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Source: Natural Areas Journal, 35(1) : 45-53

Published By: Natural Areas Association

URL: https://doi.org/10.3375/043.035.0107

CONSERVATION ISSUES

Best Management Practices: An Integrated and Collaborative Approach to Native Plant Restoration on Highly Disturbed Sites

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Natural Areas Journal 35:45–53

ABSTRACT: Revegetating highly disturbed sites in the western United States with native plants is challenging because of poor soils, harsh climates, and the lack of native plant materials suitable for many restoration sites. While there are a variety of products and equipment available to the revegetation specialist, integrating these tools into project planning and construction is often the weak link to successful revegetation. Over a decade ago, the USDA Forest Service and USDOT Federal Highway Administration formed a partnership to address the challenge of restoring native plants on roadsides. The Forest Service has used this partnership as a model for working with other agencies on revegetating abandoned mines, degraded rangelands, high elevation sites, and constructed wetlands. Beginning in the early phase of a project, engineers, environmental specialists, and revegetation specialists work together to craft a revegetation plan at the same time construction plans are being developed. As the project moves into the construction phase, the revegetation specialist, construction engineer, and contractors work together to ensure that the revegetation plan is properly implemented. When the project is completed, the revegetation specialist monitors the results of the revegetation effort and reports the findings. This collaborative effort increases the understanding of available restoration tools, including: (1) when to use them; (2) their effectiveness and costs; and (3) how they are realistically implemented on construction projects. Collaboration has been a key factor in increasing success and advancing the development of new methods and strategies for restoring native plants to highly disturbed sites.

Index terms: climate surveys, monitoring, mulch, outplanting techniques, plant materials, revegetation plan, seed production, soil compaction, soil surveys, stocktypes, vegetation surveys

INTRODUCTION

Revegetating highly disturbed sites presents particular challenges because of lack of topsoil, shallow soil depths, steep erosive slopes, soil compaction, and difficulty in locating appropriate plant materials from commercial sources. Compounding these challenges, revegetation is often conducted in a "one size fits all" approach, where contract specifications are broadly applied without regard to the uniqueness of the project environment. Failed revegetation projects often result in increased soil erosion, sediment runoff to streams, and invasive plant establishment. While there are many restoration tools, products, and methods available, appropriately integrating these practices into a restoration project is often a weak link in achieving success.

Restoration Services Team

In the late 1990s, the US Department of Transportation Western Federal Lands Highway Division (WFLHD) was under increased scrutiny concerning the impacts of roads on the environment. State and federal water quality laws were requiring greater vegetative cover along roadsides; federal agencies were applying stricter oversight on the origins of native plant materials being used on public lands; and the spread of invasive species along roadsides was an increasing problem. In order to address these issues at a project level, WFLHD created a partnership with the USDA Forest Service (USFS) in which the USFS would provide expertise in natural resource management, expertise that was lacking within WFLHD. This partnership also provided opportunities for designing roadsides for other values, such as enhancing wildlife, improving scenic quality, and sequestering carbon through the manipulation of roadside vegetation. The early partnership resulted in many successful revegetation projects, and in 2007, the USFS Pacific Northwest Restoration Services Team (RST) was formed as an interdisciplinary group that would specifically focus on restoration of disturbed lands with native plants. The team was, and continues to be, composed of revegetation specialists with backgrounds in botany, soil science, nursery management, genetics, silviculture, erosion control, and riparian restoration. RST works specifically on projects associated with road construction, mine reclamation, wetland construction, range improvement, high elevation restoration, and riparian enhancement. While assembling an interdisciplinary team to tackle complex forest management projects is not new, it is seldom done for native plant restoration projects.

THE INTEGRATED APPROACH

Moving away from a "one size fits all" or "off the shelf specification" driven approach to revegetation, the RST and WFHLD developed a "best management practice," integrating revegetation expertise and collaboration into all phases of a construction timeline. Revegetation planning that is coordinated with the early phases of construction planning is an integral part of a successful project. Collaboration during the implementation phase can ensure everyone involved understands the importance of the revegetation plan. Monitoring that follows implementation can determine the need for any further treatments or provide the opportunity to learn what can be applied to future projects.

Site Assessment

The western United States encompasses a wide diversity of soils, vegetation, and climates. Understanding how these factors affect plant establishment determines the success of a revegetation project. Early in the planning phase, RST members become familiar with all aspects of the project area by assembling information pertinent to the project site from available sources.

Soil, Climate, and Vegetation Surveys

Initial soils information is obtained prior to field surveys through the Web Soil Survey website (NRCS 2014). The project area is outlined on a web-based map of the United States, which generates a soils report and soils map. Climate information is obtained from the PRISM Climate Group website (PCG 2014) by providing the latitude and longitude of the project site. The website extrapolates weather data from surrounding weather stations, incorporates an elevation model, and reports out temperature and precipitation data for the past 30 years to that location. Federal, state, and local land management agencies may also be contacted for further information.

Field surveys build on this information by providing a more thorough assessment of the soil, vegetation, and plant associations found throughout the project. A soils assessment provides information on texture and structure, water-holding capacity, topsoil depth, site organic matter, nutrient availability, and other information that may have an impact on revegetation success. Vegetation surveys are used to develop a comprehensive species list that will aid in choosing the workhorse species, developing working groups, and identifying potential weed species. Field surveys also allow for the establishment of reference sites to serve as natural models in designing the desired plant community, and for later monitoring and evaluation of the project following implementation.

Limiting Factors

Identifying limiting factors that could hinder plant establishment and developing possible mitigating measures to overcome these factors are critical steps in the initial planning process. Steinfeld et al. (2007) identified 39 limiting factors that are common in the western United States. These are grouped into nine major categories:

- Water input
- Water storage and accessibility
- Water loss
- Nutrient cycling
- Surface stability
- Slope stability
- Weeds
- Pests
- Human interface

Although not all factors will be of equal importance, each is systematically considered, with focus placed on those of the greatest concern to the establishment of native vegetation at that particular site.

Site Resources

Resources that could be used as mitigation and for revegetation are identified during field assessments. When considered early in the planning process, topsoil, duff, and litter layers can be salvaged and reapplied to disturbed sites. Woody materials produced from clearing and grubbing operations can be chipped or ground for use as mulch. In addition, seeds, plants, and cuttings can be salvaged and used for revegetation following disturbance.

The Revegetation Plan

A revegetation plan is developed during the planning phase using the project design, objectives, and information collected on soils, vegetation, and climate. The written plan is the outcome of the collaboration between the restoration specialist and the planning agency, and serves as a framework for the entire revegetation effort. A final revegetation plan typically contains the following elements (Steinfeld et al. 2007):

- Project objectives
- Revegetation objectives
- Overview of vegetation, soil, and climate
- Description and delineation of revegetation units
- Desired future condition for each revegetation unit
- Limiting factors and site resources
- Site specific revegetation methods and techniques
- Weed management plan
- Special contract specifications
- Species and plant material needs
- Plant propagation plan
- General monitoring strategy
- Timeline
- Roles and responsibilities
- Budget

Obtaining Appropriate Plant Materials

Collecting seeds and vegetative material must be done early in the planning phase because of the length of time required to produce plant materials. The USFS has implemented policy (USFS 2009) that directs the use of genetically appropriate, locally adapted native plant materials when revegetating disturbed sites on national forest system lands. Plant materials (seeds, cuttings, bulbs, seedlings, wildlings) used on a revegetation site must be started from a reproductive source that is local and presumably adapted to the revegetation site. Seed Zone Mapper (WWETAC 2014) is a public website that provides mapping tools and guidelines for determining the appropriate distance that plant materials can be collected from the project and still be adapted to the site. Species-specific seed zone maps are based on empirical results from genecological analyses of common garden studies (for example, see Erickson et al. 2004; Johnson et al. 2010; St Clair et al. 2013). Climate-based provisional seed zones (Bower et al., in press) are used to collect and select appropriate plant materials for species lacking empirical genetic information and seed transfer guidelines (Figure 1).

Many federal agencies have collected and stored seeds from a variety of seed zones for use on restoration projects. When seeds from appropriate sources are not available, wild seeds are collected from, or near, the project site by experienced seed collectors. Because species grow in different locations and seeds ripen at different times, collecting seeds from multiple species in any given year involves good planning and execution.

Large quantities of grass and forb seeds can be harvested from seed production beds or fields that were started from wild seed collections. For federal managers, seed production can take place at federal nurseries or be administered through an indefinite delivery/indefinite quantity (IDIQ) contract at native seed production farms. Well-defined industry standards are utilized to maintain the genetic integrity of the various seed sources. When working with commercial nurseries, however, it is important to verify the origin of plant materials because not all nurseries recognize the importance of local sources. Early planning is again essential because first-year seed harvests are typically low for many species; optimum quantities of harvestable seeds are often not produced until the second and third years. Following harvest, seeds are cleaned, tested, and stored until needed for revegetation. The timeline for having adequate quantities of seeds available for a revegetation project typically spans two to three years.

Tree, shrub, and some forb seedlings for outplanting are predominantly grown from wild-collected seeds. Although bareroot seedlings are occasionally used, container plants, particularly those grown in larger containers, have proven superior to the challenging conditions of most highly disturbed sites. Because of the large container size and slow first-year growth for many native shrub and tree species, plants typically require two to three years in a nursery to reach a plantable size.

Controlling Weeds

Weed control typically begins during the planning phase with the identification of populations of invasive species found in the project area. A collaborative effort between the restoration specialist, the planning agency, and local vegetation management specialists leads to the development of a strategy to control invasive species through mechanical and/or chemical treatments. The RST often develops agreements with local government agencies for weed control on and near the proposed disturbances throughout the lifespan of the project. During the implementation phase, contract specifications are enforced that require vehicles and equipment to be steam-cleaned prior to entering the project area. Materials brought into the site, including fill material, topsoil, rock, and hay, must be "certified weed-free" or approved by a botanist to ensure they are free of invasive species.

The RST takes the approach that controlling weed invasion begins with soil improvement because a healthy, productive soil is more conducive to establishing perennial native plants than a poor one. Weedy annuals out-compete native perennial grasses and forbs on soils that are compacted, lack topsoil, or are low in organic matter. Practices that salvage topsoil, increase organic matter, reduce available nitrogen during seedling establishment, increase rooting depth, and reduce compaction will encourage the establishment of perennial species over annual weeds. Seeding with a mix that contains multiple species adapted to the site must be scheduled at appropriate times of year for optimum seedling establishment. By rapidly establishing a dense stand of the desired mix of native plants adapted to the project environment, invasive species are less likely to gain a foothold.

Implementation

Collaboration between the revegetation specialist, project engineers, and contractors during construction activities assures that the revegetation plan is understood and implemented appropriately on the ground. Through this collaboration, a timeline is created to incorporate revegetation activities at the appropriate phases of construction to increase the chances of revegetation success. When project construction begins, the revegetation specialist is available to consult on contract specifications, including placement of salvaged topsoil, soil treatments, and temporary/permanent erosion control measures. The specialist can also evaluate the quality of the material sources, such as topsoil, mulch, and erosion control products, to prevent the introduction of invasive weed seeds. As changes occur, the revegetation specialist and engineers work together to assure that the revegetation plans are modified appropriately.

Seeding and Planting

The revegetation specialist typically has direct control over plant installation operations, thereby assuring that the revegetation plan is being implemented accordingly. There are a variety of seeding, planting, and mulching methods available for revegetation projects. It is critical to select the most appropriate ones based on specific site conditions. For example, where precipitation rates are high and fall temperatures are mild, hydromulch with tackifier is often sufficient for adequate seed germination and plant establishment; on more arid sites, a deeper seed cover is required. Shredded wood fiber (wood chips) applied over seeds at a depth of 2 to 2.5 cm (0.75 to 1 in), creates a stable, moist environment for good germination in these climates. The RST has developed a pool of restoration companies that are highly skilled and who collaborate in developing better ways of accomplishing restoration work.

Plant Establishment

Plants may require some form of care for several years following establishment depending on the environmental site conditions. Planted seedlings may need protection from deer browsing using fencing, repellants, or netting around each seedling. For seeded sites, one or two fertilizer ap-

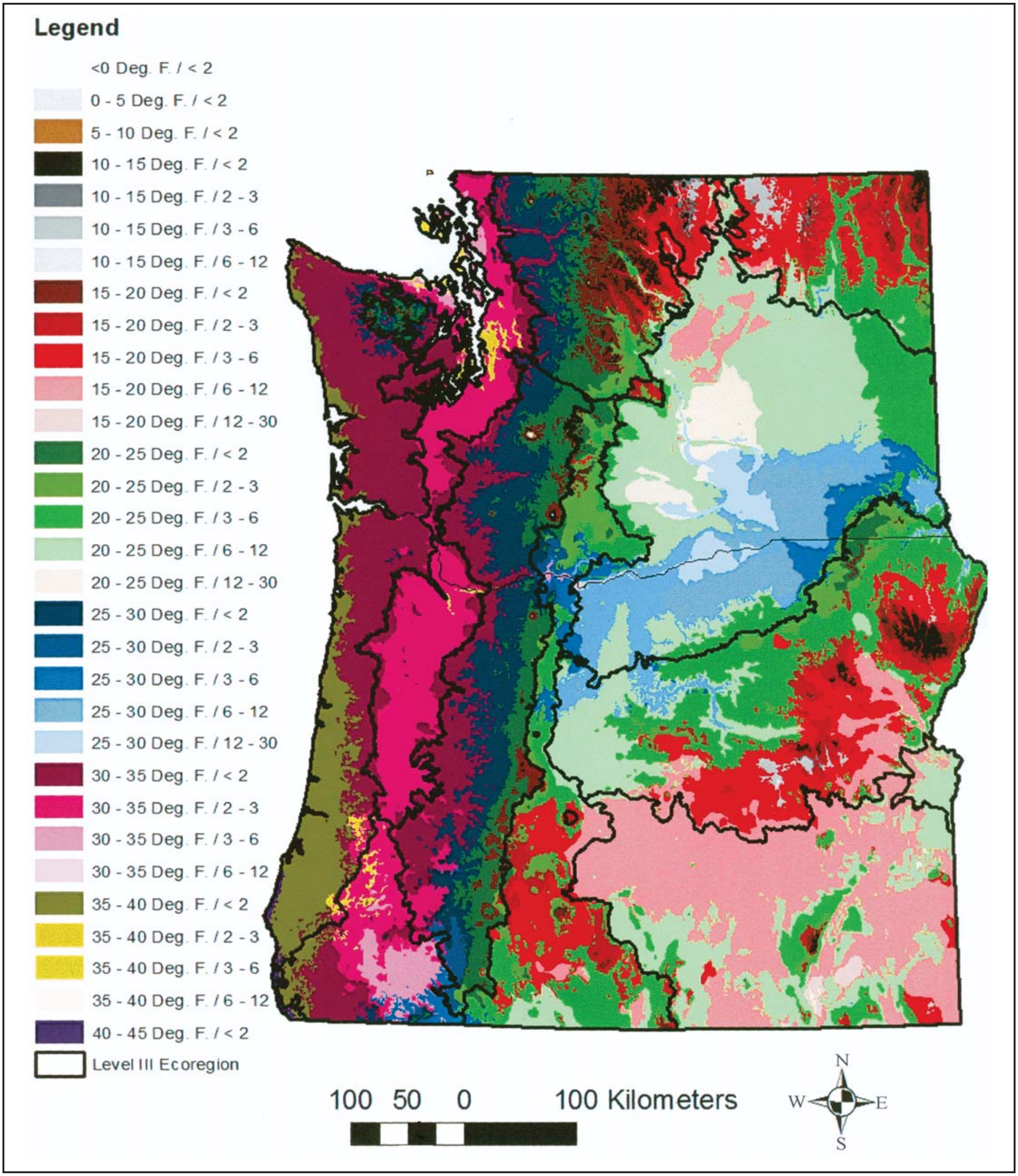

Figure 1. Provisional seed zone map for Oregon and Washington. The first variable represents winter minimum temperature class bands (5 °F bands correspond to 2.8 °C). The second variable is the annual heat : moisture index (AH:M) that was used as a measure of aridity. It was calculated as mean annual temperature (MAT) plus 15 °C (to obtain positive values) divided by mean annual precipitation in meters (Hamann and Wang 2005). AH:M was then divided into six discrete classes (2, 2–3, 3–6, 6–12, 12–30, and 30), where higher values indicate more arid environments.

plications may also be useful in the years following seeding. Where soil nutrients are very limiting, a fertilizer schedule based on when plants can best use the nutrients is recommended. Rather than the traditional method of applying a large dose of fertilizer during seeding, the RST recommends larger applications of fertilizer months or years after the plants are established. Fertilizers applied during seeding are not needed by the young germinating plants and often encourage weed development. In addition, surplus nitrogen leaches into ground water or streams and decreases water quality.

Project Monitoring

Monitoring is one of the most important, but often neglected, parts of a restoration project. A preliminary monitoring plan is developed during the revegetation planning phase, and is finalized upon project completion. The monitoring plan includes monitoring protocols and a list of the areas to be monitored. It also identifies which specialists will be needed for data collection, the month and year of data collection, and type of analysis that will be performed. Findings are presented in both interim and final reports. The RST takes the philosophy that if monitoring is not simple, inexpensive, and objective-based, it will not be done well, or done at all. A set of monitoring protocols has been developed that address the unique challenges of revegetating highly disturbed sites. These protocols are designed to be easy to use and statistically based (Steinfeld et al. 2007). One innovative monitoring program, the Cover Monitoring Assistant (CMA), was developed collaboratively by the RST and WFLHD (Steinfeld et al. 2011). Instead of collecting vegetative cover data in the field, photos of each quadrat are taken and analyzed later in the office using the CMA program (Figure 2). This protocol reduces expensive field time, increases data collection accuracy, and runs a statistical analysis of the data.

Figure 2. Photo monitoring in the field for use with the Cover Monitoring Assistant program.

The final monitoring report outlines the revegetation work conducted on the project, summarizes the monitoring data, and addresses whether the revegetation objectives that were developed in the planning phase were met. Information gathered during monitoring can be used to modify ongoing revegetation efforts, improve the effectiveness of similar projects in the future, and determine the success of new revegetation practices implemented on the project. Such findings can expand the revegetation toolbox if shared with other practitioners.

SITE-SPECIFIC RESTORATION INNOVATIONS

The following are several of the important practices that have been improved upon over the years by the RST. The implementation of these innovations would have been unlikely without the interdisciplinary approach to restoration.

Wood Fiber Mulch Production and Application

Grinding woody debris into small fibrous strands has been carried out by the RST for the past 10 years. This practice was the outcome of two problems facing the road construction engineers and revegetation specialists: 1) what to do with the large amount of slash being created by road right-of-way clearing; and 2) the need for a thicker mulch layer to increase seed germination in arid and semi-arid climates.

In the past, large slash piles composed of roots, limbs, and boles of trees and shrubs were burned as a method of disposing unwanted material. This activity, however, has become more difficult due to tighter fire restrictions (air quality and fire hazard), costs, and potential damage to resources associated with burning. An alternative was to process the material into long strands of wood, let it compost in piles, and after year or two, use it as a mulch or soil amendment.

The benefit of returning organic matter to sterile, constructed roadsides is immediate. Placing a wood fiber mulch over seeds at a depth of approximately 2 cm (0.75 in) increases germination significantly by moderating soil moisture and temperatures around the seeds during germination. The soil surface is protected from rain-splash and overland flow, so soil erosion is significantly reduced. In addition, wood fiber mulch protects the surface from evaporation, particularly on hot, dry sites, retaining moisture for plant growth that normally would be lost.

Large grinders are brought to the slash piles to process the woody debris into fibers and the resulting material is placed in large piles where it composts (Figure 3). During the composting period, pile temperatures and decomposition rates are monitored, and piles are usually sufficiently composted after one year. Sites are seeded in the fall with native seeds and immediately covered by a layer of composted wood fiber. Wood fiber is applied with either a mulch blower or mulch slinger. While mulch blowers are readily available, they are slow and frequently plug with the occasional large piece of wood that makes it through the grinder. Mulch slingers and manure spreaders, adapted to spreading shredded wood, eject the material directly from the trailer onto the site, which has significantly increased application rates.

Figure 3. Grinding woody debris from slash piles to be used as mulch.

The RST has also experimented on other projects with using ground wood fiber as a soil amendment on sterile soils with low organic matter. Wood fiber and compost have been mixed into road ditches that drain into live streams (Figure 4). Not only do these amendments improve the soil for

Figure 4. Wood fiber was mixed into the upper portion of the road ditch, which slowed runoff, improved infiltration, and allowed for filtering of chemicals from road runoff.

plant growth, but they also improve infiltration and water storage, allowing road runoff to move into the soil for filtering. Wood fiber has also been incorporated into constructed slopes, with an immediate effect of significantly reducing soil erosion and runoff after major rainfall events. The longer term effects of adding organic matter to the soils will be to speed up soil development that is vital for self-sustaining native plant communities.

Reducing Soil Compaction

Soil compaction affects plant growth by restricting root growth and reducing the amount of soil moisture available to plants. Compaction also reduces the rate at which water enters and travels through the soil. If rainfall rates are greater than infiltration rates, then water runs off the slopes, often carrying soil and seeds with it. The RST works with engineers and other specialists to develop practices that reduce soil compaction. This has taken some education of both the revegetation specialist and the road engineer. Long-standing road construction practices, such as trackwalking (Figure 5), actually require the soils to be compacted to increase slope stability, but the effects from a revegetation standpoint are to reduce successful plant establishment. RST members now collaborate with engineers on projects to determine where soils must be compacted and when it might not be necessary. Over the years, the RST has found that road engineers can often accept leaving the top 30 to 45 cm (12 to 18 in) in a noncompacted condition.

Figure 5. Trackwalking is often used to increase slope stability, but will compact both surface and subsurface soils.

The excavator is a great tool to apply soil without compaction. Soil is lifted in a bucket and placed on the slopes where it can be left rough or slightly pressed by the excavator bucket to create a smooth surface (Figure 6). Since surface roughness is important for reducing runoff and erosion rates, the buckets of some excavators have been adapted to produce imprints when the bucket is pressed into the soil. By welding several strips of angle iron to the face of an excavator bucket, the resulting imprint looks much like the imprint of tractor cleats after a slope has been trackwalked. Once soils have been placed, any travel with ground-based equipment is restricted to avoid subsequent compaction.

Figure 6. Bucket imprinting is used to press soil into place, but does not compact soils to negatively impact revegetation.

Native Grass and Forb Seed Production

The RST uses grasses and forb species for most revegetation projects. As previously discussed, the large quantities of seeds needed for RST projects require that seeds be produced at native seed production farms (Figure 7). Team members begin early in the planning process to assure that seeds are available when the slopes are ready for seeding. Typically because seed producers require two to three years for full seed production to occur in many species, the process may require up to three years before seeding is planned. When the RST first began using native seeds on projects, the per-acre costs for seeds were high. This began to change as more seed orders were being made through innovative seed companies. With greater experience in seed production, seed producers became more efficient in their practices and seed prices subsequently dropped. During the same period, the RST was gaining valuable field experience using native seeds on dozens of projects. This field knowledge, coupled with improved restoration practices, has reduced the quantity of seeds applied per acre, resulting in lower native seed costs for a project.

Stocktypes and Outplanting Techniques

Stocktypes for outplanting on highly disturbed sites often differ from those used in reforestation. For example, in areas of lower precipitation, disturbances that remove topsoil and soil cover leave harsher and drier conditions. Container stock with large root systems have significantly better success rate than traditional planting stock (bareroot or smaller containers). In areas where slope stabilization is necessary, stock grown in “long tubes” (typically 45 to 60 cm long by 7.5 cm diameter [18 to 24 in by 3 in]) will establish quickly and allow for faster root establishment for soil stabilization. The RST has worked with several nurseries to develop new stocktypes that will increase survival, establish faster, and expedite the evolution of the site into

Figure 7. Large quantities of seeds needed for restoration projects are produced at native seed production farms.

a self-sustaining plant community.

New stocktypes often require innovative planting techniques to increase outplanting efficiency and ensure survival. The RST has modified the waterjet pot planter (Figure 8) to install stocktypes ranging in size from 164 cm^3 to 15 L (10 in^3 to 4 gal). In addition, "long tube" stock can easily be planted on rocky sites, steep slopes, and riverbanks using an expandable stinger attachment on an excavator (Figure 9).

Figure 8. A waterjet pot planter can be used to install a variety of stocktypes and extend the planting season.

CONCLUSION

The outcome of integrating revegetation throughout the entire planning, implementation, and monitoring of construction projects has led to more successful revegetation projects. Typical problems in the past are averted through collaborative planning and implementation. The WFLHD and USFS partnership has increased the understanding of the restoration tools that are available, when to use them, their effectiveness and costs, and how they are realistically implemented on revegetation projects. The partnership has helped advance the development of new methods and strategies for successfully restoring native plants on highly disturbed sites.

ACKNOWLEDGMENTS

This paper, the collaborative process, and the innovations in technology would not have been possible without the remaining members of the US Forest Service Restoration Services Team: Scott Riley, Team Program Manager; Sarah Hash, Soil Scientist; Vicky Erickson, Regional Geneticist; Matt Horning, Eastern Oregon Area Geneticist. Also thanks to ad hoc team members, Kim Wilkinson, Tom Landis, and Chris Hoag.

Figure 9. Long tube stock can be planted using an expandable stinger attachment for an excavator.

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