Let Nature Do the Work: Effective Strategies for the Restoration of Drastically Disturbed Sites

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ABSTRACT

Natural systems have been 'restoring' disturbed sites (landslides, volcanic eruptions, shoreline erosion, etc.) for millions of years. By understanding how these natural systems operate they can be applied to sites humans disturb (mines, industrial developments, etc.). Natural systems initiate recovery using pioneering species such as Willows (*Salix* spp.), Balsam Poplar (*Populus balsamifera* L.) or Alder (*Alnus* spp.). The seeds of these species are designed to travel long distances and use commonly occurring conditions to get established. Balsam Poplar and Willows have light fluffy seeds that at some times of the year look like snow. They land on puddles or other waterbodies and are blown to the wet mud at the edges of the puddle or on the shore of the waterbody where they germinate and grow. By creating these conditions (making puddles) on a mine site these species can be encouraged to establish on sites that are being reclaimed. The cost of these treatments are a fraction of traditional reclamation costs and because the resulting vegetation is appropriate to the area and the site where it establishes, natural processes can provide effective strategies for the reclamation of mining disturbances. Examples are drawn from the author's experience.

KEY WORDS:

Natural processes, pioneering species, low cost, ecologically appropriate, successional processes, filters (constraints), human disturbances.

INTRODUCTION

Reclamation of drastically disturbed sites such as mines and industrial disturbances can often be a costly endeavour. Regrading angle-of-repose waste rock dumps can be very expensive if the waste dumps are high relative to the dump platforms. The concept of 'wrap around' dumps can greatly reduce the cost of regrading (Milligan and Berdusco 1978) as the angle-of-repose slope is reduced. Similarly, the use of strategies that have been used in agriculture and forestry have been found to be expensive and of limited recovery value. The idea that a dense cover of seeded grasses and legumes would foster recovery came from agriculture as agricultural lands were often covered with agronomic species that were then plowed under to add organic matter to the soil. However at a mine site seeding with grasses and legumes were found to limit the recovery of sites. In many cases sites that were seeded with grasses and legumes at the time of the first TRCR conference are still covered by grasses and legumes with no sign of real recovery (Polster 2007). Forestry approaches have not fared much better (Klinka 1977) as often late successional species were planted on sites that are ecologically at an early successional stage. Traditional reclamation treatments have failed to restore the ecological services that were found at many mine sites prior to mining. This has resulted in a loss in social licence. Building effective restoration also builds social licence.

Natural processes have been restoring drastically disturbed sites for millions of years. By understanding how these natural processes operate to restore disturbed sites these same natural systems can be applied to sites that have been disturbed by humans (Polster 1991). Natural successional processes starting with bare ground and colonized by pioneering species can build soils in areas where no soils (in the traditional sense) are present. In coastal areas, Red Alder (*Alnus rubra* Bong.) is a commonly occurring pioneering species that can build soil in areas with no soil (Rothe et al. 2002). At reasonable densities Red Alder can have a beneficial effect on the growth of conifers (Feng 2018). Alder fixes nitrogen and the leaf litter from Red Alder builds soil carbon levels. Similarly, Balsam Poplar (*Populus balsamifera* L.) can build soils in riparian areas where fresh gravel is the dominant substrate. Willows (*Salix* spp.), a common pioneer throughout North America have features that allow them to survive in harsh conditions such as on gravel bars in the middle of rivers (Braatne and Rood 1998). In addition to building soil carbon reserves, Willows can also provide important structural elements in the ecosystems where they grow. This is why they are successful as riparian species.

This paper provides information on creating the right conditions for pioneering species and on avoiding the filters that often occur at mine sites. Since these processes are based on natural systems, they are inexpensive and do not rely on non-natural materials. By following the natural recovery systems that have operated for millions of years, mine restoration strategies can be developed that are both inexpensive and effective.

CREATING APPROPRIATE CONDITIONS

Hobbs and Suding (2009) classified the constraints that restrict recovery as being either abiotic or biotic while Temperton et al. (2004) has defined the specific filers or constraints that operate. At mine sites most of the filters are abiotic and include elements such as steep slopes, compaction, adverse textures, adverse nutrient status, adverse chemical properties (e.g. Acid Rock Drainage, ARD), temperature extremes (dark substrates at many coal mines), adverse micro-climatic conditions and excessive erosion. Biotic filters include elements like herbivory - seeded grasses and legumes create pastures for deer and elk that then prevent the growth of shrub layers that limit the success of songbirds (Martin et al. 2011). In addition, biotic filters such as competition can also play a role in preventing recovery.

It is essential that solving one issue does not introduce another. For instance, in the example give above where seeding agronomic grasses and legumes has traditionally been used to address erosion, the heavy cover of seeded species has allow ungulates to prosper that then creates a problem with herbivory as well as competition for seedlings of woody species. Natural processes have evolved in a manner that avoids these issues so erosion in natural situations is controlled by the natural configuration of the ground and/or the vegetation that has established. How do natural processes control erosion? Naturally, water does not flow across the surface of the ground; it flows in the near-surface groundwater area. In a natural forest, the water that is delivered to the site by rain or snow is quickly injected into the near-surface groundwater zone. How does this happen? In high rainfall areas such as the Canadian West Coast, the dominant understory vegetation cover is Salal (*Gaultheria shallon* Pursh) with tough leaves that have channels that move rainfall to the main stem and then down the main stem into the groundwater zone. Where salal is missing Swordferns (*Polystichum munitum* (Kaulf.) C. Presl) take over the function of moving rainfall into the groundwater zone by their funnel like shape. Many of the plants that grow in coastal forests have evolved to move rainfall into the groundwater zone.

How does the ground surface function to control erosion? In a natural forest, the ground surface is rough and loose (topographic heterogeneity) and this has an influence on hydrology (Morzaria-Luna et al. 2004). The falling of trees over thousands of years in a natural forest creates a rough and loose ground surface as the up-turned roots bring up large amounts of soil while the excavated hole that is left adds to the heterogeneity of the site. This is why water does not run across the ground in a natural forest, except in streams that are fed by cool, groundwater flows that are important to fish and why cross-slope roads often have problems with seepage on the cut slopes.

These natural processes that effectively control erosion while not inhibiting the growth of forests can be used for the restoration of large industrial disturbances (Polster 2017). Making the ground rough and loose and scattering woody debris (100 m^3/ha, Vinge and Pyper 2012) on the surface can control erosion (Wischmeier and Smith 1965) by moving rainfall into the near-surface groundwater zone. In addition, making the surface of the ground rough and loose creates a diversity of microsites for seeds to lodge in and plants to grow and because there are a diversity of these microsites, a diversity of plants occurs (Polster 2017). A former dam site that was restored using this treatment is dominated by red alder (35% cover in 5 years) with a high degree of diversity (84 species, including 5 different conifer species). Making the ground rough and loose is less expensive than traditional seeding. At a northern mine, treatment using the rough and loose technique cost $715/ha while traditional hydroseeding costs on the order of $3,500/ha. Rough and loose surface conditions can be constructed with an excavator using a digging (toothed) bucket. The bucket is filled with a large scoop of soil which is dumped half in and half out of the hole that was just opened. A second hole is then opened half a bucket width from the first and the material from this hole is deposited between the holes. The material between the holes should be loosened by jiggling the bucket as the second hole is opened. This process is continued until the comfortable swing of the excavator is reached. The excavator then backs up one bucket length and a new series of holes and mounds is created aligning the holes with the mounds in the previous row. Once the operator understands the objective, making a site rough and loose is a relatively simple operation that can be employed in a variety of locations from broad dump slopes to small exploration roads.

Natural processes create ecosystems that have a high degree of diversity with a high level of resilience for ecological changes in the future. This is due to the dominance of pioneering species in the context of developing recovery for the site. By creating a diverse context in which to grow, pioneering species foster the growth of a wide variety of species. Early successional plant communities are generally more diverse than their later successional counterparts (Braun-Blanquet 1932). This is important as it allows the community that is established to be resilient to changes that occur as the community matures. The role of pioneering species in creating diverse communities is essential to the success of these processes. The high level of diversity that occurs in natural plant communities allows these communities to create resilient ecosystems where they occur. Currently many of the Western Red Cedar (*Thuja plicata* Donn ex D. Don) trees in coastal British Columbia are suffering due to extreme climatic conditions that are occurring. However in a natural forest that is resilient, the loss of Cedar trees does not mean that the forest disappears just that other trees that are more tolerant of the currently dry conditions will move in.

Working within the natural successional trajectories for the area in question creates conditions that avoid many of the problems that are often faced at mines. Invasive species are common at many mines due to the failure to address the filters that allow the natural successional processes to operate. Steep slopes can be addressed using wrap-around dumps (Milligan and Berdusco 1978) while regrading to a slope of 2:1 or 26^{o} and making the surface rough and loose provides a context that allows the natural vegetation to establish. Since invasive species are rarely problems in natural ecosystems the creation of these natural ecosystems avoids the problems of invasive species. This is also true of seeding with agronomic species as it creates a condition that is outside of the natural successional trajectory so invites invasive species to establish. Thistles (*Cirsium* spp.) have been noted as part of the monitoring at a coastal mine since the late 1990s and the biennial thistle, Bull Thistle (*Cirsium vulgare* (Savi) Tenore) has been increasing for several reasons. The relatively bare areas that are created when the Alder that were planted at the mine in the late 1990s succumb to competition from the seeded grasses and legumes provide a context where this biennial species can establish and because the seeded grasses and legumes are outside of the natural successional context for the mine area (northern Vancouver Island). Although the Alder that were planted were within the natural successional trajectory for the region, the seeded grasses and legumes are not and are influencing the recovery at the mine.

MAINTAINING ESTABLISHED VEGETATION

Natural ecosystem processes are designed to maintain vegetation on a site forever so if the site is restored using natural processes by making it rough and loose and scattering woody debris then the maintenance of vegetation on the site will happen naturally. Early pioneering species have broad ecological amplitude so significant changes in the conditions of the ecosystem are unlikely to cause a significant change in the recovery of the site. In addition, early pioneering ecosystems are very diverse so that the demise of one species does not result in the collapse of the ecosystem. It is part of the ecosystem sorting itself out.

Using natural processes for the restoration of significantly disturbed sites like mines or industrial developments integrates the disturbed site into the natural recovery processes so that the natural processes take over maintaining the site. Ideas such as the need for rich soils or fertilizers come from the historic use of traditional treatments that are the foundations of agriculture. Similarly, the idea that the trees that were growing on the site are the ones to replant has fostered a problem with successional incompatibility where late successional species are established on an early successional site. Understanding how natural processes have restored disturbed sites for millions of years allows these processes to be used to restore and maintain sites that humans have disturbed.

CONCLUSIONS

Natural systems of recovery have been ‘restoring’ disturbed sites for millions of years. By understanding how these systems operate they can be applied to human disturbances. Natural processes build soils on sites with no soil. Similarly, most natural pioneering species have seed distribution systems that allow the seeds of these species to colonize sites that are distant from the parent plants. In addition, these pioneering species often have attributes that promote the continued growth of the species in the areas where they occur so the willows growing on the riverbank create conditions that allow them to continue to grow in this area that is subject to frequent disturbances. The dense growth of willows on a riverbank slows the flow of passing water and allows sediments to drop out. As the willows can continue to grow with stems covered by sediment, the willows will continue to grow in these areas. These same processes can be used to control erosion and promote sediment collection at mines.

The use of natural processes and systems to restore drastically disturbed sites such as mines allows restoration costs to be significantly reduced. By addressing the filters that are preventing recovery (e.g. compaction, steep slopes, etc.) and creating conditions that promote the establishment of pioneering species these natural processes can be harnessed to restore sites that have been disturbed. In addition, these natural processes can be used to avoid common issues such as invasive species as invasive species rarely grow in the pioneering ecosystems that initiate recovery on disturbed sites. So in addition to being much more effective than traditional reclamation treatments, the use of natural processes to restore mine sites is much less expensive than traditional treatments.

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