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Soil Stockpiling for Reclamation and Restoration activities after Mining and Construction

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Stockpiling is a necessary part of civil engineering and mining operations. Stockpiling involves removing the topsoil (the A and B horizon of the soil). The topsoil is usually removed with heavy equipment and then piled in large, deep piles for the duration of the civil engineering or mining project. When the project is complete, the soil is re-spread to allow for the establishment of plants. The storage period for stockpiled soil ranges from a few months to several years. The depth of the stockpile and the length of time it is stored affect the quality of the soil at replacement.

Soil takes centuries to develop from parent material and organic matter. In a study of soil development of six sites where surface mines existed between 5 and 64 years earlier, the depth of the newly developed soil horizon in the 5-year-old site was 3 cm compared to 35 cm in the 55-year-old site (Thomas & Jansen 1985). Stockpiling and the subsequent reapplication of the topsoil, allows for planting conditions that are closer to the pre-disturbance condition than planting on the subsoil layers that remain. If stockpiled soil is reapplied quickly, with care to reduce the compaction inherent in the use of mechanical means for stockpiling, production potential remains.

Stockpiling procedures vary between civil engineering and mining operations. These differences and how they effect soil productivity will be discussed. Soil changes that occur when stockpiling techniques are used will also be discussed as will improvements and challenges in the use of this technique.

Soil Removal and Storage Practices

In the case of mining operations, the stockpiling process involves removal of the topsoil layer and any other soil layers necessary to get to the substance that is being mined. The topsoil is removed first and stockpiled in one pile and the soil layer below is also removed and stockpiled separately. This subsoil layer is referred to as the overburden. Stockpiles are often meters deep. When mining operations are complete, the overburden material is reapplied and leveled and then the topsoil is reapplied and spread over the overburden material to provide a planting medium (USDA Forest Service RM-447). Both removal and replacement of the soil layers involves the use of heavy equipment.

Because mining operations involve removal and storage of both layers, mixing of subsoil and topsoil layers can create plant establishment problems. The subsoil layers lack the organic and microbial organisms necessary to sustain plants. Mining operations often require that topsoil be stored in stockpiles for long periods of time, often several years.

In civil engineering activities, such as road construction, the topsoil is scraped off and stockpiled in large, deep piles due to the limited space that construction staging allows. Topsoil is stockpiled because it does not meet the density and compaction specifications necessary to use it as a base. Road base must be impervious and it is difficult to create an impervious surface for road base using topsoil. The layer just below the topsoil contains very little organic material and by comparison to topsoil is poorly aggregated, but does make a good base. It is therefore not stockpiled as in mining operations. When construction activities are complete, stockpiled topsoil is replaced. Replacement and removal usually involves the use of heavy equipment.

The soil stockpiled in road construction activities in Minnesota, USA is replaced relatively quickly. State contractors are required to replace topsoil within a couple of months, based on erosion control specifications for state projects. Most civil engineering projects involve similar standards for erosion control. Bob Jacobson, a botanist for Minnesota's Department of Transportation (Mn/DOT), explained that the existing state guideline for replacement of topsoil in construction contracts calls for the replacement of a minimum of three inches of topsoil. Contractors are in compliance by applying the three inch minimum, even if twelve inches of topsoil were removed and stockpiled (Jacobson 1999). The primary goal of road construction contractors is to build roads that last and to stabilize road cuts. The idea of replacement of topsoil to create a planting medium is a secondary consideration for contractors.

Changes in Soils During Storage

The natural process of soil development can take hundreds of years. Stockpiled topsoil becomes highly degraded the moment this long-term structure is disturbed. Research studies reviewed herein lead to one timeframe where the most damage occurs. This timeframe is when topsoil is initially stripped from the ground. Changes that occur in soil include increased bulk density, decreased water holding capacity, chemical changes, reduced nutrient cycling, reduced microbial activity, and loss or reduction of viable plant remnants and seeds.

Abdul-Kareem and McRae (1984) state that while it is clear that adverse effects due to storage and earthmoving equipment exist, the extent of deterioration of soil in stockpiles has been greatly overestimated. They go on to say that their studies in England show that there is no reason why soils should not continue to be stockpiled although with greater care given to minimize compaction and mixing of topsoil with subsoil. Studies by Williamson and others (1990 as well as Widowson and others (1982), conducted in Wales and New Zealand, have shown that the soil pH, and the mineral content of stockpiled soils are not effected, as long as the soil is not stored for long periods of time in deep stockpiles. These studies have also found that the soil biology of stockpiled topsoil bounces back relatively quickly once the soil is re-spread.

However, Harris and Birch (1989) noted that when soil was stockpiled in piles that were more than a meter deep, chemical effects such as accumulation of ammonium and anaerobic conditions occurred in the topsoil at the base of the pile. Other detrimental biological effects include absence of propagules and decrease in viability of buried seeds. In their study of soil microbial activity in British opencast coal mine restorations that utilized stockpiling techniques, Harris and Birch (1989) found less carbon stored in the soil and that this decreased further after re-spreading. Their study also noted detrimental effects of topsoil storage including heavy losses in the microbial community and decreased nutrient cycling.

In studies conducted by Visser and others (1984) in Alberta, Canada, one of the most immediate consequences of stockpiling they noted was the loss of organic carbon levels. Organic carbon levels were reduced by as much as thirty percent. This reduction in carbon was an immediate rather than a slow loss over the duration of the study.

This assertion is further backed up by research conducted by Jordon (1998) who found major losses of nutrients from ecosystems to generally occur when the nutrients are not incorporated in the food chains of soil. Losses occur when the input of organic matter ceases, such as when deforestation or strip mining occurs and soil is damaged. He further notes that in order for soil to be productive, there must be a continuous flow of energy in the form of carbon compounds through the soil organisms.

Fresquez and Aldon of the USDA Forest Service (1984) noted that topsoil stored for years, and especially the mining overburden material, has little biological resemblance to the undisturbed surface soil and that the resulting reductions to the fungal genera and microorganisms result in an unstable and unbalanced soil ecosystem. Prolonged storage was also a part of the research conducted by Harris and Birch (1989). They concluded that prolonged storage intensifies the loss of the bacterial element of the soil. Mycorrhizal fungi are a very important part of the microbial community. These fungi are often reduced or destroyed by stockpiling. Mycorrhizae fungi grow symbiotically with the roots of higher plants. The general beneficial effect of the micorrhizal condition on plant growth is one of improved mineral nutrition, specifically, enhanced nitrogen and phosphorus uptake. Mycorrhizal symbioses is also documented as protection against pathogenic fungi (Tate & Klem 1985).

An additional benefit to this symbiotic relationship, is how mycorrhizae hyphae form an extensive network in soil. These hyphae are covered with extracellular polysaccharides that form soil aggregates. These aggregates are held intact by the roots so that they do not collapse in water. This forms pore spaces and drainage channels. In a study, conducted in Derbyshire, England, of the relationship between aggregate stability and microbial biomass in three restored sites, a linear relationship was shown to exist between the health of the microbial community and the quality of soil structure (Edgerton, Harris, Birch, & Bullock 1995). The microbial community is responsible for the development of a soil structure conducive to the various biogeochemical cycles (Tate & Klem 1985). Deep stockpiles create both high and low moisture problems, which limits soil microbial respiration. To maintain a healthy microbial community, soil moisture must have some constancy in order for fungal propagules to survive.

Refining Soil Stockpiling Practices

Stockpiling techniques, and the wholesale removal of the topsoil layers, reduce the chances for succession for much of the pre-existing vegetation. Plant fragments from pre-existing vegetation are lost or greatly reduced. The seed bank is also reduced, and what does remain must compete for the reduced nutrients with microbes. These microbes become highly competitive as the base of stockpiles become anaerobic.

In addition to a loss in the breakdown of organic matter, stockpiling causes many other deleterious changes including a marked drop in the earthworm population (Johnson et al 1991) which effects soil nutrients, bulk density and water holding capacity.

Stockpiling effects the restoration/reclamation efforts in both civil engineering and mining operations. In order to mediate some of the damages caused by stockpiling, new and revised techniques are being used. One technique to mediate soil damage in stockpiling involves minimizing the depth of stockpiles. For optimum survival of mycorrhizal propagules, the depth of stockpiles should be restricted to the rooting depth of covering vegetation (Tate & Klem 1985). If plant cover can be maintained with roots extending throughout the depth of the stockpile, nutrient cycling processes and microbial activity can continue while the stockpile is stored.

Depth is important, but the duration of storage is also a major factor in maintaining soil health and productivity. In a recent reclamation effort in northern Minnesota, USA, shallow, bermed stockpiles were used to allow for better soil health during a road construction project. The project involved the Department of Natural Resources, Department of Transportation, and numerous local volunteer groups working together to protect an area that contained a prolific swath of orchids native to Minnesota including the state flower. The road improvements were necessary to handle the increased traffic due to growth in the seed potato industry in the area, and due to the roads deteriorating condition. Orchids are long-lived and slow to develop. Seventy-five percent of their natural habitat has been destroyed, but orchids were growing in great numbers along these roadside ditches (Haapoja 1999). With wet soils and railroads nearby to keep the area clear of trees and brush, optimum conditions were created for the native orchids. In order to protect the plants as well as the seed bank during construction activity, a modified stockpiling technique was used. The topsoil was carefully stripped and stockpiled in low berms and replaced in less than a month so that the seed bank, the plants, and the mycorrhizal fungi necessary for their continued success would not be lost (Jacobson, 1999).

Another technique that will allow for greater success of stockpiling is to re-spread topsoil at the same depth or greater than what existed pre-disturbance. In civil engineering projects, contractors often re-spread only what is minimally required by local standards and contractual obligations. They then sell any remaining topsoil. Soil inoculation with the mycorrhizal fungi that existed pre-disturbance is also a technique currently being used with some success.

Recommendations and Conclusions

With all of its deleterious effects, topsoil stockpiling is still better than attempting to establish plants in the soils that exist below the topsoil layer. Recent research shows that anaerobic conditions and poor nutrient cycling result from deep stockpiling, especially stockpiles deeper than one meter. Studies also show that long-term storage is detrimental to soil health. New techniques are being used with varying rates of success. Engineering and mining firms involved in restoring mining and civil engineering sites are being made aware of how long term storage and depth of stockpiles affect the soils' productivity. Standards for optimum size and shape of stockpiles need to be established.

Mining operations were to use the same types of staging techniques used in civil engineering operations soil productivity after stockpiling may improve. For example, road construction projects use staging so that only limited parts of the road must be closed at any given time. Staging the project means that stockpiles are often re-spread in a very short timeframe, a few months or less. If mining operations could be staged in a similar manner, it is possible some of the effects of long term stockpiling could be reduced. Another challenge in both mining and civil engineering operations that use stockpiling is in the use of heavy equipment to remove and replace topsoil. Although research shows that use of heavy equipment results in compaction, no research was available on a better way for moving the large amounts of soil to be stockpiled.

In conclusion, in order to achieve site stabilization, minimize degradation, and facilitate the long-term recovery of these mining and civil engineering sites with an aesthetically pleasing landscape, an understanding must exist that the successful recovery of these sites is dependent on soil quality. Topsoil stockpiling is a valuable technique, but restoration plans must be guided by research such as those studies reviewed herein so that the soil that is re-spread back onto these sites is productive.

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