SUCCESSIONAL RECLAMATION IN WESTERN CANADA: NEW LIGHT ON AN OLD SUBJECT [1]

by

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Abstract Successional reclamation is defined as the enhancement of natural successional processes for rehabilitation of drastically disturbed sites. Formulation of grass and legume seed mixes which enhance natural successional processes is described. The use of key pioneering woody plant species and the dynamics of vegetation succession are discussed in the context of reclamation of western Canadian sites. The benefits of using the successional reclamation approach in terms of improved species performance, decreased cost, and enhancement of ecological stability are discussed. Development of bioengineering techniques for use on difficult sites is discussed with reference to techniques, costs and benefits. Key factors in the planning of a successional reclamation program are detailed. Examples are drawn from reclamation programs conducted at mining and other industrial sites.

Additional Key Words: natural successional processes, bioengineering, difficult sites.

Introduction

Reclamation of drastically disturbed lands has developed over the past several decades to the point where reclamation considerations are now an integral part of the development process (Thirgood 1986). Details of soil conservation measures as well as revegetation prescriptions are now a standard part of most major mine or industrial developments (Ziemkiewicz et al. 1980). Techniques for the revegetation of disturbed sites have been developed using modified agricultural and forestry methodology (Errington 1988). In general, reclamation practitioners have succeeded in the "re-greening" of disturbed sites.

Reclamation designs have been developed to return the land to a productivity which is as great or greater than that which was supported prior to the disturbance. Recreation of wildlife habitats, restoration of watershed values, development of agricultural lands and the development of productive forests are but a few of the many land uses which reclamation programs have been designed to meet. In cases where the disturbed land is to be continually maintained, such as under agricultural production, most reclamation programs have worked well. However, where the disturbed lands are to be returned to some "natural" state, most of the reclamation programs which have been developed have fallen short of the desired results. This paper describes a reclamation format which addresses these shortcomings.

Successional reclamation is the term applied to the re-establishment of the natural successional processes on disturbed sites. The primary thrust of the successional reclamation process is the development of soils and vegetation patterns which will allow the site to return to the natural successional processes which would, over time, revegetate the site. It is clear that most sites which are being reclaimed were, prior to the creation of the disturbance, vegetated. By directing reclamation efforts into the re-establishment of the natural successional processes, the forces which act to vegetate the surface of the earth can be used to develop a vegetation cover on disturbed sites.

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[1] Paper presented at the Canadian Land Reclamation Association and American Society for Surface Mining and Reclamation conference, Calgary, Alberta, August 27-31, 1989.

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Proceedings America Society of Mining and Reclamation, 1989 pp 333-338
DOI: 10.21000/JASMR89010333

https://doi.org/10.21000/JASMR89010333

There are a number of benefits to utilizing a successional approach in the development of reclamation programs. The primary benefit is that such an approach will, in the long term, be more effective. Costs will be less, and the cover which eventually establishes will be self-sustaining. The following sections of this paper explore the use of successional approaches in the development of effective reclamation programs.

Successional Processes

Vegetation succession may be defined as the changes in plant species composition which result from the ability of different species to utilize different niches (Oosting 1956). The presence of the plants changes the environment in which they are living, creating new niches for different species, and so the process continues, with differing assemblages of plants developing on any given site until the climatic climax vegetation develops. As shifts in the climate occur, over geologic time periods, different assemblages of plants develop. The propensity of plants to colonize areas which have been devoid of plant life is the key to the succession process.

Primary successional processes develop on sites where there has never been a cover of plants. This may be on a recent lava flow, or on recently deposited mine wastes. In North America, lichens are generally the initial colonizers of bare rock. The ability of the lichens to synthesize nitrogen from the air, and the development of organic acids which break down the rock into soils, enables other plants to establish. Eventually, over centuries, the area which was once bare rock is vegetated.

Secondary successional processes occur where vegetation has been removed from the site but where the effects of the vegetation which was on the site are still felt. Fire, land clearing and other such activities initiate the process of secondary succession. In cases where soils .have been salvaged for later use in the reclamation of a site, the successional processes which will occur on the site will be secondary successional processes.

Successional reclamation processes are founded on a clear understanding of the natural successional processes which would occur on the site being reclaimed given sufficient time. In effect, it is the enhancement of these natural processes which is the basis of the successful successional reclamation program. The following sections of this paper describe the development of a typical successional reclamation program.

Pioneering Species

Establishment of the initial cover of vegetation on the reclamation site is often the most challenging task facing the reclamation practitioner. The factors precluding vegetation must be evaluated and species which will ameliorate these adverse factors sought. Conditions such as low nutrient status, poor moisture and nutrient holding capabilities, and adverse physical conditions of the substrate are common on reclamation sites. Adverse chemical characteristics such as presented by sodic spoils or acid generating wastes may also present barriers to plant growth and development. Selection of species which have evolved to develop in situations where these adverse conditions naturally occur will initiate the process of successional reclamation.

In general, pioneering species should be selected on the basis of their ability to perform some function which will ameliorate the adverse conditions of the site and allow future species to establish. The following paragraphs outline some of the commonly occurring barriers to plant growth and the species characteristics which can be utilized to overcome these barriers.

Low Nutrient Status

Nitrogen is the nutrient which is most commonly limiting on reclamation sites. Species which will fix atmospheric nitrogen and make it available for other plants must be considered in the selection of pioneering species. Legumes, such as clover and alfalfa are excellent in this capacity. Other species such as alder, buffaloberry, mountain avens and native legumes can also aid in the amelioration of low nutrient status sites. Other nutrients may be added with fertilizers.

Poor Moisture and Nutrient Retention

A general lack of soil organic matter can result in an inability of the site to retain nutrients and moisture, limiting plant growth. Species which will incorporate significant amounts of organic matter will aid in ameliorating these deficiencies. Fine textured mineral soils such as clays can also be used to improve the nutrient and moisture retention status of the site. Grasses can contribute organic matter both through root decomposition and through above ground biomass.

Adverse Chemical Characteristics

Selection of species which have developed a tolerance to the particular conditions being experienced can initiate the process of natural succession on these sites. For instance, Distichlis stricta (Torr.) Rydb. develops naturally on saline areas on the Prairies. This species contributes to the amelioration of the saline conditions through the incorporation of organic matter and improved drainage. In some cases, it may be necessary to physically ameliorate the adverse condition prior to the establishment of vegetation. Weathering, which will in the long term reduce adverse soil conditions, can be enhanced through the incorporation of additives.

Adverse Physical Conditions

Adverse physical conditions such as steep or unstable slopes can be treated with species which would naturally pioneer on such sites. Areas of groundwater induced instability are colonized naturally by willows, poplars and other such species. Similarly, areas which are oversteepened and are continually moving, will be colonized by species which have adapted growth forms which can accommodate such conditions. Willows will resprout from buried stems, and can be used to stabilize oversteepened slopes. Once the site is physically stabilized, the establishment of additional species is possible and the natural successional process can develop.

Fostering Successional Processes

Successional reclamation programs are designed to enhance the further development of vegetation on the site. There are two features of the site which will allow this to occur; the development of spaces which the invading species can occupy, and the modification of the initial site conditions to allow other, different species to develop. These factors are discussed in the following paragraphs.

Space for Others

Provision of space into which invading species can establish will enhance the potential for further succession. Every golf course keeper knows that the best way to prevent the invasion of weeds onto the fairways is to maintain a dense stand of the desired grasses through fertilization and watering. Once there are spaces between the grass plants, other species, which in the case of the golf course, are undesirable, soon invade. The same holds true for the reclamation site, except in this case, the invasion by additional plant species is often desired. The stand of pioneering vegetation must be open enough to allow for the invasion of the secondary species.

Grasses and legumes are often used by the reclamation practitioner as the pioneering vegetation. These are seeded onto the site to reduce erosion, enhance fertility and provide cover for other more permanent species. The development of grass and legume seed mixes which are designed to allow spaces to develop between the plants will foster the successional process. The use of bunch forming species, and limiting the use of sod forming species will aid in this process. Similarly, species which are relatively short lived can also be used to provide space for invading species. Limitations must be placed on the use of fertilizers which enhance the growth of the grasses and legumes at the expense of the invading species.

Seed mixes must be balanced according to seed weights to achieve the desired end results. Seed is sold by weight, so a mix composed of 50% bluegrass and 50% brome would have equal weights of both species. However, by species composition the mix would result in a stand which would be 94.5% bluegrass. This might be fine for a lawn, but in a successional reclamation program, it would not leave room for invasion by other species. Dense stands of single species, or closely related species, which do not allow room for invaders result in a stagnation of the successional process which will persist until some change in the system occurs. In the example given above, the bluegrass stand would persist until there was some change such as a reduction in the nutrient status which allowed other species to invade.

Modifying Site Conditions

Pioneering species modify site conditions to permit the establishment of the invading species. In most cases, there are a variety of conditions which must be modified prior to the successful establishment of the secondary species. For instance, mountain avens (Dryas drummondii Richards) is a pioneer on gravel bars in the Rocky Mountains (Fyles 1976). It forms dense mats of vegetation which initially precludes the invasion of other species. However, as the plant expands, the older portions die, leaving space for other species such as spruce and cottonwood to invade. The initially harsh conditions of the gravel bars, notably lack of nutrients and lack of soil organic matter, are ameliorated by the mountain avens.

Species such as alder, which is commonly used as a secondary species in successional reclamation programs, may modify site conditions in a variety of ways and allow the enhanced growth and development of conifers. Alder fixes nitrogen, and can provide up to 62 kg/ha/yr of fixed nitrogen (Haeussler and Coates 1986) for other plants to use. Alder can also ameliorate micro-climatic conditions for young conifers. In the early spring, when soil temperature are low and growth is limited by the low soil temperatures, the alder allows a maximum amount of sun light to reach the ground. However, during the heat of the summer, the alder shades the young conifers, with the canopy providing a trap to prevent moisture loss by the young plants. Care must be taken however to ensure that the canopy of alder does not reduce light intensities below the light compensation point for the young trees (R. Stathers 1989, pers. comm.). For the British Columbia Interior, alder stocking rates of 3,000 stems/ha appear to be ideal in terms of aiding in conifer growth.

Successional approaches to the reclamation of disturbed sites can lead to enhanced ecosystem stability. The development of reclamation systems which are open to invasion by new species and the enhancement of natural ecosystem repair mechanisms leads the reclaimed environment to become more heterogeneous. This diversity in the reclaimed system results in a greater opportunity to accommodate perturbations in the system. In addition, the potential for significant perturbations is reduced in the reclaimed lands because of the natural feedback mechanisms which tend to limit such problems. For instance, large increases in small rodent populations are well known in traditional reclamation environments. Mice and voles thrive in the protection of a dense cover of grasses and legumes. The grasses and legumes provide a cover for these animals from their natural predators. However, in a successional reclamation environment, population explosions are limited by the open nature of the initial cover. Predators can control these populations, leading to a healthy predator/prey relationship.

Productivity of sites reclaimed using successional approaches develops to the optimum for the site without the need for continual maintenance or external inputs. Vegetation develops naturally to optimize the use of all available niches. Maximum productivity in natural systems is achieved at a state immediately prior to the establishment of the climax vegetation (Whittaker 1973). Development of reclaimed systems which mimic the natural successional processes will lead to maximum utilization of the available niches. It should be noted that this considers only systems which are not supplied with external inputs such as fertilizer. It also relates to natural vegetation processes, not artificial systems such as an agricultural development.

An understanding of the successional processes which drive vegetation establishment and development can lead to a manipulation of these systems to achieve some desired end result. The artificial enhancement of early successional stages can be used to maintain these systems. Revegetation design for some sites may seek to preclude the growth of woody species. By limiting the space into which woody species would invade through the use of sod forming species and additional fertilizers, further succession can be limited. It should be noted that this process, however, is only temporary, and without the additional input of fertilizers and other maintenance, the natural forces of succession will eventually result in the establishment of woody species.

Difficult Sites

Successional reclamation methods provide an ideal approach to the reclamation of difficult sites. Bioengineering techniques, where living plant materials are used to perform some engineering function, fit neatly into the successional reclamation process (Schiechtl 1980).

Wattle fences, where living willow, poplar and red-osier dogwood cuttings are used to construct short retaining walls have been used to initiate successional processes at a number of sites in western

Canada. The fences are constructed at frequent intervals up steep slopes, breaking the slope into a series of short, shallow slopes which can then support vegetation. The materials used to construct the fences sprout and grow, resulting in an initial cover of the pioneering species which were used. Slopes of 50 to 60 degrees are treated with wattle fences.

Live pole drains are used to drain excess moisture from sites where the moisture is causing soil stability problems. Live pole drains are constructed of bundles of living cuttings placed in shallow trenches in the problem area. The drains initially act by draining moisture through the voids created by the bundle of cuttings. As the cuttings grow, excess moisture is removed by transpiration of the plants. The root systems also tend to hold the soils in place. Live pole drains are built using species which would naturally invade on wet seepage sites, again initiating the process of succession.

Living baffles are used to control erosion in drainage channels and erosion gullies. The baffles are built of living cuttings laid across the channel to slow the flow of water. As the baffles grow, the channel becomes lined with the vegetation which would naturally develop on such a site.

Other bioengineering techniques, such as brush layering, hedge brush layering, the use of living cuttings to hold sod in place on steep slopes and soil binding seeding make use of the concepts of successional reclamation by utilizing plant materials to solve the problems which were precluding plant growth initially. Once these initial problems are solved, further vegetation can establish on the site.

Conclusions

Successional reclamation is the term applied to the re-establishment of natural successional processes on reclamation sites. By utilizing the natural forces which act to revegetate sites, reclamation processes can be enhanced. These natural processes can be harnessed to revegetate sites which for a variety of reasons would not easily support vegetation. Significant savings in terms of cost and effort can be realized by using successional approaches to the reclamation of disturbed sites. Sites which would otherwise require significant civil engineering works can be stabilized and revegetated using successional approaches. An understanding of the natural processes which act to develop vegetation on a site and the incorporation of methods which enhance these processes will result in a more efficient utilization of resources and better results in the long term.

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