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THE ECOLOGICAL BASIS FOR RECLAMATION SUCCESS CRITERIA

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ABSTRACT

Reclamation success criteria were incorporated into federal and state coal strip mining laws or regulations of the 1970's. Other surface disturbing agencies, following the lead of the Office of Surface Mining, have attempted to develop similar reclamation success criteria. State hardrock mining and sand and gravel regulatory agencies, highway departments, the Forest Service, the Bureau of Land Management, and the Environmental Protection Agency have attempted to clarify what they consider successful reclamation efforts. Final determination of reclamation success for these groups has always been based on the appearance and production of vegetation but plants are very opportunistic and resilient. They mask deficiencies of reclamation for years but will eventually fail if the soil resource is not rehabilitated sufficiently to insure the perpetuation of the plants. That is the reclaimed plant community must be enhancing the soil, it must be increasing the quality and quantity of the resource in which it is growing or natural loss of the soil will eventually contribute to the destruction of vegetation on the reclaimed site. It seems reasonable, therefore, that the soil resource is the criteria that should be evaluated for final bond release rather than the vegetation covering the soil.

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INTRODUCTION

The question - to reclaim or not - is no longer relevant. Every reputable mining company, the EPA, state highway departments, and other industries or government agencies attempt to rehabilitate to some extent the lands they disturb or the lands within their jurisdiction. The question today is what is adequate reclamation.

A definition of reclamation is appropriate at this point. Reclamation is the goal of returning the soil and the plant community it supports to conditions in which the stability and productivity of the site are comparable to that of the site prior to disturbance. Reclamation includes components of hydrology, soils and vegetation. Arguments that disturbed sites should be returned to pre disturbance conditions aren't relevant because it is not possible to do so.

We cannot restore a site even after an action as simple as plowing because of all of the changes produced in the soil physical, chemical, and biological properties by the action of turning over or mixing the top six inches of the profile. However, we can revegetate the site to some or most of the plant species found on the site prior to disturbance by very careful and selective reclamation. Whether this is called restoration or reclamation is not relevant, it is simply academic and I prefer to use the term reclamation. Many researchers call this type of reclamation restoration but as Allen (1995) pointed out, "...even the best examples of restoration have been able to reintroduce only a fraction of the plant species richness and natural recolonization is slow at best."

In the late 1960's and early 1970's western coal mining was bursting out of the constraints imposed by transportation costs and cheap eastern coal because of the growing demand for energy and air pollution awareness. The Arab oil embargo simply exacerbated the demand for western coal. At that time the potential for returning livestock to range sites after they had been surface mined was not considered good. Curry (1975) for example was quite skeptical that Great Plains minesoils would ever be productive after stripmining. Today we know that livestock gain weight and reproduce as well on reclaimed mined lands as they do on native range. We know that the land can be as stable as it was before disturbance and that wildlife invade the land even before mining is finished. These generalizations pertain to reclaimed mountain soils as well as reclaimed soils on the plains.

We now have thousands of acres of western land that was disturbed by surface mining in various stages of reclamation. Some of this land has been supporting crops or livestock since before the Surface Mining Control and Reclamation Act was enacted in 1977 but little of this land has received approval as successfully reclaimed. If the soils and vegetation were considered successful, then one would assume that final and complete bond release would be authorized. This has rarely been the case on coal mines in our region and I do not know of any superfund sites that have met with widespread approval after rehabilitation. Therefore I must assume that the reclamation of these sites is lacking in some quality.

THE QUESTION

The big question today at mines, superfund sites, linear rights-of-way, and other disturbances is, are the results of reclamation good enough for final approval be it as full bond release on coal mine sites or some other criteria that signifies adequacy at a superfund site or along a highway right-of-way. For various reasons many agencies (e.g. EPA), advocacy groups, and others are attempting to apply the final bond release criteria of SMCRA to disturbances of interest to the group, therefore, I shall use the success criteria of this law as the basis for my discussion. But, please be aware that what I am about to say pertains to the determination of reclamation success on all forms of surface disturbances in the semiarid west.

In an attempt to answer this question of successful or unsuccessful reclamation a group of terms were introduced into the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87). These include diversity, production, self perpetuating, native, and succession among others. All of these terms pertain to the plant community growing on the disturbed site and all have shortcomings that lessen their ability to quantify successful reclamation. This I believe is the cause of our inability to document successful reclamation. Our definition of successful reclamation is based on ambiguous terms or on ideas and concepts that we have not fully considered. I will attempt to illustrate this.

Diversity

The first of these terms was 'diversity'. As several authors have pointed out this term has almost as many definitions as individuals attempting to define it (Chambers 1983, Whittaker 1975, McIntosh 1967). It definitely is not species richness, or simply the number of species within a predetermined area because diversity includes some intangible reference to the distribution and number of each species. This is what makes it so hard to quantify, these intangibles. In addition to this weakness if we carefully inspect undisturbed environments we find that in areas of uniform soil, slope, aspect, and exposure the number of species is surprisingly small. The reports of large numbers of species are always from more mesic areas to the east or if from our region then they are from disturbed sites, grazed sites, or landscapes of diverse soils, slopes, aspect, exposure, etc. But, both federal and state law or regulation require that those disturbing a site reconstruct a uniform soil of relatively constant slope on the site after the disturbance. How can the individual responsible for reclamation produce a diverse plant community on a disturbed site, even if we could define it, when they are restricted to a uniform environment? As Prodgers and Keck (1996) so apply pointed out habitat is one of the critical keys to vegetational diversity.

Production

Production was the second term I mentioned. In every instance in which a report describes the production measured on a disturbance the parameter measured was actually standing crop not production. Production is the amount of tissue produced by the plant not the amount of above ground biomass that was measured after a number of herbivores have chewed on the vegetation. Production should include the underground component of the plant. This is rarely measured. But in terms of site

stability it is probably more important that above ground biomass. Several years ago Rich Prodgers carried out a vegetation study in the area of a proposed coal mine near Circle, Montana. In one year of sampling he recorded between 10 and 20 lb/a of standing crop. On the same transects he recorded almost 2,000 lb/a the next year. A plant parameter that varies over two orders of magnitude from one year to the next is not a reliable interpreter of revegetation success.

Self Perpetuating

Many groups and individuals ask if the vegetation growing on a disturbance is self perpetuating. Federal and state laws or regulations state that vegetation on coal minesoils must be 'self perpetuating' or 'self regenerating'. I presume this means the plants must be reproducing themselves. This can not be addressed other then stating that the plants are forming seedheads because there are no safe sites for new plants to develop on young minesoils for many years after the original seeding. The following example illustrates this principle.

Area to be reclaimed: One acre

Seed Mix:	Rate (PLS)	
Grasses	Seeds/ft^2	lb/a
Western wheatgrass	4	1.5
Blue bunch wheatgrass	4	1.5
Needle-and-thread	4	1.5
Forbs		
Purple prairie clover	2	0.3
Prairie coneflower	2	0.1
Black sampson	2	0.6

If we assume that half of the seed germinates and establishes there remain nine plants on each square foot of soil. There are neither adequate nutrients nor sufficient water to support that number of rapidly growing plants. By the time of review for determination of adequacy of reclamation there are probably only one or two plants surviving on this foot of minesoil. Which plant will it be. Probably the one with the genetic constituents that enable it to utilize the resources of the site rapidly before another plant can absorb them and the plant lucky enough to find these nutrients and moisture. That is, the most competitive and tolerant of the seeded species. We are selecting cultivars for exactly those reasons. We want the new plants to be rapid growing and tolerant of the cold and drought of our prairies and mountains. They do this so well they absorb most of the nutrients and moisture in the soil and leave little for most other plants of the system.

What is the life expectancy of these plant on the Great Plains? We do not know exactly but we know that it is 10 years for some of these species and probably much longer than that, possibly several

decades, for many of the perennial grasses. Since our seeded area has produced the maximum number of plants permitted by the soil and climate of the area there are no safe sites for seeds to germinate and establish. How then can the investigator state that new plants are establishing on the site. The new plants cannot enter the ecosystem until one of the older plants dies and this will not occur for many years. The investigator can state that the plants growing on the disturbed site are setting seed and there may be a young plant or two but it is rare that it can be definitely stated that new plants have established from seed produced by the plants growing on the reclaimed site.

Native

Vegetation seeded on disturbed sites is to be composed predominately of native species. The reason given for this regulation is that natives are better adapted to the rigors of our soils and climate than introduced species. That isn't necessarily true and is becoming less so each day as more and more exotic plants invade our native grasslands. If it were true we would not have so many noxious weeds and few plants are as well adapted to the west as Crested wheatgrass (Walker et al. 1995). Introduced species may be undesirable but lack of adaptation to the site, low forage production, or lack of palatability can not be used as rejection criteria.

Succession

Finally, new plant communities growing on disturbed sites are supposed to be undergoing succession. Succession is defined as the progressive changes in vegetation and animal life that culminate in the climax plant community. Succession is readily observable during the first few years of plant growth on disturbed sites. Let us say three to five growing seasons as the annual weedy species that rapidly invaded the new plant community during its first growing season are replaced by the very aggressive, perennial, stress tolerant cultivars in the seed mix. During the next undetermined number of years very few changes occur in the plant community. Possibly a few tough weeds invade it, possibly two or more seeded species disappear from the community but the anticipated invasion of the site by propagules from adjacent rangeland does not occur in any great amount during anything close to the bonding period. Observations have not shown a return to anything like original vegetation on semiarid grasslands even when grazing is excluded (Laycock 1991, Allen 1988).

Successional concepts as developed in the more mesic coniferous forest of the west or in the more mesic east occur at such a slow rate on the plains that the changes cannot be measured in a few decades. We have no idea what final climax vegetation would look like on the Northern Great Plains and the foothills of the Rockies. What European man found when he arrived in the west was an ecosystem maintained by burning and grazing. This system was never allowed to develop to a climatic climax but was maintained in a fire climax. Lewis and Clark (Ambrose 1996) noted the large fires used by the native Americans to mark the flotillas progress westward and fire was also used by the American Indians to remove vegetation surrounding winter villages. As early as 1793 fires on the Northern Great Plains were noted. Fidler (1793) said, "These large plains either in one place or another is constantly on fire..." He further noted that, "The lightning in the spring and fall frequently lights the grass, and in winter it is done by the Indians." These were not small fires. Haley (1929) gave an account of a fire in

1885 that started in the Arkansas River country of western Kansas and burned 175 miles to the Canadian River Breaks of Texas. He also gave accounts of several large fires of 20 by 60 miles.

Clearly fire and climate are the major factors controlling vegetation on the Great Plains (Wright and Bailey 1980) and many authors maintain that fire is the reason why the Great Plains are treeless (Stewart 1953). Which stage of succession are the reclamation programs of the Great Plains to strive to create - the unknown climax, a forested stage, some seral grassland stage, or none at all. Many say establish what was there prior to disturbance. With the exception of plowed crop land most of the acreage disturbed by mining and linear rights-of-way on the Great Plains is native rangeland. But, this vegetation is a midseral stage of succession, a disclimax maintained by burning and grazing. If this is what we want than we in fact do not want succession to take place.

Clearly we need better criteria for reclamation success or final bond will never be released on many acres of western surface mined land. Reference areas or technical standards have value and should be incorporated into these new criteria but the terms mentioned above have serious shortcomings.

A POSSIBLE SOLUTION

If the soils, land forms, and hydrologic balance of the disturbed site have been rehabilitated and an approved seeding and planting has taken place what final criteria should be evaluated to determine reclamation success. Obviously, a thousand years of stable soil and vegetation production would be a good answer but not a realistic one. Some set of parameters must be defined to answer this question and they must be applicable within a reasonable amount of time. In our region the ten year bonding period of SMCRA is a reasonable starting point for a reclamation time frame.

For all disturbances from highway meridians and shoulders, through all types of mining, to hazardous and non hazardous waste disposal sites vegetation cover has been the parameter evaluated for determination of final reclamation success. At best this analysis has been a contentious determiner of reclamation success and in the worse case vegetation is simply not acceptable as the determiner. The best case occurs on surface coal minesoils with all of the problems noted above obstructing a clear definition of reclamation success. The worse case occurs on hazardous waste sites on which vegetation can be readily grown but is of questionable longevity. Rather than placing total confidence in plant performance I would like to propose that we give a better look at the soil profile than is presently advocated. The rootzone is less influenced by perturbations in the weather and several characteristics of this soil layer may be more clearly defined and evaluated than vegetative parameters. If the surface soil horizons express certain characteristics vegetation will develop on and in it whether intentionally seeded or not. Vegetation is in reality a visible reflection of the attributes of the rootzone. I shall discuss several attributes of soil on a disturbed site which might be evaluated to determine reclamation success.

Topsoil

Coal mine regulations necessitate that topsoil be salvaged and saved for application to recontoured minesoils, but, both the quality and quantity of this material are important to a functioning soil system. Stored topsoil may be degraded and require some type of rejuvenation after application to the disturbed landscape to quickly regain its predisturbance plant supporting capacity. The coal industry has rapidly learned how to maximize recovery and minimize destruction of this valuable resource. Highway departments have been slow to maximize recovery of better surface soils and still often spread poor quality material for topsoil along meridians or shoulders. The EPA, Forest Service, Bureau of Land Management, and state Abandoned Mines Programs often find themselves without any topsoil at disturbed sites under their jurisdiction. At these sites the construction of good quality topsoil may be accomplished but it is expensive and time consuming. Nevertheless, the importance of this soil layer to the performance of vegetation cannot be overstated. The quality and quantity of topsoil directly influence the germination, growth, production and reproduction of plants (Barth and Martin 1982, Doll et al. 1984). The quality of topsoil can be defined by determination of the chemical, physical, and biological characteristics of the material.

Biological System in the Soil

Organisms within and on the soil represent an integral component of a functioning soil system. While concentrated in the topsoil cover they also extend in limited quantity into lower horizons. They range from the small bacteria to animals as large as earthworms and small rodents. The major types and ranges of their numbers are available. The larger animals initiate the decomposition of plant and animal tissues by pulverizing, granulating and incorporating these materials within the soil. The smaller invertebrates and worms continue the process by degrading large organic materials to smaller pieces. Finally bacteria, fungi, and actinomycetes complete the conversion of large organic molecules to carbon dioxide, water and nutrients. All of these organisms are, therefore, indispensable in a healthy soil. Trends in the populations and species of these organisms can or already have been established. Decreases in the number of species precede degradation of plant communities. On coal mine sites when direct haul topsoil in applied to recontoured minesoils populations of these organisms are maintained or recover rapidly. When stored topsoil is spread on a site these numbers have been reduced. On polluted soils of many superfund sites the number of species are markedly reduced (Hartmen 1973) but construction of a new topsoil may raise their numbers.

Chemical System in the Soil

The enumeration of all of the chemical reactions in the soil is impossible but several major components of these reactions may be measured and serve to indicate that the disturbed soil has or is in the process of recovering from disturbance. Like the biological components of the soil system these reactions are concentrated in topsoil but they also occur to greater or lesser degrees in lower horizons. Parameters such as the infiltration rate and water holding capacity, cation exchange capacity, organic matter content, and concentrations of the major and minor nutrients are of major importance to a healthy soil system.

On coal minesoils the characteristics of materials in the top four feet of the profile are carefully regulated but such is not the case on superfund sites or hardrock mine wastes. At these latter sites the presence of materials with low water holding capacity or elevated levels of alkaline, saline, or acid generating materials within the top four feet of the soil profile are common. It may be as subtle as sandy materials with inadequate number of exchange sites to prevent leaching of nutrients or selenium leaching into ground water from surface layers; it may be an obvious problem such as acid generation in the cap on a tailings pond. These soil deficiencies may not even pose a problem within a reasonable amount of time (10 years). They may not be detectable without special studies but preliminary determinations can indicate their possibility and prevent construction of soils possessing these attributes. The presence of low cation exchange capacity and coarse textured materials or detrimental soluble trace element concentrations should be enough to prevent declaration of reclamation success even though plant growth on the soil surface may meet all success criteria as defined by pre-reclamation agreements.

Depth of the Rootzone

The Office of Surface Mining has already addressed this problem. Federal and most state regulations clearly state that a non-toxic layer of soil at least four feet thick must be laid over recontoured coal mine disturbances. Montana requires eight feet of this non-toxic material. Numerous range plants and many woody species commonly develop roots deeper than four feet. A toxic layer at four feet hinders the establishment or presents an obstruction to the long term persistence of these species on prairie or mountain soils.

The depth of non-toxic material is especially important at numerous superfund and abandoned mine sites across the west. The use of an 18 inch coversoil over toxic material has been demonstrated at Butte and a few other locations with phytotoxic surface materials. The limitations of this type of reclamation are obvious: few species composing the plant community and a continuing maintenance problem. The more subtle problems with this reclamation are not so obvious. Is the development of new soil on these sites compensating for soil loss? Is this what we want to call successful reclamation?

SUMMARY

This discussion was not intended to be a condemnation of any existing system of reclamation success determination but simply a suggestion that looking at other facets of the reclaimed landscape might provide a faster and better determinant of final reclamation success. Obviously, something is wrong. At one of the few coal sites approved for final bond release in Colorado a massive land slide wiped out many years of excellent plant growth. On the other hand many acres of livestock supporting minesoils in Montana have been awaiting final bond release for over a decade because they do not meet some minor determinate of reclamation success. At superfund sites the growth of three or four acid and metal tolerant species on 18 inches of coversoil over toxic wastes is considered successful reclamation despite the lack of topsoil and an adequate root zone. We should reevaluate present success criteria and develop a realistic set of parameters to be measured for final determination of reclamation success.

The vegetation growing on our prairie and mountain soils are the result of centuries of slow weathering, plant growth, grazing, regrowth, fire, and again regrowth. Every time they are disturbed they change. If you drive a vehicle across the prairie during the wet season the tracks of the vehicle are visible for many years. Plowed fields returned to grazing in the 1930's still do to support vegetation comparable to that found on adjoining non disturbed areas. Yet, we expect a minesoil to support vegetation comparable to that on the site prior to disturbance. At the same time in our haste to cover the scars of past mineral exploitation in our mountains we pull a few inches of non-toxic material over the disturbance and call it reclaimed. Somehow these two extremes do not mesh. There should be some middle ground, some criteria that indicate that in the long run things will continue to improve even though the site will never get back to what it was before disturbance. Yellowstone National Park will never be the same as it was before 1988 but it is improving daily. The vegetation and soils along many of our highways, on numerous minesoils, and around some superfund sites are also improving daily. We should be able to distinguish those that are improving, those that are successfully reclaimed, or those changing in a manner that suggests that they are successfully reclaimed and separate them from those sites that are destined to fail. I believe that looking into the soil profile is a step in the right direction.

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