situations.

### *2.1. Botany, plant ecology*

In order to restore successfully, one must know the difference between native and invasive plants, and must also know how prescribed plantings will do when confronted with different abiotic conditions or by competition with other species (Harker et al., 1999).

### *2.2. Freshwater and estuarine ecology*

Wetlands are not simply terrestrial systems with water added. They have unique species and a different soil biogeochemistry. Hydroperiods vary, and have an impact on vegetation structure. Wetlands react with the matrix in which they occur in different ways. Coastal systems have varying tidal and salinity patterns (Mitsch and Gosselink, 2007).

### *2.3. Systems ecology and ecological modelling*

Natural systems provide ecosystem services (hydrologic, water quality, habitat and others), and at the same time are driven by complex biotic and abiotic forces. Keeping the biotic systems within an acceptable range of variation is an intrinsic restoration goal (Brinson, 1993).

### *2.4. Drainage, hydrology*

Landscapes produce runoff or contribute to the water cycle in other ways. Sub-watersheds provide meaningful management units for restoration planning. Wetlands are dependent on adequate runoff and on soil conditions (Bedient et al., 2012).

### *2.5. Earthwork, wetland construction, hydraulics*

If grades are altered to either move water or store it, earthwork is required. This choice is common in wetland construction (Bureau of Reclamation, 2005). In river restoration, a basic knowledge of channel flows allows the restorer to create new stream channels that will flood and allow the stream to interact with its floodplain.

### *2.6. Estimating and budgeting*

Restoration projects require work and the expenditure of money or time or both. (Peurifoy et al., 2010). Most projects require the development of cost estimates before they can be bid, or before a grant proposal can be written.

### *2.7. Project management*

Projects are usually expected to be done within a certain time period and for a particular amount of money. Even activities that are entirely volunteer-driven depend upon the adequate matching of work to task. Environmental regulations often allow certain kinds of work to occur only during an acceptable window of time, and successfully working with this constraint is one of the consequences of successful project management (Gido and Clements, 2014; Nunnally, 2011; Peurifoy et al., 2010; Turner, 2014).

### *2.8. Solar management, micro-climate, and ecophysiology*

In all landscapes there is interplay among regional climate, topographic location, canopy structure, soil water and restoration plants (USDOE, 2000). These factors have an impact on human perception of a site, but also on the physiological responses of plant material that is used in restoration projects.

### *2.9. Sustainable site management*

Sustainable sites are the landscape equivalent of the LEEDs criteria for building functioning (Sustainable Sites Initiative, 2014). In urban areas there is a definite benefit in energy and public health that can be obtained by using sustainable restoration techniques and by critically evaluating options.

### *2.10. Sustainable agriculture*

Agricultural methods impact the cost of products, public health (due to materials used on the farm), and the public perception of the desirability of farm products. There is a real intersection between agriculture and natural systems (Robins et al., 2001). Sustainable practices can increase the presence of natural pollinators and beneficial insects, can decrease the amount of pollutants in runoff, and can decrease the use of water.

### *2.11. Solid waste, pollutant and wastewater management*

Wastewater management is a traditional focus of ecological engineering. Restoration projects are often sited on landfills and brownfields. Understanding the interactions between vegetation and pollutants is an important component of restoration in such degraded systems (Mitsch and Jorgensen, 2004).

### *2.12. Slope stabilization and erosion control*

Vegetation adds stability to sites, even if it is just to reduce the impact of raindrops on the movement of sediment. Restoration sites are often, by their very nature, disturbed and thus require stabilization and protection from erosion. There are many bioengineering techniques that are valuable in this context (Gray and Sotir, 1996; Morgan and Rickson, 1995).