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# PROPER SEEDING METHODS TO PROMOTE RAPID REVEGETATION OF DISTURBED DEPARTMENT OF DEFENSE LANDS

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# PROPER SELECTION OF HYDROSEEDING MIXTURES AND COMPONENTS TO PROMOTE RAPID REVEGETATION OF DISTURBED DEPARTMENT OF DEFENSE LANDS

## 1. Purpose

a. This Public Works Technical Bulletin (PWTB) provides guidance on selecting seeding methods for re-establishing vegetation on disturbed sites within military installations.

b. When correct seeding methods are chosen, re-establishment of vegetation on disturbed sites can be cost-effective, efficient, and ultimately more successful in protecting sites subject to disturbance by military activities.

c. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through URL:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

d. Applicability. This PWTB applies to engineering activities at all Continental United States (CONUS) Army facilities.

## 2. References.

a. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement," 13 December 2007.

b. Clean Air Act Extension, Public Law (PL) 91-604, 31 December 1970, as amended in 1990 (PL 101-549).

c. Clean Water Act of 1977 (PL 95-217, U.S. Code, Title 33 Part 1251).

d. Executive Order (EO) 13514, “Federal Leadership in Environmental, Energy and Economic Performance,” 5 October 2009.

3. Discussion.

a. Implemented in 2007, AR 200-1 requires that military installations be good stewards of land resources through the minimization of environmental impacts, which includes impacts of construction and maintenance practices, and of training.

b. Laws such as the Clean Air Act and Clean Water Act apply by dictating how Army training grounds are managed to maintain air and water standards.

c. The goals for EO 13514 establish an integrated strategy toward sustainability of federal lands which includes reduction of water use, water runoff, and the use of native plants for both land management and landscaping.

d. Failed efforts to establish vegetation on disturbed land can often strain environmental management budgets. With costs of vegetation establishment exceeding $2,000 per acre in some cases, successful establishment of vegetation during the first planting is necessary (cost information from PWTB-200-3-33, http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_3_33.pdf).

e. Seeding technologies should be chosen on the basis of topography, soil type, seed mixture, time of application, and price, and always with a goal of maximizing seed germination and promoting rapid vegetation growth at reduced costs.

f. Particular emphasis for this work was placed on comparisons between drill seeding, broadcast seeding, and hydroseeding indigenous vegetation, along with the optimization of these practices from a land management perspective. Variables associated with each practice were then matched with conditions present at Department of Defense lands across the contiguous United States. The results and proposed plan for optimally seeding disturbed sites are presented in this paper. Successful implementation of the plan will reduce expenses by improving vegetation growth efforts on the first attempt.

g. There currently exists no means of quantifying limitations of seeding methods. Such a lack of optimization too often leads to implementing one preferred method on an installation that could not only cost more but also result in reduced germination and reduced success of a seeding project. Methods presented are aimed at not only establishing long-term vegetation and erosion control but also providing short-term protection to assist in the re-establishment process. By implementing the recommended techniques, users can select seeding methods which will increase establishment results and reduce costs.

h. Appendix A reviews seeding methods by giving an overview of each technique, describing advantages and disadvantages, and discussing necessary equipment.

i. Appendix B describes a process for selecting seeding methods by considering slope, soil moisture, debris present, seed type, area to be seeded, and cost.

j. Appendix C describes the location, soil, slope, and weather patterns for each of the U.S. Army's Tier I CONUS installations, as well as a seeding method selection tool for these installations.

k. Appendix D lists major manufacturers of seeders and implements as well as companies specializing in other seeding products. This list is *not* an endorsement of these products but is meant to aid installations in researching individual products and to provide assistance in locating vendors.

l. Appendix E includes a list of acronyms used in this document and a short glossary of technical terms.

m. Appendix F lists references used in Appendices A–E.

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# Appendix A

## SEEDING METHODS OVERVIEW

### Introduction

Construction projects and land rehabilitation efforts frequently focus on what is often referred to as "hard engineering" such as structural and land form changes. Generally, the "soft engineering" efforts such as seeding and revegetation do not receive the necessary considerations required because project managers are limited by budget and time constraints. However, any endeavor to establish vegetation after construction or to rehabilitate a disturbed area after military training should be carefully planned because the rapid growth of vegetation will frequently determine the long-term success or failure of a construction or rehabilitation project for site sustainability and erosion control.

Frequently, the decision to use a particular vegetation technique is based on past practices at other sites and available equipment. While using such an approach may be expedient, it can backfire and end up costing more over time than is necessary. Costs can be controlled and the uncertainty of unsuccessful revegetation efforts can be reduced by carefully considering several vegetation planting techniques. The cost of site revegetation is mainly due to planting methods and materials (seed, bedding, etc.), and there are many seeding methods available that have made the selection of the most appropriate seeding strategy quite difficult. The most popular techniques are drill seeding, broadcast seeding, hydroseeding, and dry mulch seeding.

Each method has advantages and disadvantages relating to topography, soil type, time of seeding, and cost of seeding. Each of those factors should be considered carefully when choosing the best seeding method for the project. Seedbed preparation must also be factored into revegetation efforts because the seedbed creates the proper conditions for germination. Successful germination is the goal, and a higher rate of germination yields a higher percentage of cover. The importance of seedbed preparation, the factors affecting germination, and potential seeding technologies will be discussed to support a decision-making process that ultimately selects the best seeding method for a project.

**Seedbed Preparation**

The first step to successful re-establishment of vegetation is seedbed preparation. Seedbed preparation transforms the soil surface into a more desirable environment for germination. The soil matrix must provide adequate moisture and access to sunlight for increased germination. Moisture can be retained in the soil through conservation tillage and planting practices. Tillage and planting methods that help retain moisture include no-till drilling, cultipacker after planting, and non-inverting tillage methods. The goal of seedbed preparation is to provide the optimum moisture to the seeds through seed-to-soil contact such as that found in firm seedbeds. Without this optimum seedbed condition, a reduction in seed germination will occur. Additional factors such as weed competition can reduce available moisture, even in optimum soils. Weed establishment may be deterred through plant control by using chemicals, mechanical tillage, or fire.

Creating a firm seedbed will be the most effective way to provide recently planted seeds with much-needed moisture. The best way to conserve moisture is by minimizing soil disturbance during seedbed preparation and planting. This is difficult to achieve considering that construction sites and military training areas consist of predominantly disturbed soils. When soil is disturbed, infiltration tends to increase and moisture is retained at first.

After tillage operations, the soil surface is roughened, which can help retain moisture but can also cause crusting to occur, reducing infiltration. In the long term, no-till soils will tend to have much greater infiltration and moisture retention due to better soil structure (Franzluebbers 2002). Poor infiltration and loss of moisture can promote soil crust formation which will hinder germination.

If fieldwork is necessary, it should not be done if too much moisture is present because severe soil compaction may result. A cone penetrometer may be useful in determine soil compaction. Generally, soil resistance values of 1.5–2.0 MPa (megapascal) or higher are considered too compact to support dense vegetation. Soil compaction in this range will inhibit root growth, which is a necessity in preventing soil loss and controlling erosion. To test the soil moisture content, take a small handful and try to make a ribbon between the index finger and thumb. If the ribbon breaks off in 1–2 in. lengths, the risk of compaction is much less than if the soil forms a longer ribbon. This field test should be performed on the top 3-4 ft of the soil profile to determine if the soil moisture content is suitable for tillage operations (Al-Kaisi 2007).

To limit soil disturbance and to leave surface litter or mulch intact, non-inverting or conservative tillage methods should be chosen over those that invert the top layer of soil. Examples of non-inverting plows include paraplows, scarifiers, and rollers. These tillage methods leave a great deal of surface litter or mulch that will assist in conserving moisture. The use of rollers or chaining to cover broadcast seeds and to mechanically control weeds also creates depressions to catch and reduce runoff from rain events or snowfall, thus reducing soil erosion.

Deep-furrow drilling can increase soil moisture during germination by as much as 100 percent. Deep furrows will help reduce temperature and increase moisture around seeds. If deep furrow drilling is chosen, it should not be done in dry soils, since under these conditions, seed depths tend to be too large for successful germination (McGinnies 1959).

Oftentimes when the seedbed is tilled, it must be compacted again mechanically. The goal is a firm, weed-free seedbed. To achieve necessary seed-to-soil contact and conserve moisture, the seedbed must be made firm (where "firm" means that an adult footprint will be slightly visible on top of the prepared seedbed) (NRCS). Many times, seedbeds are at the correct firmness after chaining or no-till drilling (Monsen and Stevens 2004).

*Herbicide use*

Plant competition can often reduce moisture availability to germinating seeds. Herbicides can prove to be an excellent means of reducing weed competition to increase available moisture. Dead plant material left behind acts as mulch, and protects the surface from wind and runoff while allowing sunlight penetration.

There are several application methods used to apply herbicides including foliage application, stem application, and soil application. Foliage applications can use selective and nonselective herbicides. Foliage applications can be done by ground broadcasting or aerial broadcasting. Stem applications may also be performed on larger, stubborn weeds and brush. Applying herbicides directly to the stem, cutting trunks and wiping cut areas with herbicides, or a trunk injection will increase control measures on shrubs, large weeds, and brush in general. Soil-added herbicides can also be used to control weed competition, but must be used with care as many of these will stay in the soil for an extended period of time (Bohmont 1983).

After treating an area with herbicide, planting may be done within 7–10 days. If broadcast seeding is the selected method, light tillage could be done after seeding with a disk, leaving half of the residue remaining on the surface. Interseeding may also be done directly into dead plant matter, if done with proper planting equipment (MN/DOT Seeding Manual 2007).

Using herbicide correctly is an excellent way to prepare a seedbed. Not only does the use of herbicide leave surface litter on the site to further prevent erosion, but also the method leaves the ground undisturbed to create a firm seedbed and retain soil moisture. All herbicide use should follow the guideline set forth by AR 200-1.

*Primary tillage*

Primary tillage is another way to control plants. Primary tillage implements often invert topsoil (equipment in this category includes moldboard plows and disks). Some primary tillage implements that do not invert soil are chisel plows or paraplows (Gruver and Wander 2009). Inverting soil will increase soil erosion and may leave the soil in need of compaction before planting. There are several requisites associated with these seedbed preparation options. The soils must be free of rock and large debris, the operation occurs at slow speeds, and this seedbed preparation option cannot be operated by tractors on slopes exceeding a 3:1 ratio of horizontal distance to vertical height (Monsen and Stevens 2004).

Lighter tillage methods include land imprinting, harrowing, cabling, and chaining. Land imprinting creates small depressions that catch and hold moisture. This method does not work well in areas with highly compacted soils, rocky surfaces, or areas with dense shrubbery. Harrowing scarifies the soil while removing small shrubs and covering seeds (Figure A-1).

**Figure A-1. Pipe harrow (U.S. Forest Service 2004).**

Cabling is used to uproot larger trees and cover seed while limiting soil scarification. Cables are usually 1.5–2 in. in diameter and are towed in a U-shape or half circle behind two crawlers or bulldozers. Costs associated with operating are usually low as cables can be anywhere from 100–550 ft long and can cover larger amounts of space.

Chaining can simultaneously accomplish the same tasks as the land imprinters, harrows, and cables. There are a few types of chains including disk chains, smooth anchor chains, Ely chains, and Dixie-Sager chains. All anchor chains should weigh 40–160 lb per link with chain lengths of 90–350 ft (Larson 1982). Disk chains could be considered more of a primary tillage method. These chains have large disks cut out and mounted to every other link. Disk chains have been found to reduce vegetation establishment costs by 50 percent compared to conventional disking on rangelands, while also improving grass establishment (Wiedemann 1985). Smooth anchor chain is used to cover seed and release understory vegetation. Ely chains have railroad rails cut and mounted crossways on links (Figure A-2). Ely chains uproot and break off trees, scarify soils, cover seeds, and can operate on rough, rocky surfaces (Monsen and Stevens 2004). Dixie-Sager chains have railroad rails welded horizontal to each side of the chain link (Figure A-3). Dixie-Sager chains are used for the same purposes of Ely chains but are better at uprooting and killing shrubs and brush (Monsen and Stevens 2004). Chains are mainly used in semi-arid, rough, or rocky terrains that are free of trees and where anchor chain is available.

Priorities must be set when choosing a mechanical tillage method for weed control and seedbed preparation. A tradeoff exists between erosion prevention and weed control for all tillage types. Correct tillage methods must be selected for each site.

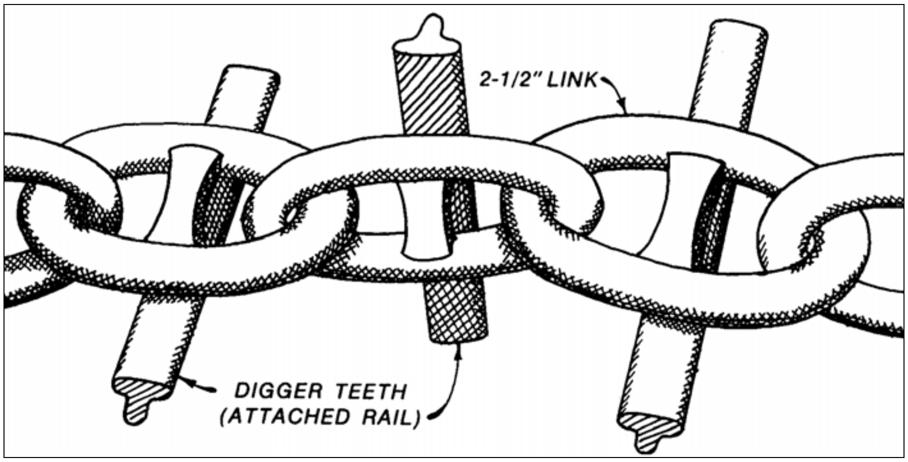


**Figure A-2. Ely-anchor chain (U.S. Army Corps of Engineers 1986).**

**Figure A-3. Dixie-Sager chain (U.S. Forest Service 2004).**

*Prescribed burning*

Prescribed burning is another widely used means of preparing seedbeds through controlling weeds and promoting grass growth. Burning should be done during periods of dormancy. When plants become dormant, they are seldom fatally damaged by the effects of burning. If cool season grass growth is to be promoted, burning needs to take place in the fall, when cool-season grasses become dormant. If the goal is to promote warm-season grasses, burning should take place in the spring when cool-season plants are actively growing and warm-season grasses are still in their dormant stage. Burning should not take place in the first or second year during establishment. Roots must have time to establish or the planting may be lost. Roots must be growing deep in the soil to ensure survival; the deeper the roots, the better the survival rate (Flinn and Wein 1977).

Another important consideration with prescribed burning is soil moisture. After burning, plants must have the necessary moisture to re-establish; therefore, prescribed burning should take place when soil moisture is relatively high (Wright 1974). Burning for maintenance typically requires a cooler fire because it should take place during seasons of cooler temperatures and higher relative humidity. Burning with cooler fires will reduce grass mortality. Another advantage of burning is that it consumes surface litter and debris while promoting grass growth.

**Pre-germination**

Many native grasses must be planted in the fall or early winter. Planting during this time of year yields the greatest vegetation coverage as this approach takes advantage of the natural seeding cycle of many native plants. Planting in cooler, damp weather allows seeds to overcome embryo dormancy; this process is called "stratification" (Shopmeyer 1974). For some seeds, a stratification period of 100–150 days is necessary. Some native grasses have been pre-stratified. These can be planted in the spring, but issues with weather in the spring season can hinder success. Seeding operations should be concluded just before longest periods of most desirable moisture conditions if no stratification is needed. Optimum moisture conditions allow seedlings to establish before periods of draught. Often germination during receding snow allows for higher survival rates during drier summers (Monsen and Stevens 2004).

*Seed priming*

To increase vegetation establishment, "seed priming" is an option for improving germination rates and reducing the days needed for germination. Priming is designed to break down seed hulls that are thick and/or hard and allow quick, even germination via faster moisture penetration. In conjunction with stratification, priming can be done with chemicals, physical scarification, matriconditioning, or water (Warren and Bennett 1997; Haynes et al. 1997). Salt compounds provide seeds with essential nutrients used for protein synthesis during germination. These compounds include polyethylene glycol, $KNO_3$, $K_3PO_4$, $KH_2PO_4$, $MgSO_4$, NaCl, and glycerol. These compounds can cause some toxicity in seeds; however, when conditions are right, these salt treatments can improve seedling performance. Other chemicals that improve seedling emergence are sulfuric acid, gibberellic acid, sodium hypochlorite, and hydrogen peroxide.

Physical scarification uses solid carriers to fracture seed coats. Matriconditioning uses substances with low matric potentials and incorporates them with the seed surface. The result is that water is attracted and brought closer to the seed (Copeland 2001).

Another seed-priming method is to use water as the priming system. There are three different ways to prime seeds with water: (1) soaking, (2) humidification, and (3) drum priming. The use of water as the priming agent confers several advantages (Warren and Bennett 1997):

- There is no waste.
- Water is readily available at most locations.
- The cost of water is low.

When choosing a method of priming, research not only the method, but also the time and conditions that each method requires. Priming methods are also largely species-specific. Correctly accelerating seedling establishment and taking seeds out of dormancy makes native grasses a better choice for erosion control because of faster seedling establishment.

**Seed planting**

Determining the optimal planting depth can be quite challenging for a given seed mix; seeds planted near the surface require less energy to emerge, but seeds planted at deeper depths can access more moisture. Both conditions have seed-to-soil contact, but diurnal effects can reduce moisture and increase temperature near the surface. Optimally, seeds would be placed at a depth no more than three times the thickness of the bare seed and then covered with a mulching product to conserve moisture and reduce erosion until establishment. If seeding mixes of seeds requiring different planting depths, it is essential that these seeds be planted separately for best germination. Depth variation can be achieved by broadcast seeding followed by harrowing or chaining, which causes a mixed effect (Figure A-4). Drill seeding will also achieve varying depths by implementing different seed dispersion boxes, and by setting the corresponding drops at the required depths. Increasing seed rates (i.e., by simply using more seed) is not an acceptable correction for varying seed depths and only increases project cost (Monsen and Stevens 2004).

A seed drill plants in rows through placement just under the surface (Figure A-5). Drills are able to accurately disperse seeds using a metering system in each box. Many native grass drills have up to three boxes for large fluffy seeds, cool season seeds, and small seeds. The metering system releases seeds into drops that lead to furrows cut in the ground by disks. These planted furrows are then closed with packing wheels.

**Figure A-4. Broadcast seed mixed under soil (U.S. Dept. of Transportation 2007).**

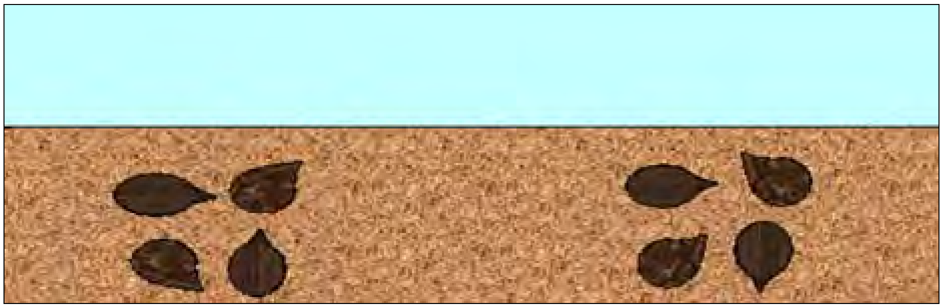

**Figure A-5. Drilled seed (U.S. Dept. of Transportation 2007).**

Drills have been developed to accommodate a number of seedbed surfaces. One of these drills is the rangeland drill, developed by the United States Forest Service (USFS). The rangeland drill was developed to seed semiarid regions with rough terrain. This drill can also simultaneously break up compacted soils and drill seed into deep furrows. Furrows can range from 2 to 6 in. in depth with row spacing of 12 to 18 in. Mechanical failures are reduced by individually pivoting opener disks. Therefore the drill is able to plant seedbeds with debris because the seeder arms can go over obstacles without bearing the entire weight of the drill. Drags behind the opener disks cover seeds. Rangeland drills can be operated at speeds of 3.5 to 4 mph or 2.5 to 5 acres/hr. A disadvantage of the rangeland drill is its inability to specify depths in loose seedbeds (Doerr 1986).

**Figure A-6. Truax rangeland drill roughrider (Truax).**

Many drills have been designed based on the rangeland drill, but with the ability to seed in seedbeds of varying firmness. These drills have three seeding boxes able to perform separate row seeding out of each box at different rates and depths (Figure A-6). One disadvantage of the modified rangeland drills is their lower clearance. Reduced clearance limits the drill's ability to pass over debris. Some of these drills also have optional trailing cultipackers behind each opener. Trailing cultipackers increase seed-to-soil contact by increasing seedbed firmness (Truax Company 2009).

The no-till drill was designed to seed into existing stands of vegetation. One preferred method is to drill native grasses into a non-native cover crop. A common practice is an herbicide burn down to kill existing growth, yet to still provide much needed erosion control and an intact seedbed. No-till drills can also interseed new grass into remaining seedbeds in an effort to achieve denser stands. Many drills on the market today have options for ordering no-till models on many native grass drills.

Grain drills do not work for native grasses, as the depths are often too deep for most native species and the metering devices do not allow for an even flow of seed. Also, grain drills are often built for agricultural purposes, to be used on smooth prepared seedbeds; therefore, their construction is for more light duty purposes compared to native grass drills, rangeland drills, and modified rangeland drills (Monsen and Stevens 2004). Monsen and Stevens (2004) list the advantages of using drill seeders over other types of equipment are that the method:

- has low operating expenses,
- accurately places and disperses seed, and
- yields excellent seed-to-soil contact.

No other seeding method obtains such ideal conditions for germination and establishment for native grasses.

Disadvantages of using drill seeding include:

- higher start-up cost for equipment purchases (start-up costs can reach $20,000 just for the drill [Truax Company 2009])
- slower implementation of seeding
- limited applicability on highly disturbed sites and uneven surfaces
- maximum slope limitation; slope limitations for a drill and tractor are a 3:1 slope (33 percent), or 18.3 degrees (Steinbacher 2000).
- concentration of seeds into rows with row spacing of 10–18 in. As moisture becomes scarce, row spacing must be widened to reduce competition—in the 15 to 18-in. range. Narrow rows usually increase weed control and produce better initial results if sufficient moisture is present (Cook et al. 1967).

When seeding both grasses and legumes together, or when seeding grasses and shrubs, separate row seeding is beneficial to enhance varying development. Plants developing at slower rates will benefit from being separated from other initially competitive plants (Monsen and Stevens 2004). Broadcast imprint seeders can separately seed species if equipped with seed boxes that can have row dividers added rather than having one box stretching across the entire width. On models with three separate boxes, seeds can be distributed at independent seeding rates for each box. Boxes can also be split by using dividers; however, dividers only allow the planting of multiple species in separate areas at the same rate.

Ground broadcast seeding is one of two types of broadcast seeding. The most popular method of ground broadcast seeding is done by using a rotary wheel spreader to disperse seeds. A hopper mounted above the rotating spreading wheel allows seed to fall out and be spread. These spreaders can be mounted to vehicles in multiple ways. One way is to fasten spreaders to a crawler, tractor, or ATV in front of a drag harrow or chains. This configuration allows seed to be spread and then covered to increase seed soil contact (Figure A-7). Broadcast seeding may also be performed by hand. The same apparatus, only smaller, can be worn like a chest pack. The rotary wheel is then turned by hand. The seed can then be raked into the surface by hand. This hand seeder method is the most economical for very small areas.

Another method of ground broadcasting is a spreader positioned between cultipackers, which is known as a broadcast imprint seeder (Figure A-7). The imprint seeder shown has the ability to seed three different types of seed at once with different seed rates. The seed boxes can be split to allow two species to be seeded side-by-side. Figure A-8 shows the seed-to-soil contact produced by an imprint style of broadcast seeder. The following are the advantages of the imprint style:

- improved seed coverage,
- accurate seed metering, and
- improved seedbed firmness.

A large disadvantage of the imprint broadcast seeder is its need for well-prepared seedbeds with no debris. Also, its operation depends on tractor limitations.

Another broadcast method, aerial seeding, can also produce successful establishment of native grasses. Using airplanes and helicopters, it is possible to disperse seed over larger areas with gentle slopes more economically than with drill seeding. Unlike drills, aerial seeding can effectively seed areas that are far too rocky, too moist, sloped less than 3:1, or unevenly shaped. Airplanes are excellent for seeding forested land just before leaf fall as well as burned lands that still have debris. Success often depends on season, seedbed conditions, and seed coverage. Like ground broadcasting, some form of coverage should occur if possible.

**Figure A-7. Broadcast imprint seeder (Truax Company 2009).**

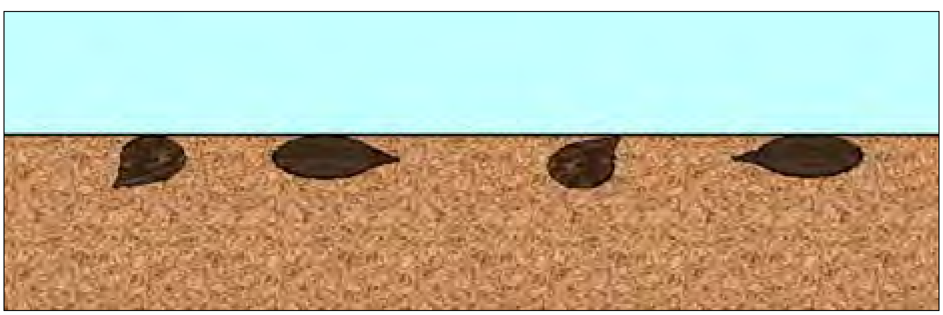

**Figure A-8. Imprinted seed (U.S. Dept. of Transportation 2007)**

On burned forests and areas with large amounts of debris, even seed coverage may not be possible or necessary. Seeding by helicopter is adapted for oddly shaped areas, right-of-ways, fence lines, slopes up to 3:1, smaller areas, and rocky terrain. Often, high elevation sites, stream banks, and roadways can be unsafe for airplanes to seed. Helicopters are equipped with seed bins or seed hoppers similar to those used in ground broadcasting. Helicopters use smaller landing pads rather than runways, and are more maneuverable (Monsen, Stevens, and Shaw 2004).

Like other methods of seeding, broadcasting seed has its advantages and disadvantages. With broadcast seeding comes the concern of poor seed-to-soil contact. Poor soil contact with the seed is the result of neglect to mix seed into the soil surface (Figure A-9). Light tillage, such as scarification, simultaneously helps to control competing plants and to cover seeds. Other disadvantages of broadcast seeding include:

- The possibility of seed waste and incorrect seeding depths.
- The need for more personnel to help flag areas and to load seed.
- The need for a nearby landing strip if airplanes are used.

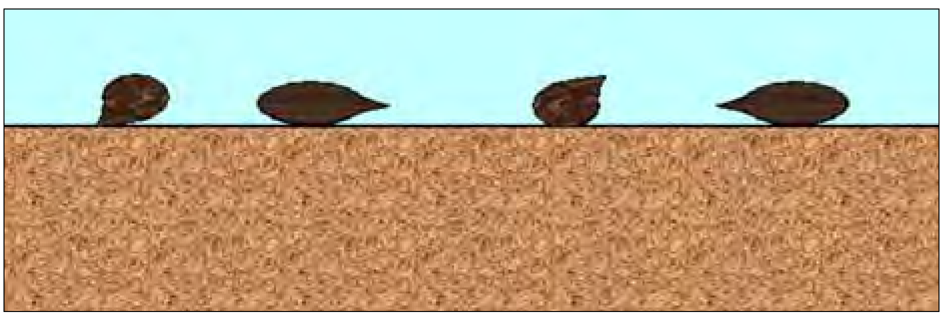

**Figure A-9. Broadcast seeds (U.S. Dept. of Transportation 2007).**

Broadcast seeding includes the following advantages (Monsen, Stevens, and Shaw 2004).

- lower risk of crust formation compared to drill seeding
- possibility of lower costs
- less tendency of rodent damage
- more diversity

Other variations of broadcast seeding, hydroseeding and hydromulching, have become increasingly popular alternatives to traditional seeding practices. Hydroseeding uses water to apply seeds onto seedbeds. Mulches, fertilizers, soil additives, and tackifiers may be mixed together into slurry and applied at the same time. Four basic types of hydromulch are:

1. Hydraulic mulch (HM), which consists of shredded paper or wood; it is applied on less than 4:1 slopes for periods of less than 3 months.

2. Stabilized mulch matrix (SMM), which is a hydraulic mulch with a tackifier; it is applied to less than 3:1 slopes for an expected life of 3–6 months.

3. Bonded fiber matrix (BFM) is wood fiber bonded together with a tackifier; it is best suited for less than 2:1 slopes for time periods of 6–12 months.

4. Flexible growth mediums (FRM) are the highest grade of mulches, consisting of wood fiber or man-made crimped fibers bonded with a tackifier. FRMs are applied on less than 1:1 slopes for time periods greater than 12 months.

Hydromulch is appealing because of its ability to rapidly stabilize the soil surface. Mulches also retain moisture to be used by germinating seeds. Necessary equipment to apply hydromulch products varies by size, pump, and agitation schemes. These factors are determined by the size of the project area and the slurry to be applied. Larger areas may be hydromulched by tank-mounted applicators, while small, oddly shaped areas may require smaller units. Mechanical agitation and jet agitation are the two methods used to keep seed and mulch evenly mixed. Mechanical agitation is preferred, because it performs better with heavier slurries.

The following are advantages of the hydromulching method (Monsen and Stevens 2004).

- rapidly stabilizes soil

- can be used to seed steep or rocky slopes

- can be used to seed inaccessible sites using smaller units

By contrast, the following are the disadvantages of the hydromulching method.

- yields poor seed-to-soil contact (Figure A-10)

- uses mulch, which inhibits germination

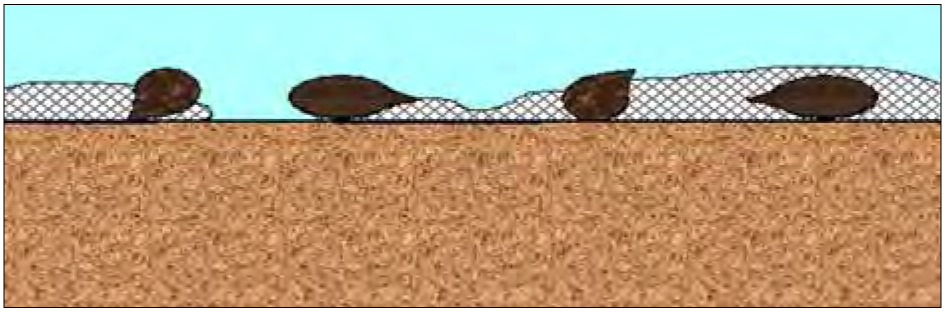

**Figure A-10. Seeds mixed with hydromulch (U.S. Dept. of Transportation 2007).**

- uses agitators and pumps that can damage seed
- can be very expensive
- requires large amounts of water

For more in-depth information about choosing hydromulch components, refer to Public Works Technical Bulletin 200-1-65, *Proper Selection of Hydroseeding Mixtures and Components to Promote Rapid Revegetation of Disturbed Department of Defense Lands,* available at http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_65.pdf.

Dry mulch seeding is yet another form of broadcast seeding. Seeds may be either seeded with mulch or broadcast before spreading mulch. If seed is mixed with mulch, a tackifier is applied to areas with slopes steeper than 3:1. Seeding before mulch is preferred, as seed-to-soil contact is increased (Figure A-11 and Figure A-12). Dry mulching is relatively inexpensive as a mulching option. Wood fiber, straw, or hay may be used as mulch mediums. Generally straw is a good choice as it is generally cheaper, and contains less weed seed as it is baled stubble. Native hay, hay made from desirable native plants, can be used to seed and spread mulch at the same time. Mulching tends to create high porosity, keeping moisture near the surface where seeds germinate. Mulching depth should be no deeper than 1 in., but 1 in. is the depth that helps deter evaporation (Slick and Curtis 1985). Approximately 15 to 20 percent of the soil surface should be visible after spreading mulch (Kay 1983).

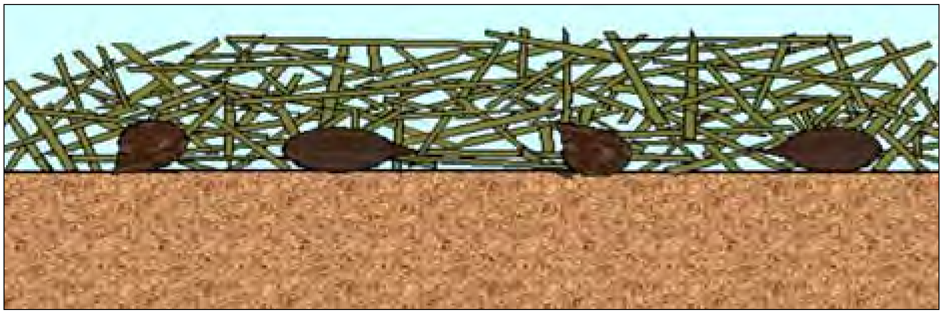

**Figure A-11. Covered broadcast seeds (U.S. Dept. of Transportation 2007).**

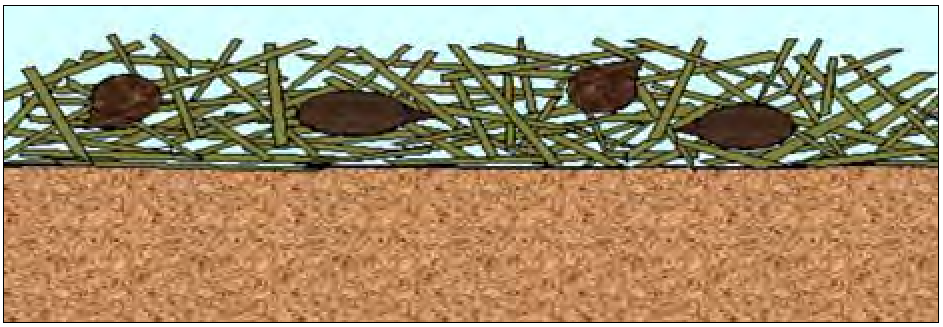

**Figure A-12. Seeds mixed with mulch (U.S. Dept. of Transportation 2007).**

Mulch may also be applied using Erosion Control Blankets (ECB) jute netting, straw with netting, coconut fiber with netting, or wood fibers with netting. These are temporary structures aimed at reducing erosion while vegetation is establishing. ECBs are best suited for smaller plots with drainage areas less than 1 acre and no longer than 100 feet. These small areas have moderate slopes and slower flows. For more information on installing and maintenance of erosion control blankets refer to Public Works Technical Bulletin 200-1-62, *Low Impact Development for Sustainable Installations: Stormwater Design and Planning Guidance for Development Within Army Training Areas* p. 91-94.

After broadcast seeding, mulch is either spread by hand or by a mechanical mulch spreader (Figure A-13). Mechanical spreaders may blow mulch or have hose attachments to apply more concentrated amounts of mulch. After mulch has been spread over the top of the seeds tackifiers, crimping, or netting is applied over the top to hold down the mulch. Crimping is a mechanical means of holding straw in place by pressing straw into the surface on the contour (Figure A-14).


**Figure A-13. Mechanical bale shredder (Finn B260T).**


**Figure A-14. Straw crimper (Finn 3-point Krimper).**

When applying straw or native hay as mulch, they should be certified weed-free. Many states have programs that inspect hay and straw to deem it weed-free or not. Introduction of weed species is undesirable; it should be weighed against the cost of certified straw or hay and rapid erosion control with straw or hay from unknown sources.

When establishing vegetation on a disturbed site, it is important to keep in mind the factors of seedbed preparation and seed-to-soil contact. Seedbed preparation can require tillage or a similar ground-disturbing method, chemical plant control, or prescribed burning. These methods should be chosen based on their ability to provide a firm, fertile seedbed. Seed-to-soil contact can be increased through seeding methods using a shallow soil covering—more specifically, by drill seeding and covered broadcast seeding. Additionally, moisture and soil structure should be deemed important factors in the success of a revegetative effort. Mulching can improve moisture retention by increasing soil porosity and by protecting new seedlings from climate variations. No-till options should also be considered as they promote surface litter, infiltration of runoff, and firm seedbeds.

Hydroseeding has its place, as many areas are far too steep or receive too much precipitation to be planted by conventional planting methods. The choice of hydroseeding as the preferred planting method should be done carefully, however, as it costs significantly more than other methods and may result in poorer germination. Finally, weigh seeding options based on cost and the resulting odds of successful establishment. This will have to be based on seeding method, environment of seedbed, extent of soil stabilization required, and available funds.

# Appendix B

## CHOOSING SEEDING METHODS

A method of seedbed preparation should be chosen before selecting the best-suited seeding technology. Cost data in the *Regional Cost Estimates for Rehabilitation and Maintenance Practices on Army Training Lands* (PWTB 200-3-33) is categorized by regions in the contiguous United States of America, which include:

- Pacific Coast
- Intermountain
- Northern Great Plains
- Southern Great Plains
- Central Lake
- Northeast
- Humid South.

Table B-1 lists the states associated with each region.

**Table B-1. States associated with each region.**

| Pacific Coast | Intermountain | Northern Great Plains | Southern Great Plains | Central Lake | Northeast | Humid South |
|---|---|---|---|---|---|---|
| California | Arizona | Montana | Colorado | Illinois | Connecticut | Alabama |
| Oregon | Idaho | Nebraska | Kansas | Indiana | Delaware | Arkansas |
| Washington | Nevada | North Dakota | New Mexico | Iowa | Maine | Florida |
| | Utah | South Dakota | Oklahoma | Michigan | Maryland | Georgia |
| | | Wyoming | Texas | Minnesota | Massachusetts | Kentucky |
| | | | | Missouri | New Hampshire | Louisiana |
| | | | | Ohio | New Hampshire | Mississippi |
| | | | | Wisconsin | New Jersey | North Carolina |
| | | | | | New York | South Carolina |
| | | | | | Pennsylvania | Tennessee |
| | | | | | Rhode Island | Virginia |
| | | | | | Vermont | |
| | | | | | West Virginia | |

This source also provides data that gives a sense of relative cost. Figure B-1 shows the relative cost for each technique on a regional basis.

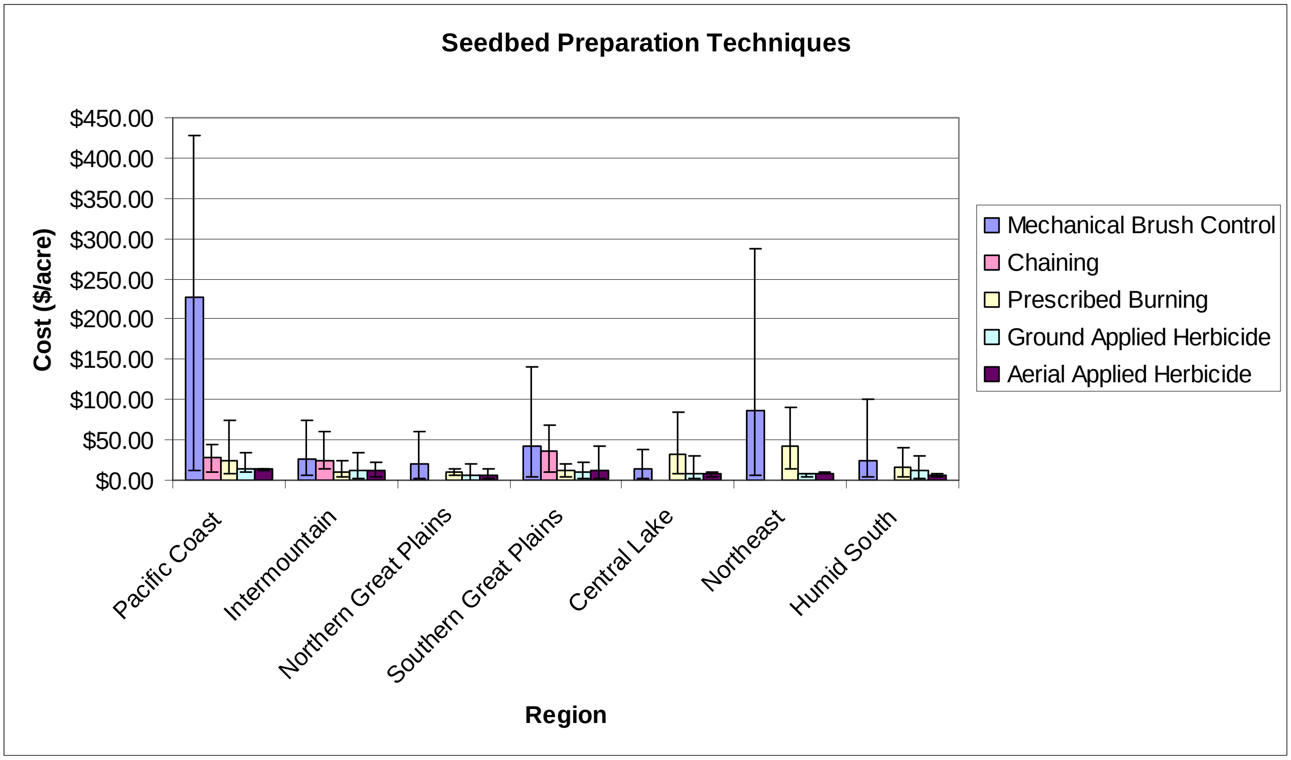


**Figure B-1. Cost comparison of seedbed preparation techniques.**

Notice in the Northern Great Plains, Central Lake, Northeast, and Humid South regions that there are no chaining costs present. This is due to either equipment unavailability or environmental factors, such as trees that would prevent the use of chains. Incorporated with the graph are error bars to show variability of the costs associated with each method. The Pacific Coast and Northeast regions may experience even larger price differences for mechanical brush control, depending on tree content and size of equipment required. Alaska and Hawaii are not included because of the diversity in ecosystems and varying costs. For more detailed information, contact the NRCS Plant Materials Center of the respective region.

After choosing the most suitable method of seedbed preparation a method of seeding must be chosen. The data in Table B-2 can form a basis for choosing a suitable seeding method. Terrain limitations affect many of the suggested seeding methods. These terrain limitations include slope, soil moisture, and presence of debris. Drill seeding, ground broadcast seeding, and broadcast imprint seeding are limited by tractor operation. It is unsafe to operate tractors with heavy machinery on slopes steeper than 3:1.

**Table B-2. Characteristics of seeding methods.**

| Seeding Method | Max Slope | Soil Moisture (% Field Capacity) | Max Debris | Seed Type | Area to Seeded |
|---|---|---|---|---|---|
| Drill | 3:1 | 50%–75% | Little (Removed Trees or Shrubs) | AnyI | Medium 5–35 acres |
| Ground Broadcast | 3:1 | 50%-75% | Moderate (Tractor Limiting) | Smooth Flowing' | Small-Large < 100 acres |
| Aerial Broadcast | 3:1 | — | Dense (Trees & Shrubs or Rocky) | Smooth Flowing' | Large > 100 acres |
| Brillion Broadcast | 3:1 | 50%—75% | None (Smooth Prepared Seedbed) | AnyI | Medium 5-35 acres |
| Hydroseeding | 1:1 | — | Dense (Trees & Shrubs or Rocky) | Any | Small-Large < 100 acres H |
| Dry Mulch Seeding | 1:1 (If tackifier or ECB is used) | * | * | * | Small-Medium |

— Not applicable for this seeding method

* Depends on seeding method (if seed mixed with mulch, refer to hydromulch)

' Trashy/Fluffy Seed Types may be used with appropriate carrier

I If equipped with 3 box system

H Area restrictions follow aerial broadcasting

The use of tractors, crawlers, or all-terrain vehicles (ATVs) should also be limited to soils with moisture contents in the range of 50%–75% of the soil's field capacity (FC). Operating equipment on soils moister than 75% FC will result in compaction, but operating tillage equipment on soils drier than 50% FC may cause excessive soil structure damage.

The use of vehicles and implements is also limited by the amount of debris present. Trees, shrubs, or boulders may limit tractor or crawler mobility, and those factors must be considered when choosing the best planting method. Drill seeders have openers that must be able to penetrate the ground for accurate seed placement. The modified rangeland drill accounts for moderate debris, but is limited by ground clearance. Broadcast imprint seeders do not tolerate debris as cultipackers must be able to imprint seeds into well prepared seedbeds.

Hydroseeding and dry mulch seeding are limited by the equipment necessary to spread mulch and seed. The mulch and tackifier also limit hydroseeding and dry mulch seeding. Mulches and tackifiers should not be used on slopes steeper than they are rated for. Aerial broadcasting operations are not affected by terrain limitations such as slope, soil moisture, or debris. However, seeds must be able to survive where they are spread.

Terrain is not the only limiting factor in seeding. Some native seeds are considered "fluffy or trashy" and cannot be metered accurate without the correct equipment. Native grass seeders account for this difference by implementing a fluffy seed box equipped with special agitators. Seeders with a legume seed box, small seed box, and fluffy seed box can accurately meter many different types of seeds. Without this three-box system, the types of seeds that can be seeded are specific to the implement. Broadcast seeding with trashy or fluffy seed requires the use of cracked corn or vermiculite as a carrier, unless the seeder has specially designed agitators incorporated into the design.

The seeding area can also limit the effectiveness of specific seeding methods. When planting native grasses, the area to be planted determines much of the cost for any given planting method. The area determines the required amount of seed, man-hours, materials, water, and fuel. Ideally, large areas would be drill seeded, but the window of opportunity for the ideal planting time may limit drill seeding. Ideal conditions may exist – right before rainfall, when trees are dropping leaves, during drier periods, or following burning but before rainfall. Seed broadcasting will typically be a much-faster method, especially aerial broadcast seeding or aerial hydroseeding. For all area recommendations, a period of 8 hr was used. Assuming ideal conditions, the amounts listed in Table B-2 are the maximum that can be planted in 1 day.

After selecting the best-suited seeding methods, a cost comparison must be done. One site may have several acceptable methods that will result in similar results. Figure B-2 graphs costs by region in dollars per acre that are associated with simply seeding, not including cost of seed. These are average values, with error bars to show variability in each region for individual seeding methods. The y-axis is shown in a logarithmic scale to highlight the differences in seeding cost. Averages found for hydroseeding include prescribed seed, mulch, and soil amendments. Hydroseeding can cost thousands of dollars more in some areas, which can complicate a side-by-side comparison of all methods. Values of hydroseeding are given in dollars per acre, due to increased error when reading the logarithmic scale.

The basis for choosing a seedbed preparation method should be on the method's ability to conserve moisture while promoting a firm seedbed. While seedbed preparation is only the beginning, it should be considered as important as the seeding practice itself. After choosing a preparation method, a seeding method should be chosen based on terrain, seed type, extent, seed-to-soil contact, and cost.

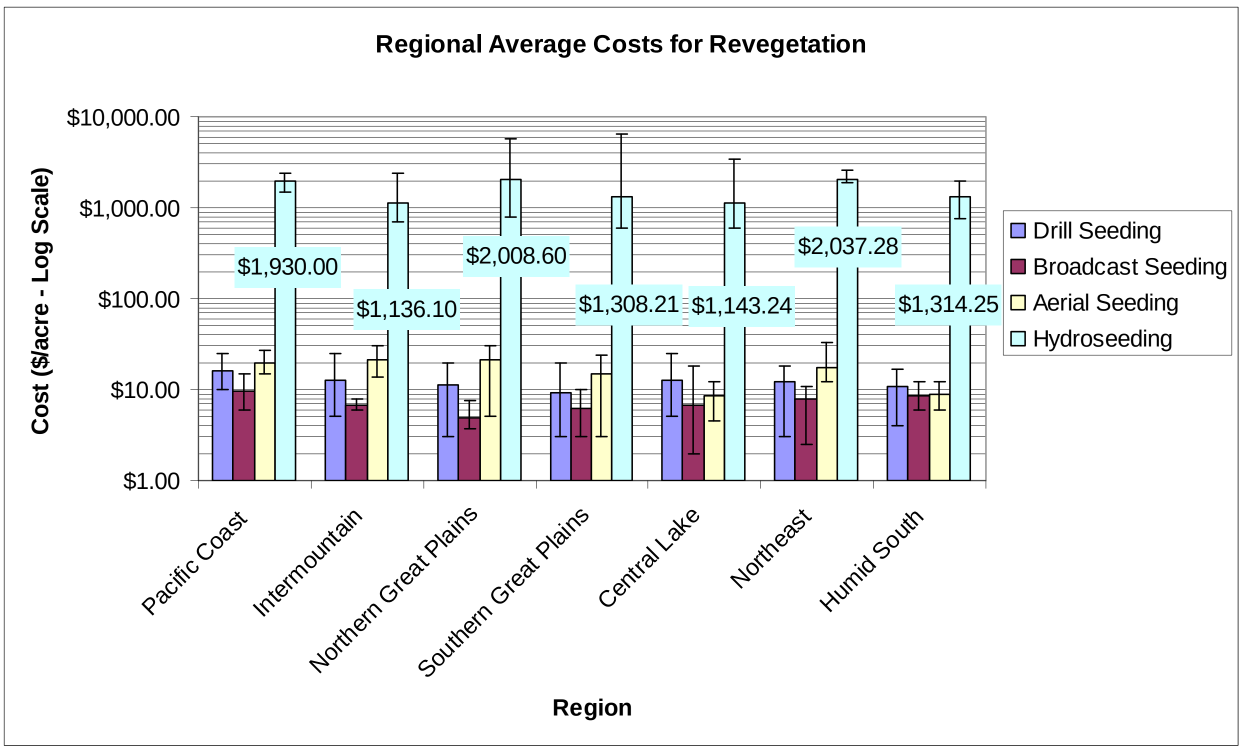


**Figure B-2. Cost comparison of seeding methods.**

# Appendix C

## SEEDING METHOD RECOMMENDATIONS

### Fort Benning, GA

Located in western Georgia, Fort Benning contains sandy loam soils. These soils are composed of 40-85% sand, 0-50% silt, and 0-20% silt. The Ultisol soils on the installation are on slopes from 0-30%, with evergreen and deciduous forests as cover. Average yearly rainfall varies from 40-50 in. with the heaviest rainfall occurring January–March, when there is an average of 5 in. monthly. During the fall months, August–November, average rainfall decreases to 3 in. monthly. Based on prior information, general recommendations for establishing native grasses in the Fort Benning area should be the following:

> Planting is optimum during the late fall and early winter season as long as emerging growth does not encounter frost, and planting is concluded before substantial rainfall begins. If reclamation projects must be undertaken during dry periods, mulch should be used in conjunction with an artificial source of water to ensure adequate moisture levels. If slopes do not exceed 3:1 (33%), and soils are 50-75% of field capacity, then any seeding may take place. If soils are too moist, aerial seeding or hydroseeding may be used. If the seedbed is located on highly erodible soils, mulch and tackifier or hydromulching may need to be used. Also, on sandy soils mulch may be necessary for moisture retention.

### Fort Bragg, NC

Fort Bragg is located in eastern North Carolina. Much of the soils on the installation are sands or loamy sands. Sandy soils are comprised of 80%-100% sand, 0%-20% silt, and 0%-10% clay; loamy sands are 70%-90% sand, 0%-30% silt, and 10%-15% clay. Sandy soils will be unable to retain as much moisture, making moisture conservation more important. Slopes range from 0%-25%, with land cover consisting of evergreen forests and grasslands. Precipitation averages range from 40-50 in. annually. Month-to-month averages are fairly constant at 3-5 in. monthly. Considering these factors, general guidelines for revegetation at Fort Bragg should be:

A good time to perform seeding operations is April or May. These months have lower amounts of rainfall and come before the wettest time of the year during June-September. Seeding may also be done in the fall, so long as seed will not germinate and be harmed by freezing conditions. Any seeding techniques may be performed on slopes under 33% (3:1). Mulch is recommended for sandy soils to conserve moisture. A tackifier may need to be used if the site is erodible or is expected to receive large amounts of rainfall.

**Fort Campbell, KY**

Fort Campbell straddles the Tennessee and Kentucky border (part of the Hot Continental ecological region) and has, for the most part, silty clay loams. Silty clay loams are made up of 0%-20% sand, 40%-75% silt, and 25%-40% clay. These Alfisol soils are covered mainly by mixed forests. Average slopes on the installation are 35%. Precipitation averages 50-60 in. annually, with monthly averages ranging from 3-5 in. General seeding guidelines for Fort Campbell are:

Seeding should take place during April or earlier spring, before the highest rainfall in May. It may be possible to establish vegetation in the fall as long as plants have ample time to establish before freezing conditions during winter months. Drill is preferred for those conditions safe for tractor operation. On slopes too steep for tractor operation, USE either dry-mulch seeding with a tackifier or hydromulch. If the area is smaller than 1 acre, ECBs may be used for slopes up to 1:1. During moist conditions, aerial broadcast seeding may be used if the site is greater than 100 acres.

**Fort Carson, CO**

Fort Carson is south of Denver in east-central Colorado and features sandy loam soils. These soils consist of 40%-85% sand, 0%-50% silt, and 0%-20% clay. The installation contains grasslands on slopes ranging from 0%-50%. Average annual precipitation is 15-20 in. Most of this rainfall is received April–August, averaging 2 in. per month. The driest months, October until March, have rainfall averaging less than 1 in. Recommended seeding guidelines at Fort Carson should be:

Seeding can take place from May through June, to avoid low winter temperatures and have seeds in the ground before wettest portion of the year. For slopes less than 3:1, a drill seeding technique should be used for smoother surfaces. Broadcast seeding followed by chaining or very light harrowing should be used on rougher surfaces. For steeper, more erodible slopes, a hydromulching or dry mulch seeding technique with tackifier should be used.

**Fort Drum, NY**

Fort Drum, part of the Hot Continental ecological region, contains mainly silt loams. Silt loams typically have a particle range of 0%-50% sand, 50%-85% silt, and 0%-25% clay. Alfisols are the dominate soil type; these soils formed under forest vegetation. Slopes range from 0%-50%, and land covers are dominantly mixed forests and grasslands. Annual precipitation averages 50-60 in. Monthly averages are relatively constant between 3-5 in. General guidelines for seeding at Fort Drum are:

Planting should take place during April or May to avoid low temperatures and risk of damage to establishing vegetation. A planting could take place in early fall or late summer to encourage establishment before winter weather. Drilling or broadcast imprinting should take place on smoother surfaces, and broadcast with mixing should be used for rougher terrain. For steeper slopes, use a hydromulch or dry mulch seeding.

**Fort Hood, TX**

Fort Hood is located in the Tropical/Subtropical Steppe ecological region and contains Mollisol soils, which are predominately clay loams made of 20%-45% sand, 15%-50% silt, and 25%-40% clay. Mollisols are soils that are remnants of prairie lands and are generally excellent at retaining moisture. Fort Hood has slopes that vary from 1%-8%. Average land cover for the installation consists of a mix between deciduous and evergreen forests, with grasslands and shrubs. Annual average rainfall is typically 30–35 in. Heaviest rainfall occurs in May and June, usually 5 in. per month. Lightest periods of rainfall fall within July and August, usually 2 in. each month. Considering all of the mentioned factors, general seeding guidelines are:

Ideal seeding time is in March or April before larger amounts of precipitation in May and June. A fall seeding may take place if establishment is possible before December. A rangeland drill or modified rangeland drill is recommended for grassland and shrub areas where slopes are moderate. On shrub lands, the use of chaining, cabling, or prescribed burning may be required before seeding. Aerial seeding may be performed on all lands if followed by covering.

**Fort Irwin, CA**

Fort Irwin is a part of the Tropical/Subtropical Desert ecological region. These regions encompass a variety of land covers, soil types, and precipitation trends. Fort Irwin is made of gravelly loamy sands with prevalent rock outcroppings. Loamy sands are made of 70%90% sand, 0%-30% gravel, and 10%-15% clay. The Natural Resource Conservation Service (NRCS) defines gravel to be particles varying from 2–75 mm in diameter. Slopes are widely varying, from 0%-100%. Annual precipitation can be 1–10 in. The months of January–March are considered to be the wettest of the year with an average monthly precipitation of 0.5 in. From April–July, there is essentially no rainfall. Arid environments are typically dominated by shrubs and scrub. General seeding practices in the Fort Irwin area are described below.

Seeding attempts should take place in December. Dry mulch seeding with a tackifier, erosion control blanket (ECB), or hydromulch is a necessity to conserve as much moisture as possible. Broadcast seeding may take place if seed is covered and then mulched. Seed at first will likely require water from an artificial source to encourage establishment.

**Fort Lewis, WA**

Fort Lewis is located in the Marine ecological region. Soil textures found there include gravelly sandy loams, as well as silt loams. Gravelly sandy loams have a particle size distribution of 40-85% sand, 0-50% silt, and 0-20% silt, with gravel particles 2-75 mm in diameter. Silt loams consist of 0-50% sand, 50-85% silt, 0-25% clay. Soils in this area were formed by accumulated ash, called Andisols. Evergreen forests and grasslands surround the installation. Slopes can be very steep varying from 0-70%. Usually Fort Lewis can receive anywhere from 50-60 in. annually. Months with the most precipitation include November, December, and January, normally 6-8 in. each month. May through September should be considered the dry part of the year, with only 1.5-2 in. of rain each month. General guidelines in the area are:

February should be considered as the month with the best conditions for seeding. Higher precipitation that occurs

> during cooler periods is not best for germination. So long as seed has time to germinate before freezing conditions and has access to ground moisture, native grass will establish. If planting must be done before drier periods mulch should be used to help conserve moisture and to deter erosion. Drill or broadcast seeding can be done on areas with slopes less than 3:1 with few rocks or debris. Due to high rainfall in fall and winter months a mulch or erosion control blanket is recommended on all slopes greater than 3:1 or those that experience erosion. For slopes over 33%, 3:1, a hydromulch or dry mulch seeding with tackifier is recommended.

**Fort Polk, LA**

Fort Polk is located in the Subtropical ecological region. The predominant soil texture in the west-central Louisiana installation is sandy loam. Sandy loams are usually 40-85% sand, 0-50% silt, and 0-20% clay. Annual average precipitation is between 50 and 60 in. Land cover consists of evergreen forests, grasslands, and shrubs. Monthly precipitation is constant across each month, usually 3–7 in. Precipitation is spread evenly, from 3-7 in. each month, throughout the year. Given this information, the general seeding practices in the area should be:

> Seeding should be done during March or April if possible. Seeding may also be done in September, but the warmest part of the year has already past. Slopes of 0-20% allow for drill seeding or broadcast seeding. The high precipitation experienced in the area should be taken into consideration; a mulch and or tackifier is recommended to help stabilize the soil surface. Seedbed preparation will be necessary to control competing vegetation and remove shrubs or under growth.

**Fort Riley, KS**

Fort Riley is part of the Prairie ecological region and for the most part, is comprised of Mollisol soils. These Mollisols typically feature a silt loam texture with a particle distribution of 0-50% sand, 50-85% silt, and 0-25% clay. The grasslands and mixed forests of the area have a 0-30% grade. Average annual precipitation varies from 30-35 in. During the months of May, June, and July there is typically 4 in. of rainfall per month. From December through February, there is about 1.5 in. of rainfall monthly. General seeding recommendations should be:

> Due to extreme summers and winters, planting is recommended during the month of April. Seeding may also be done in August or September. Due to lower slopes and better structured soils, drill seeding is recommended over other types of seeding. Mulch may be needed if planting is to be done during the fall to help protect newly germinated plants during a harsh winter.

**Fort Stewart, GA**

Fort Stewart is located in the Subtropical ecological region. Loamy sand is the dominant soil texture of these Ultisol soils containing 70-90% sand, 0-30% silt, and 10-15% clay. Evergreen forests form the majority (from 0-20%) of land cover on slopes. Annually Fort Stewart receives 40-50 in. of precipitation each year. The wettest season occurs from June to September, with 4-8 in. of rainfall each month. October to December is the driest part of the year when there is 2-3 in. of rainfall each month. General seeding guidelines for the fort should be:

> Planting should take place during April or May just before rainfall events. A fall seeding may take place as well since winters, on average, are mild. Due to the large amount of evergreens and forest cover seeding will be very site specific. Where little debris exists a drill may be used, but where stumps and brush are found a broadcast method may be required. For periods of high rainfall, a mulch and or tackifier are recommended.

**Fort Wainwright, AK**

Located in the east-central portion of Alaska within the Subarctic ecological region, Fort Wainwright contains mainly silt loam soils. Silt Loams are 0-50% sand, 50-85% silt, and 0-25% clay. Evergreen forests and shrubs cover slopes ranging from 0-45%. Precipitation averages annually between 10 and 25 in. Most of the rainfall is received July through September, 1.5-2.5 in. per month. During the dry season, which runs from December to the following April, less than 0.5 in. falls monthly. General guidelines for seeding at Fort Wainwright should be:

> Seeding is recommended during the late spring and early summer before higher amounts of precipitation and warmer temperatures. The silt soils found in this area should be drill seeded since these soils should be able to retain some moisture. For steeper slopes a hydromulch or dry mulch

seeding should be used with a tackifier. Both will help retain moisture and protect seed from runoff.

Soil and precipitation data was obtained from PWTB 200-1-65 (Svendsen 2009).

**Conclusions**

These recommendations are made by using monthly averages of precipitation and temperatures. Many of these seeding techniques are site-specific. While hydroseeding may be used on any site, these recommendations have been made to help not only choose the least expensive technique to successfully establish native grass but also to choose the most successful method for revegetation of disturbed sites.

Figure C-1 shows a flowchart that can guide selection of an appropriate seeding method for slopes less than 3:1 (33%). This structured approach to choosing a suitable seeding method is a "work in progress" and thus should be taken as a starting point.

Two things that the chart does not address are the choices of hydraulic erosion control products (HECPs) or hydromulches. For information on these products, refer to PWTB 200-1-65 (Svendsen 2009). A third element that Figure C-1 does not cover is soil texture. Sandy soils will need to be treated to increase moisture retention, whether by application of mulch, by some other method such as deep furrows, or even by application of soil conditioners that assist in conserving water. Soils should be tested to determine if they are deficient in the nutrients necessary to establish and maintain plant health.

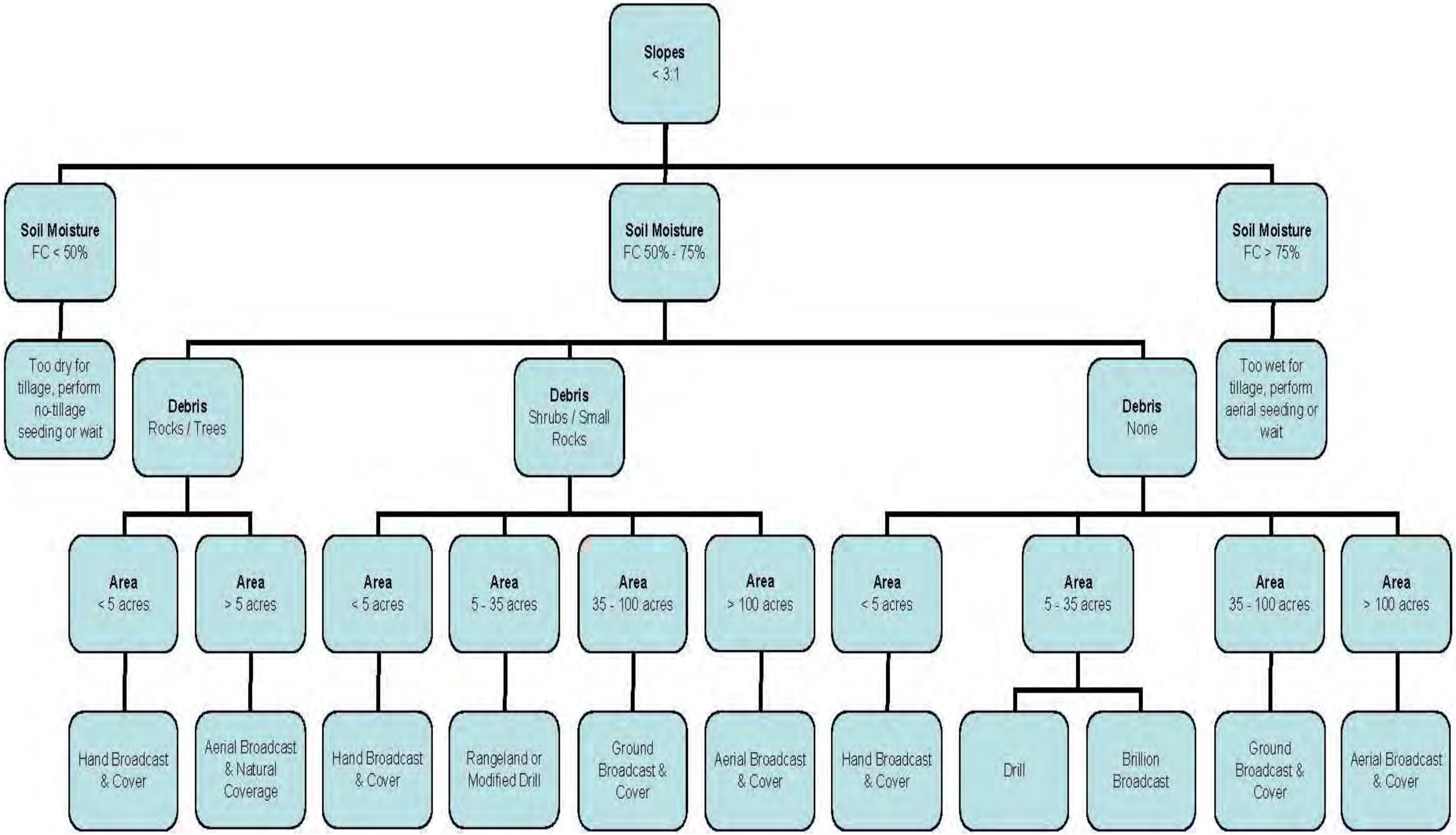


**Figure C-1. Selecting seeding method by site characteristics (ERDC-CERL).**

## Appendix D

## MAJOR MANUFACTURERS OF SEEDING PRODUCTS

Table D-1 lists major manufacturers of seeders and implements, along with those companies specializing in other seeding products and services. This list does not include all producers or service providers, and it is not meant to endorse or recommend one product over another. This list is to help readers obtain knowledge and understanding of various products and ultimately to obtain maximum results in their revegetative efforts.

Many areas may already have a more comprehensive list of manufacturers available through their state’s transportation department. Those lists will be more region-specific and extensive in their recommendations of products suitable for use in roadside grass establishment.

**Table D-1. Major manufacturers of seeding products (prepared by ERDC-CERL).**

| Company | Website | Telephone Number | Products |
|---|---|---|---|
| Aerial Specialists, Inc. | www.asicopters.com | 1-803-685-5900 | Aerial applications-Southeast |
| Aero Tech | http://aerotechteam.com | 1-575-763-4300 | Aerial applications-Southwest |
| Agrium | www.agrium.com | 1-800-403-2861 | Fertilizers |
| Air Tractor | www.airtractor.com | 1-940-564-5616 | Aiplane manufacturer |
| American Excelsior Company | www.americanexcelsior.com | 1-800-777-7645 | HECPs |
| Applegate Mulch | www.applegatemulch.com | 1-800-627-7536 | HECPs |
| Bowie Industries, Inc. | www.bowieindustries.com | 1-800-433-0934 | Equipment |
| Central Fiber Corporation | www.centralfiber.com | 1-800-654-6117 | HECPs |
| Finn Corporation | www.finncorp.com | 1-800-543-7166 | Equipment |
| Great Plains Manufacturing, Inc. | www.greatplainsmfg.com | 1-785-823-3276 | Drills and implements |
| JRM Chemical | www.soilmoist.com | 1-800-962-4010 | Soil amendments |
| Mat, Inc. | www.soilguard.com | 1-888-477-3028 | HECPs |
| Northwest Helicopters | www.nwhelicopters.com | 1-360-754-7200 | Aerial applications-Northwest |
| Strobel Manufacturing, Inc. | www.strobelmfg.com | 1-308-548-2254 | Drills and implements |
| Truax Company, Inc. | www.truaxcomp.com | 1-763-537-6639 | Drills and broadcast seeders |

# Appendix E

## ABBREVIATIONS AND TERMS

**Table E-1. Abbreviations.**

| Term | Spellout |
|---|---|
| AR | Army Regulation |
| ATV | all terrain vehicle |
| BFM | bonded fiber matrix |
| BMP | best management practice |
| CEERD | U.S. Army Corps of Engineers, Engineer Research and Development Center |
| CERL | Construction Engineering Research Lab |
| CONUS | Continental United States |
| DA | Department of the Army |
| ECB | erosion control blanket |
| ERDC | Engineer Research and Development Center |
| FRM | fiber-reinforced matrix |
| HECP | hydraulic erosion control product |
| HM | hydraulic mulch |
| HQUSACE | Headquarters, U.S. Army Corps of Engineers |
| NRCS | National Resource Conservation Service |
| PE | program element |
| POC | point of contact |
| PWTB | Public Works Technical Bulletin |
| RECP | rolled erosion control product |
| RUSLE | revised universal soil loss equation |
| SFM | stabilized fiber matrix |
| SMM | stabilized mulch matrix |
| USACE | U.S. Army Corps of Engineers |
| USDA | U.S. Department of Agriculture |
| USDOT | U.S. Department of Transportation |
| USEPA | U.S. Environmental Protection Agency |
| USFS | U.S. Forest Service |

**Table E-2. Explanation of terms.**

| Term | Definition |
|---|---|
| Cultipackers | Cast wheels used to compact seedbeds and promote seed-to-soil contact |
| Embryo | Part that is enclosed within seed and develops through germination to become a sprout |
| Furrow | A shallow trench made to place seeds closer to moisture |
| Interseed | Process of planting seed into existing vegetation |
| Legumes | Nitrogen-fixing plants (e.g., clover and alfalfa) |
| Matriconditioning | Process of creating areas of low matric potentials around seeds |
| Matric potential | Measure of work per unit of water to remove water from a solid surface, soil in this case |
| Metering system | Mechanical part of seeder used to accurately space seeds |
| Opener disks | Part of drill seeders used for seed placement |

# Appendix F

## REFERENCES

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