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NATURAL VEGETATION SUCCESSION AND SUSTAINABLE RECLAMATION

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ABSTRACT

Natural vegetation successional forces can be used to enhance reclamation of drastically disturbed sites. This paper presents a concept for land reclamation which is based on the use of successional processes. Identification of the factors which are precluding vegetation growth or which are limiting the establishment of additional species is the first step in the formulation of a sustainable reclamation program. Solutions for overcoming these growth limiting factors are sought from those which would occur under natural circumstances. These are then utilized in the reclamation program. Successional reclamation programs can revegetate sites which otherwise defy revegetation attempts. Examples are drawn from reclamation programs conducted by the author in western Canada.

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La succession naturelle de la végétation et la réhabilitation soutenable

Les principes de la succession naturelle de la végétation peuvent être utilisés pour faciliter la réhabilitation de sites fortement perturbés. Cette communication présente un concept, pour la réhabilitation de sites, se basant sur l'utilisation des processus de succession naturelle. L'identification des facteurs environnementaux qui conditionnent la croissance de la végétation, ou gui limitent l'introduction de nouvelles espèces, représente la première étape dans la formulation d'un programme de réhabilitation soutenable. Les solutions, pouvant contrer l'effet des facteurs limitants sur la croissance des végétaux, sont recherchées parmi les situations qui *se* rencontrent en conditions naturelles. Ces solutions sont ensuite utilisées dans le cadre du programme de réhabilitation. Les programmes de réhabilitation se basant sur la succession naturelle, peuvent revégétaliser des sites rébarbatifs à d'autres efforts de revégétalisation. Des exemples sont tirés de programmes de réhabilitation dirigés par l'auteur dans l'ouest canadien.

INTRODUCTION

Reclamation of drastically disturbed lands in British Columbia has progressed to the point where the achievement of self--sustaining vegetation covers are now not only possible, but a requirement of the legislation (Section 10.6.6, MEMPR, 1990). The incorporation of successional theory in the development of land reclamation prescriptions is essential for the restoration process to be successful, (Allen 1988). Key elements of the newly established plant cover can make a significant difference in the long term performance of the vegetation. Successful re-establishment of ecosystem function requires that the site be reintroduced to the natural successional processes.

Natural successional function is based on the theory that individual plants have an optimal range for growth and development. Once plants become established on a site they modify the site through changes in the soil conditions, micro-climatic conditions and physical space, until those original species are no longer functioning at their optimum level. New species, whose optimum range fits more fully with the new set of conditions can now establish and grow. These in turn change their environment and lead to the establishment of a new assemblage of species. This process continues until a climax condition is reached. The seral stages of vegetation can be broken into convenient units, although in fact, the process represents a continuum.

This paper describes how natural successional theory can be used to produce sustainable ecosystems on drastically disturbed lands. Natural successional processes have developed over the millennia since plants first colonized the earth. These process represent the optimum means of establishing vegetation on disturbed sites and are the culmination of this long process of vegetating the earth. Although humans can assist in this process, it is unlikely that improvements can be made, at least not for the long term viability of the ecosystems involved.

The paper is organized to present key features of the different seral stages; vegetation goes through so that the reclamation practitioner can make appropriate decisions to assist in the natural revegetation of the disturbance which is to be treated. Establishment of the initial vegetation is of paramount importance in the future development of the site. This aspect of revegetation is discussed in greater detail, with later seral stages being accorded less importance.

INITIAL COVER ESTABLISHMENT

Vegetation covers most land areas of the earth's surface, although the rate of vegetation establishment on freshly clreared surfaces varies in accordance with the climate and the conditions of the site. A cold dry arctic tundra may take many years to recover from a disturbance, while a lush tropical jungle will grow over in a few months. Similarly, sites which are composed of large, coarse rock, such as the toe of a waste rock dump, will be more difficult to revegetate than a site with a good loam soil. Clearly, site conditions play an integral role in the establishment of vegetation.

Identification of the factors which limit vegetation growth, and amelioration of these conditions is the first step in the successional reclamation of a site. Site factors which commonly limit vegetation growth at drastically disturbed sites include:

1) Steep slopes. Slopes on which the surface materials are unstable will be difficult, if not impossible to revegetate. Slopes up to 70 degrees can be revegetated provided the surface is stable.

2) Adverse texture. Moisture retention, nutrient retention and a host of other plant sensitive site features are related to texture. Textures which are too coarse and those which are too fine can impede plant growth. Soils having about 20 percent passing a 200 mesh screen will be suitable for plant growth.

3) Nutrient status. Many drastically disturbed sites are low in essential and micro nutrients. Although successional reclamation programs can build soils, some initial nutrient additions are usually required.

4) Adverse chemical properties. Extremes in pH, high levels of metals, high SAR levels and other chemical properties can preclude plant growth. It may be that some species will tolerate the existing conditions, but unless a balance of species can be established, a functioning ecosystem will not result.

5) Soil temperature extremes. Soil temperature extremes, often associated with dark coloured substrates, can prevent plant growth. Micro-climatic conditions greatly influence vegetation growth and development.

Other edaphic factors, such as exposure, both to sunlight and prevailing weather conditions, can influence the successional trends along which an established plant community can proceed.

Site edaphic features must be appropriate for the species being established to develop a successional reclamation program. Plants must fit the edaphic conditions or their growth and development will be impaired. Late successional species, such as Spruce, in many parts of British Columbia, should not be planted on sites which are not in a late stage of succession. The conditions for establishment must mimic the natural successional patterns or poor responses can be expected.

Establishment of appropriate plant species is essential for the long term development of successional trends on a site. The initial cover must provide the appropriate conditions for the succeeding species to establish. This cover should be developed so that the next species to become established are afforded all of their requirements. The initial cover must provide "space" for succeeding vegetcition to utilize. The "space" is in the form of physical space and space in the use of the resources (moisture, sunlight, nutrients, etc.). This is clearly the case in areas of low rainfall, where moisture is the limiting factor and vegetation develops in open, evenly space stands related to moisture partitioning.

Development of a suitable initial vegetation cover on drastically disturbed lands must account for the "space" requirements of later successional species. The seed mix which is used to establish this initial cover should be designed to provide this space. In most cases, seed mixes are based on a percentage by weight. As seed weights differ for different species, this leads to having a seed mix which is not balanced for species composition. Seed mixes must be balanced for species composition to allow "space" for new species to establish. A seed mix which has a preponderance of sod forming species will prevent additional species from establishing. Conversely, a mix with a high proportion of sod forming species can be used to prevent the successional advancement of the vegetation cover. This can be useful in those cases where the natural invasion of the site by woody species is not desired, such as along a utility right-of-way. Table 1 presents a comparison of the percentages of different species for the seed mix recommended by the British Columbia Ministry of Energy, Mines and Petroleum Resources for alpine areas.

TABLE 1
Seed Mix For Alpine Areas Not
Balanced for Seed Weights

Species	Percent by Weight*	Percent By Species Composition
Meadow Foxtail	10.0	4.51
Creeping Red Fescue	40.0	15.10
Toothy	25.0	19.74
Tracenta Bentgrass	10.0	53.73
Alsike Clover	15.0	6.92

* As given in Appendix G, "Suggested seed mixtures for use on areas disturbed by exploration activities in British Columbia."

TABLE 2
Seed Mix For Alpine Areas
Balanced for Seed Weights

	Percent by Weight**	Percent By Species Composition
Meadow Foxtail	11.42	10.0
Creeping Red Fescue	54.57	40.0
Timothy	16.30	25.0
Tracenta Bentgrass	0.96	10.0
Alsike Clover	16.75	15.0

** As calculated from number of PLS/gram of seed.

Table 2 presents the percentages by weight which should be used to provide the desired percentage by species composition. A comparison of the percentages for the bentgrass in both Tables 1 and 2 shows that if 10 percent by weight is used (Table 1), then the percentage by species composition will be almost 54 percent, that is, over half of the established stand will be bentgrass, a dense sod former. However, if a 10 percent cover of bentgrass is desired as the established cover, then 0.96 percent by weight should be used (Table 2).

Seeding rates are also very important in the development of a successional reclamation program. The seeding rate given for the mix presented in Table 1 is 60 kg/ha. This mix will contain 563,220 Pure Living Seed (PLS) per kilogram. A seeding rate of 60 kg/ha will be far heavier than is needed. The dense stand resulting from such *a* high seeding rate will result in increased seedling mortality. A seeding rate of 9.77 kg/ha will provide 550 PLS per square meter, a reasonable density given the expected high mortality in an alpine reclamation situation. With a balanced seed mix, such as given in Table *2, a* seeding rate of 18.96 kg/ha would be used to apply 550 PLS/square meter.

Most reclamation programs rely on the use of fertilizer to promote establishment of the initial cover. As with the seed mixes, care must be taken to ensure the fertilizer does not prevent the establishment of species comprising the next successional stage. Fertilizer is applied to most reclamation areas at the time of seeding.

Maintenance applications of fertilizer are made on a regular basis once the initial cover becomes established. However, if the desired result of the reclamation program is to promote the establishment of natural successional processes on the site, then the purpose of the initial cover should be to provide a suitable environment for the natural invasion of the site by species comprising later successional stages. In most cases these species will be woody species. The use of fertilizer during reclamation of a site must be carefully regulated to ensure the seeded species do not become so firmly established that new species are prevented from establishing.

Studies of the effects of rodents on woody species establishment have shown that high population levels of small mammals can prevent the establishment of woody species (Green 1982). In cases where the establishment of woody species is desirable, control of small mammal populations is required. Green (1982) found that:

"1. Dense ground covers predominated by agronomic grasses (creeping red fescue, brome grass and crested wheatgrass) and legumes (alfalfa and common clover) seriously hinder tree and shrub performance (e.g., poor growth, condition and survival); and

2. Sparse herbaceous ground covers, such as that present on the Reduced Cover and Combined Treatment study areas, appear to be the most suitable for good tree and shrub performance (good growth, condition and survival)." (Green 1982).

It is clear that a balance between a very dense cover which will prevent erosion, and a more open cover which might be subject to erosion, is required for the successional advancement of the vegetation on a reclaimed site. The following points must be addressed in the development of the initial cover for a successional reclamation program:

1. The factor (s) precluding vegetation establishment growth must be determined and addressed (e.g. physical properties, chemical properties, steep slopes, unfavourable micro-climatic conditions, etc.) prior to the establishment of the initial cover.

2. The initial cover should avoid the excessive use of sod forming species as these will not leave "space" for later successional species.

3. The initial cover should be composed of successionally "early" species, such as grasses and legumes, and

4. The initial cover should enhance conditions at the site for the subsequent development of later successional species.

The initial cover provides the fist stage of succession on the reclamation site. Later seral stages will be dependent upon this stage for the conditions of the site. it is therefore important that the later successional stages be assessed to ensure that the requirements of these stages are met by this initial cover. These are discussed in the following section.

LATER SUCCESSIONAL STAGES

The establishment of a self-sustaining vegetation cover on drastically disturbed lands requires that the initial cover eventually give way to a cover of more permanent species. Natural seral stages progress from the initial vegetation cover, usually pioneering herbaceous species, through stages composed of woody pioneering plants and eventually to a climax vegetation cover. In the reclamation context, the initial cover of grasses and legumes serves the purpose of the pioneering herbaceous cover. However, establishment of later successional stages can be problematic. The factors which will allow later successional stages to successfully establish on a site, modifying the site edaphic features so that further vegetation development is enhanced, are discussed in the following paragraphs.

Determination of the cover which is desired is required for establishment of appropriate later successional stages. In much of British Columbia, productive forest ecosystems are the desired end result of the reclamation process. The following successional patterns provide a general indication of the species which might be appropriate for establishment in a successional reclamation program where forests are desired:

Bare Ground	-->	Pioneering Herbaceous Species	-->	Pioneering Woody Species	-->	Pre-climax Woody Species	--->	Climax Woody Species

An open cover of grasses and legumes will perform the role of the pioneering herbaceous species. Pioneering woody species, such as alder, willow, poplar, maple, and *a* variety of other shrubs, can be used as the pioneering woody species. These species can be planted on the reclaimed site along with the grasses and legumes of the initial cover. The planting of later successional species, such as those which comprise the climax stage, should be avoided until those species making up the earlier successional stages have been established.

Selecting species which enhance the site edaphic conditions, such as alder, which is associated with bacterial nitrogen fixation, can expedite the successional progress of the site. In many cases, pre-climax conifers, such as Douglas Fir, and climax conifers, such as red cedar, hemlock and spruce, can be planted in the cover provided by the alder. As with the initial cover of pioneering herbaceous species, maintenance of "space" for the later successional stages must be maintained in the cover of the pioneering woody vegetcition.

Successional stagnation of a site is common where pioneering woody species have established too densely for later successional species to establish. Dense stands of Red Alder and Big Leaf Maple are common in coastal British Columbia. Stands of Sitka Alder, Mountain Ash, Thimbleberry and Willows with stem counts of 10 to 20,000/ha are common at high elevations in the interior. These prevent the establishment of later successional species. However, as these stands mature, "spaces" open for pre-climax conifers to establish.

The pioneering woody species provide the edaphic requirements for later successional species. It is clear that the presence of the pioneering species is required for the optimum growth and development of later successional species. Many reclamation programs have met with limited success because later successional species were planted without first establishing the pioneering woody species. These pioneering woody species, along with the initial vegetation established on a site, modify the site in ways that the reclamation practitioner may not fully understand. However, natural ecosystems have developed over millennia to provide the best long term productivity which can be achieved on a given site. Humans can only hope to duplicate this, not improve upon it.

Woody species will establish naturally into a cover of seeded grasses and legumes provided there is a seed source available and there is space for the woody species to become established. Stocking rates for woody pioneering species should be determined on the basis of the density which will allow development of later seral stages. in general stocking rates for pioneering woody species such as alder, should not be greater than about 2,500 stems/ha (a 2 meter spacing). Pre-climax conifers can be planted among the pioneering woody species at about the same density as the pioneering woody species. It should be noted that the density of the pioneering woody species can be increased if the species being established are small, such as Thimbleberry, or if there is a potential for significant browsing, as might occur in the Southeast Coal Block on species such as willow.

Climax species generally do not need to be planted as these will establish naturally once conditions are optimum. However, there may be times when the return of the site to forest productivity is desired. Generally, pre-climax conifers such as Lodgepole Pine and Douglas Fir will provide greater productivity, provided they are supported by the preceding successional stage, in most cases, the pioneering woody species. Climax species, such as Spruce, Alpine Fir, Cedar and Hemlock can be established directly under the cover of the pioneering woody species in many cases. On sever sites, it is advisable, however, to follow through the entire successional series, rather than trying to skip a stage.

DIFFICULT SITES

Successional reclamation methods can be used to establish a vegetation cover on difficult sites. In many cases, the most difficult stage in the reclamation effort involves the establishment of the initial cover. On sites where slopes exceed the angle of repose, or where site conditions, such as moisture, have prevented vegetation from establishing, specialized reclamation techniques can be used to provide the initial cover.

Determination of the factors precluding vegetation growth will be the first step in the establishment of vegetation. For instance, on a long, steep waste rock dump slope, factors limiting vegetation growth may be surface stability ("A rolling stone gathers no moss.") and texture (Polster and Bell 1980). Pushing the fine textured materials from the crest of the dump down the face can solve both of these problems (Lane 1980). some cases, vegetation can be used to overcome vegetation limiting problems.

Bioengineering can be used to provide an initial vegetation cover on difficult sites. Wattle fences, which are short retaining walls built of living plant materials, can be used to reduce the effective slopes on some sites to those which will support vegetation. Similarly, live pole drains, which are "French Drains" built of living materials, can be used to establish a "successional correct" vegetation cover on sites where excessive soil moisture is causing slope stability problems. Direct seeding of pioneering woody vegetation can be used on sites where for a variety of reasons, traditional planting methods can not be used. Specialized techniques can not be used as a substitute for following the successional patterns established by nature. Direct seeding of climax species on bare ground will be a waste of seed and resources, although seeding these species into a stand which is at the successional stage for establishment of the climax species might be a useful technique to avoid the high cost of planting.

CONCLUSIONS

Natural successional processes can be mimicked in the reclamation of drastically disturbed sites. Identification of those factors which are preventing vegetation growth and development is the first step in the process. Once these are ameliorated, an initial cover of seeded grassses and legumes, balanced for seed weight, can be used to start the successional sequence. Space for the next species to establish must be left in the initial cover. Pioneering woody species which enhance site conditions for later successional species can be established into the initial cover. As the adverse site conditions are ameliorated by the growth of the earlier successional stages, later successional vegetation can be established. In general, this will happen naturally, with little or no effort on the part of the reclamation practitioner.

Successional reclamation methods can be used to ensure that the established vegetation is self-sustaining. Natural ecosystems have evolved to provide a durable vegetation cover on most land surfaces. Successional reclamation may be described as a feminist approach to reclamation in that it seeks to work with the natural processes, rather than to fight against them. The best the reclamation practitioner can expect to accomplish is to equal the natural reclamation efforts. Utilization of successional reclamation techniques will be cost effective, as the naturally occurring forces which serve to revegetate land will be harnessed, at no cost to the reclamation practitioner.

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