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"Biology 4920G: Benefits of Ecological Restoration Techniques"

Umama Karim
Western University, ukarim2@uwo.ca

Olivia Tran
Western, University, otran5@uwo.ca

Winston Herold
Western University, wherold@uwo.ca

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Herold J.R. Winston, Karim Umama, Tran Olivia
University of Western Ontario

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Introduction

Human activity has resulted in tremendous habitat degradation and loss throughout Canada. In Ontario, agriculture and urbanization are some of the leading causes of natural habitat loss. The decrease in established systems such as forests, wetlands, and tallgrass prairie has pushed a large variety of species to or near extinction, reducing the species diversity and richness necessary for providing ecosystem services and stability. These effects are further exacerbated by climate change and its associated ecological and hydrological effects. Ecological restoration seeks to reconstruct habitats and restore them to their previous structure to maintain ecosystem services such as nutrient cycling, soil health, and hydrology. In this essay, we will examine three different restoration project types and evaluate their effects on soil health. Soil health may be defined by soil aggregate structure, organic matter content, water retention properties, and microbial community composition.

Restoration Approach #1: Tree Planting

Tree planting is an effective restoration approach that improves long-term environmental health and is dependent on external circumstances. Tree planting at the highest level begins with theoretical work and statistical analysis of ecosystems being restored. These endeavours incorporate extensive research to acquire the necessary biological knowledge to determine which tree species are most likely to reach complete growth[1]. This is necessary before tree planting because the selection of improper trees could diminish the environmental supply of nitrogen and reduce essential resources used by neighbouring organisms[1]. To avoid potential risks that trees could impose on other established species, it's important to take biological data from the environment and understand interactions between species that share ecosystems. Increasing tree abundance is important to accelerate the productivity of nitrogen that is cycled between the soil, organisms and their environment. Trees take up nitrogen from the soil and use this raw organic material to perform nitrogen fixation which facilitates their growth and reproduction. The majority of taken up nitrogen, however, is returned to the soil and environment which helps stabilize nitrogen cycling and support ecosystems[1]. Environmental nitrogen cycling is also effective in removing threatening chemicals and preventing dryness by constantly renewing the soil's organic material. This ensures that soil remains fresh, and that nitrogen quality remains high[1].

The growth of trees post-planting is dependent on external factors and the process is much longer than other restoration techniques. Ideal weather conditions, soil health, toxicity, native organisms, and invasives all dictate the pace at which growth occurs[2]. However, compared to other restoration approaches it is also much safer and more reliable in preserving other organisms and the environment. Planted trees minimize the physical stress on ecosystems, and in most scenarios will not be threatening to the health of other organism[2]. Additionally, chemical products and growth hormones should not be required for successful tree planting if the plants are properly monitored and supplied with natural nutrients consistently[3]. Trees are a multi-viable restoration resource because there is a large diversity of trees that can be used for tree planting. Some trees can only be reproductively successful under limited environmental conditions, while others are adaptable and effectively respond to environmental changes[3]. This is important for restoration because although scientists can predict environmental trends, the evolution of landscapes is not always consistent. Plants that can survive under non-predictable changes help ensure the long-term success of tree planting restoration projects.

New trees can be implemented through two methods being seeding and transplanting. Long term restoration projects with smaller budgets prioritize seeding and are most suitable when the goal is to maximize volume. However, transplanting is more suitable for projects with higher budgets where very low-quality environments are being restored. Restoration via transplanting is most effective for ecosystems under high environmental stress and sensitivity. These ecosystems are unfavourable for seedlings because they are unequipped to support plants through their juvenile growth phase[4]. However, transplanted plants have a greater chance of reaching adulthood since their juvenile growth is completed in a controlled environment. In this scenario, seed growth is carefully monitored and adjusted in laboratories which prepares them to develop resistances and increase their growth success post transplanting. Bypassing this difficult maturation process enables transplanted species to have a greater chance of success in unhealthy ecosystems[4]. Trees reaching adulthood represent the completion of many long-term restoration projects because, at this stage, they are most effective in cycling nitrogen and increasing available resources to support environments. In time, these transplanted plants as adults will be effective in restoring damaged land to a more balanced naturalized state[4]. However, there are drawbacks to this restoration technique and is not possible for many farmers.

Transplanted organisms are more costly and require excessive labour and time to be planted[5]. However, seeds are much lighter for transportation and require less energy to survive during initial growth. The workload of humans and their ability to facilitate seedling growth is also much lower compared to the attention that transplanted plants require[5]. However, seeded species are highly sensitive and won't grow under environment inhibitors. These would include factors such as high species diversity and competition, invasives, agricultural detriments, limited resource availability, low light and reduced soil quality[6]. When planted under unfavourable conditions such as these, seed growth is threatened and most of them will likely die off before germination. Also, to reach complete growth which is the purpose of most tree planting restoration projects, the seedling approach requires more time until completion. Ultimately, both tree planting approaches have their benefits and drawbacks and are tailored to different circumstances and restoration goals.

Restoration Approach #2: Tallgrass Prairie Planting

Once covering 90 million hectares of land across the central US, southern Ontario, and Manitoba, less than 3% of North America's native tallgrass prairie ecosystems exist today due to land use changes[7]. With the conversion from native prairie to agricultural use, soil loses structure, organic matter content, water retention, and nutrient cycling abilities. Restoration and management projects take advantage of the vast diversity of tallgrass prairie to restore soil health and species diversity in the land that was previously degraded by agriculture and urbanization.

Reconstruction of tallgrass prairie from an agricultural site confers many benefits to soil microbial communities and their associated ecosystem services. Compared to a corn monoculture, planted prairie systems support a higher diversity of microbes, including many species of fungi and bacteria[8]. In the event of a disturbance or stress such as drought, high microbial diversity facilitates increased resiliency and maintenance of ecosystem services such as soil carbon cycling by microbial extracellular enzymes[8]. These microbial functions are essential to maintaining a healthy and fertile soil structure. 62% of all Canadian corn is grown in Ontario, making it the second-largest user of agricultural land[9]. Restoration plans may consider taking marginal land out of production and replacing corn and other crops with tallgrass prairie to maximize soil benefits and minimize economic loss.

The effects of tallgrass prairie restoration are variable depending on the seeds selected for planting. When a site is sown with a greater number of different plant species, accumulation of plant root biomass occurs faster than in a restoration site with low plant diversity[10]. As root biomass increases, soil microbes also recover because plant root exudates provide nutrients for microbial metabolism[10]. Microbes, in turn, contribute to the recovery of soil aggregates crucial for oxygenation, organic matter decomposition, water retention, and more. Thus, the high biodiversity of vegetation supports microbes required for healthy soil. When considering a prairie restoration project, it may be useful to know the timeline of expected changes in soil health and how long it takes for the system to become re-established post-reconstruction. In an evaluation of soil health indicators in a chronosequence of restored prairie sites ranging from 0 to 13 years since reconstruction, soil aggregate stability, enzyme activity, and organic carbon and nitrogen content all increased within 8 years of prairie reconstruction[11]. However, these numbers did not quite reach the same levels as remnant prairie sites, suggesting more time may be required to reach an equilibrium state[11]. Overall, it is crucial to consider that many biogeochemical processes contribute to the variability of soil health recovery, thus each site requires unique considerations regarding the approach and timeline of management strategies.

Restoration Approach #3: Wetland Creations

Wetlands are ecologically important ecosystems that provide habitat to a highly biodiverse range of species. Globally, wetlands account for 40% of ecosystem service, including roles in sediment trapping, nutrient cycling, preventing flood and erosion, and water purification[12]. Due to urbanization, economic development, and other anthropogenic activities, wetlands are vulnerable to alterations in their water supply quality[12]. The future of wetland management is also threatened by the escalating global impact of climate change. Since approximately 64% of the world’s wetlands have been threatened, many restoration projects have designed wetland creation projects to develop wetlands in new areas[12].

Previously, wetlands were considered insect-infected and not valued for their conservation, which causes the market incentive to protect wetlands to be very low[13]. Climate change threatens hydrology, temperature increase, increased soil erosion, and flooding runoff.

Floodplains refer to grassland, shrubland, woodland, and forest. With an increase in their degradation, it is important to preserve floodplains for restoring hydrologic dynamics, sediment transport, and vegetation. Many areas have been impacted by agriculture drainage, specifically the hydric soils[13]. Restoring hydric soils is crucial for carbon sequestration.

Many restoration projects determine the state of a wetland ecosystem through comparison to a nearby target site[14]. Since soil composition responds to the disturbances, restoration projects investigate belowground characteristics. One method is examining phospholipid fatty acid (PLFA) analysis[14]. Phospholipids degrade after cell death, so to determine the condition of a living community PLFA is measured. A previous study found that PLFA biomass in restored riparian soils resembled reference wetland soils after seven years. PLFA was also found to be higher in sites that experienced low anthropogenic disturbances[14]. This indicates the timing of when wetland ecosystems begin to recover when agriculture disturbances are diminished.

Important management strategies for wetland restoration are the maintenance of hydrology, pollution reduction, and protecting wetland biological diversity to ensure resilience[14]. The hydrologic changes that occur from climate change will impact surface water management systems. These effects will lead to two consequences: the number of functioning wetlands will decline in capacity and the geographic location of wetlands will shift[14]. Restoration and creation assessments should consider the species interaction, soil quality, and ecosystem resilience when considering sites for new wetlands. This is because wetland effectiveness is dependent on pre-restoration conditions[15].

Riverine floodplains are the most diverse and threatened ecosystem from the usage of dams, levee systems, and river modification[16]. Their degradation is linked to declining freshwater biodiversity. Approximately 90% of floodplains are cultivated and extinct in North America[16]. Therefore, to prevent future degradation of important wetland systems, restoration projects should focus on restoring hydrological dynamics, sediment transport, and riparian vegetation[17]. This will aid in preventing the extinction of aquatic and riparian species in wetland ecosystems.

Conclusion

The ecological integrity of protected areas continues to decline because of multiple stressors such as invasive species, habitat fragmentation, water pollution, and global climate change. Ecological restoration provides mechanisms and management plans to prevent, slow, or reverse processes of ecosystem degradation. We examined three types of projects that are of particular significance to restoring Ontario's natural landscape and soils. Successful tree planting restoration requires strong ecological knowledge, an understanding of plant and organism activity, as well as how human intervention will influence ecosystems. Tree planting is highly viable under many scenarios due to diverse organism availability, and they can be implemented through transplanting and seeding. Tallgrass prairie restoration strengthens the diversity and stability of microbial communities essential for soil structure and nutrient content, allowing for the growth and maintenance of other species. Wetlands are important ecosystems that harbour large biodiversity. Recovering soil health and hydrology is crucial to recover wetland conditions to sustain native species and provide ecosystem services. To preserve Ontario's ecosystems, landowners and managers must be equipped with the necessary knowledge and resources to make sustainable land management decisions. We must invest in restoring and sustaining the ecological integrity of local ecosystems, both for the wide variety of human benefits and to rescue species at risk.

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