Sagebrush buttercup (*Ranunculus glabberimus*)

Revegetation Guidelines for the Great Basin: Considering Invasive Weeds

Ecologically-based Invasive Plant Management Workshop
USDA-Agricultural Research Service
Eastern Oregon Agricultural Research Center, Burns, OR
April 5-7, 2005

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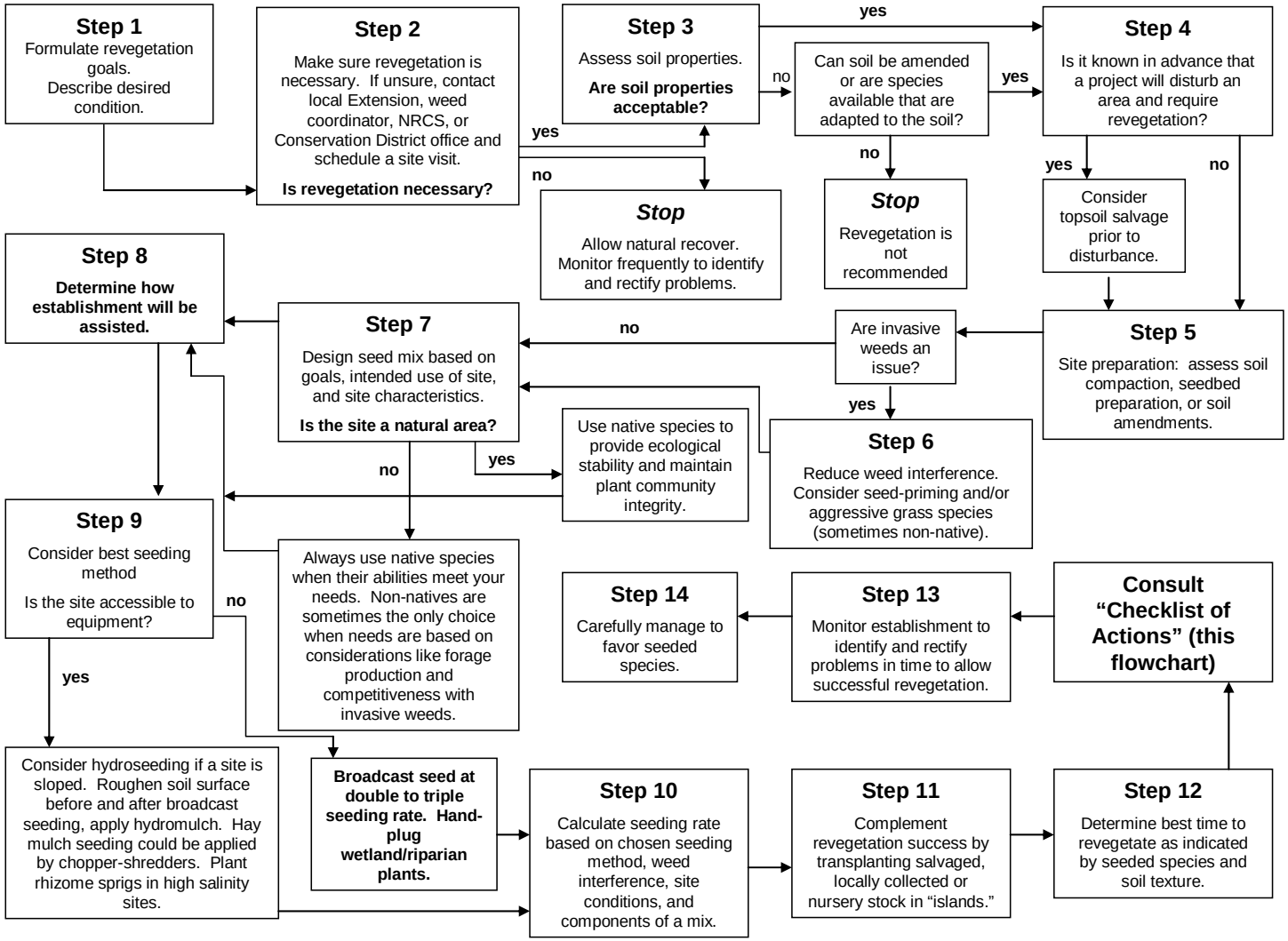
Revegetation of Guidelines for the Great Basin has been adapted from the Revegetation Guidelines for Western Montana. Montana State University Extension Service.

Natural revegetation can be slow. Artificial revegetation of degraded or disturbed areas can speed or direct recovery and mitigate or prevent soil erosion. Revegetation can also mitigate weed invasion and reestablishment. Revegetation should only occur when necessary, as determined by the abundance of desired plants and seeds at the site. Revegetation is also useful in cases where rangeland improvement is desired. This publication provides an in-depth, step-by-step guide to the processes and procedures of establishing desired species in most revegetation circumstances in the Great Basin. Detailed information for every situation is beyond the scope of this publication; experts and specialists should be consulted as necessary, especially on large or particularly challenging projects.

Checklist of Actions



Step 1 Make a goal statement

Historically, pest management in cropping systems focused on controlling pests. Today, land managers often focus on controlling weeds, with limited regard to the existing or resulting plant community. On grassland, forestland, and roadsides, the effectiveness of various weed management strategies depends on how land is and will be used and managed. Invasive weeds must be considered when establishing revegetation goals. This implies that weed control alone is an inadequate objective, especially for large-scale infestations. A generalized objective for ecologically-based weed management is to develop and maintain a healthy plant community while meeting other land use objectives such as forage production, wildlife habitat development or recreation land maintenance (Sheley et al. 1996). Revegetation efforts are often a key component of ecologically-based weed management.

A healthy, weed-resistant plant community consists of a diverse group of species and life forms that maximize niche occupation. An available niche for a plant could be bare ground with suitable resources. A diverse community that maximizes niche occupation captures a large proportion of the resources in the system, which may preempt their utilization by weeds. Plant communities with representatives from various functional groups also optimize ecosystem functions and processes that regulate plant community stability. Ecologically based weed management programs should focus on establishing and maintaining desired functional plant communities. Thus development and adoption of management strategies promoting desirable species offers the highest likelihood of sustainable weed management. For instance, consider enhancing the functional diversity of plant communities, especially the native forb component. Pokorny (2002) demonstrated native forbs compete better with spotted knapweed (*Centaurea maculosa*) than grasses because native forbs and non-native invasive forbs (e.g., spotted knapweed) are in the same functionally similar plant group. Maintaining a diversity of native forb functional groups such as shallow- and deep-rooted forbs could be a primary objective of land managers. Such ecologic knowledge is important in formulating revegetation goal statements.

Goal statements should describe the desired conditions to be developed. Revegetation goal statements might include the following:

- Improve rangeland forage production or rehabilitate degraded or disturbed sites
- Quickly reestablish vegetation to minimize erosion
- Establish species that can minimize noxious weed invasion or reestablishment; and/or
- Restore a healthy plant community.

Ecologically based weed management programs should focus on establishing and maintaining desired functional plant communities.

Step 2 Determine the necessity of revegetation

Revegetation should only be implemented when necessary. Determine if adequate desired vegetation is present at the degraded or disturbed site to assist the natural recovery process. Kotanen (1996) states revegetation should be constrained by the abundance and types of plants already available at the site. Determine the necessity of revegetation based on this advantage. Natural revegetation, therefore, may be the best option when desired plants are adequate at the site. Revegetation may be necessary, however, where rangeland improvement is desired to accommodate seasonal forage requirements and when quick groundcover is needed to mitigate erosion. Revegetation may also be necessary when desired plants are inadequate at the site to meet land use objectives, such as to minimize noxious weed invasion or restore healthy plant communities.

Rangeland improvement/forage production

Profitable ranching includes many components specific to the management of land, livestock, and resources. A year-round forage plan that satisfies livestock needs while maintaining the forage resource is essential. Often this includes seeded complementary pastures that supply nutritious forage at times of the year when other sources are inadequate or unavailable. Revegetating to meet this need and improve rangelands is often necessary.

Erosion control

Revegetation is often necessary to speed natural recovery. Site disturbances creating bare slopes require revegetation in combination with mulch, netting or erosion control blankets to prevent erosion while assisting germination and establishment. Prior to a planned disturbance, some projects require a topsoil or vegetation salvage operation. Topsoil containing plant propagules or whole plants and blocks of native sod are removed, set aside, and replaced. Wildfire-affected areas may also require revegetation to prevent erosion, especially on severe burns, stream corridors and slopes greater than 15 percent.

Revegetation is not necessary on every degraded or disturbed site. Adequate desired vegetation may be present or immediately adjacent that can assist the natural recovery process. Kotanen (1996) states that revegetation should be constrained by the abundance and types of propagules available at the disturbed site. As a result, natural regeneration may be the best option when desired plants are adequate within the site as propagules or whole plants.

Desired plant introduction

Weed-infested sites with inadequate desired plant canopy cover (Figure 1, p. 4), usually of less than 20 percent, may require revegetation with competitive plants to meet various land-management goals. On these sites, weed control is often short-lived because desired species are not available to occupy niches opened by weed control (James 1992, Sheley et al. 1996).

To determine canopy cover of a site:

1) Obtain a hoop made from coated cable up to ½ inch thick (available at most farm and ranch supply outlets). Purchase 93 inches of cable and fasten the ends with a cable ferrule, clamped with a chisel or heavy screwdriver and hammer.
2) Randomly toss hoop and let it land flat on the ground.
3) Visually estimate the percentage of ground covered by the canopy, as shown below, of desired vs. non-desired plants (do not count plants as this will give you density, not cover).
4) Repeat 2-3 at least ten times.
5) Add the desired plant percentages and divide by ten, or the number of times

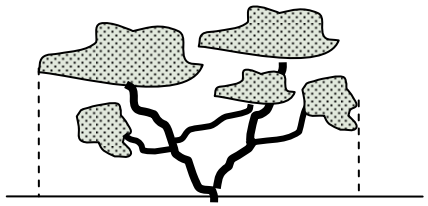


Figure 1. *Canopy cover is the area of ground covered by the vertical projection of the outermost perimeter of the natural spread of plant foliage.*

Introducing and establishing competitive grasses, and eventually forbs, will be essential for successful long-term management of weed infestations and the restoration of desired plant communities (Sheley et al. 2001a). Weed density should be significantly reduced in order to minimize competition with seeded species. This will require effective management for the first couple of years or longer, to weaken an infestation and significantly reduce weed competition for light, water and nutrient resources. Spot-treating with herbicides or hand-pulling weeds should be done when possible to protect and enhance the growth and vigor of native forbs. Unnecessary broadcast herbicide treatments will injure or permanently damage remaining native forbs. Once removed, forbs are difficult and expensive to reestablish. With effective, long-term weed management, weed-infested sites with more than 20 percent desired vegetation canopy cover do not usually require revegetation. When the cover of desired plants is adequate to direct natural revegetation, desired grasses and forbs steadily occupy open niches made available by the removal of weeds.

Step 3 Determine the likelihood of successful revegetation

It is important to determine if revegetation is likely to succeed or fail prior to implementation. Several soil properties provide a good indication of the likelihood of revegetation success. In some cases, problematic soil properties can be amended. For instance, soils with low organic matter can be amended with the addition of compost. Highly acidic or highly alkaline soils can be amended with sulfur, peat, lime, or fertilizer. Another practical alternative to amending acidic or alkaline soils could be to seed with species adapted to these extremes.

The decision index below is found in most Natural Resource Conservation Service (NRCS) county soil surveys and helps the user assess soil condition. Soil testing also provides more accurate and site-specific information. Most serious revegetation projects test the soil first.

Contact local experts if your soil properties are outside the acceptable range. Proceed with Step 4 if your soil properties are acceptable.

Soil Decision Index

Use this chart to determine if revegetation is likely to succeed without soil amendments based on soil properties.

Soil Parameter	Ideal Condition	Acceptable Range	My soil's properties	Are my soil's properties within the acceptable range? Yes or NO
Bulk density (g soil/cm^3)	1.4	1.2-1.6		
Soil texture (sand, silt, clay)	loam	clay loam to sandy loam		
Salinity (electrical conductivity (mm hos/cm soluble salts))	0-2	<8		
Organic matter (% in soil)	>3	>2		
pH	6.5-7.5	5.5-8.5		
Soil adsorption ratio (SAR)	<6	<10		

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Step 4 Salvage vegetation and topsoil prior to planned disturbances

Consider salvaging a portion of the vegetation that was on the site before disturbance. If it is likely a project will require revegetation, salvaging or protecting existing plants and seeds already adapted to the site is recommended. This will prevent permanently losing this resource and supplement the revegetation process (see Step 11, Transplanting, p. 36). For instance, blocks of the existing native sod can be removed, stored, and replaced after the construction work has been completed.

As an alternative to salvaging whole plants, some seed companies offer on-site hand collection and custom grow-outs. Hand collectors gather seeds from plants on the project site and provide them back to the project as requested. For large or long-duration projects, the collected material can be cultivated for a steady supply in subsequent years.

In addition to salvaging vegetation, also consider salvaging healthy topsoil. After wildfire, replace soil that was pushed aside for firebreak development. Topsoil contains beneficial microorganisms (bacteria, fungi, protozoa, etc.), earthworms and insects. It also contains living plant propagules such as seeds, plant fragments, and whole plants—valuable revegetation resources well adapted to the site. Biological activity in this zone cycles soil nutrients, increases nutrient availability, aerates the soil, maintains soil structure and increases soil water-holding capacity. Reapplication of healthy topsoil enhances revegetation success and promotes establishment of a persistent vegetative cover. Topsoil that is damaged or unfit, for instance containing invasive weeds, should not be salvaged; instead, it should be removed and replaced with healthy topsoil.

Avoid damaging topsoil by keeping the soil alive, protected, and weed-free until it can be returned to the site. Salvage topsoil during the fall while it's moist (not wet) to avoid depressing potential recruitment of seeds present in the soil. Store in shallow piles less than two feet high, exposing as much soil to air as possible to avoid damaging microorganism numbers with anaerobic conditions and as briefly as possible. A study in Yellowstone National Park showed topsoil stripped and replaced within 90 days retains viable populations of mycorrhizae fungi, but topsoil stored over one winter lost most of its mycorrhizal propagules (Williams 1991). Rokich et al. (2000) found stockpiling topsoil for one or three years demonstrated substantial, significant declines in seedling recruitment from the available seed bank—to 54 percent and 34 percent of the recruitment achieved in fresh topsoil, respectively. If you must store topsoil longer than a few weeks, sow it with a protective, sterile cover crop such as Regreen, a sterile hybrid cross between common wheat and tall wheatgrass (*Triticum aestivum* x *Elytrigia elongata*), or triticale, a sterile hybrid cross between common wheat and cereal rye (*T. aestivum* x *Secale cereale*). Monitor the stored topsoil often and remove invasive weeds.

When replacing topsoil to a site, do so with a minimum number of machine passes. To avoid weed invasion or soil erosion, schedule topsoil replacement when there is assurance that the area will be revegetated within a few days. If the volume of topsoil is limited, concentrate the returned topsoil in small pockets to allow increased retention of the biological activity of the soil (Claassen and Zasoski 1993). However, if you have enough topsoil, spread at least six inches deep. Redente et al. (1997) found topsoil spread to this thickness was sufficient for the

establishment and continued productivity of vegetation at a northwest Colorado mine site. They found deeper topsoil depths (12, 18 and 24 inches) were associated with plant communities dominated by grasses and shallow topsoil depths supported more diverse plant communities with significantly greater forb production and shrub density.

A topsoil salvage operation may assist long-term roadside revegetation success. Biologically inactive and nutrient-poor construction fill materials used along roadsides predicate the addition of topsoil to serve as a source of nutrients and mycorrhizal inoculum and thus enhance the likelihood of successful long-term revegetation.

Step 5 Site preparation

Soil-compacted sites

Soil consists of organic material, air spaces and different-sized clumps and particles of sand, silt, and clay. A loss of soil structure from compaction, excessive tillage, or tillage when soil is too wet, affects soil processes. Compaction limits air exchange to roots and the ability of water to percolate through the soil. Compaction also limits the number of safe sites, or areas suitable for seed germination and growth. Broadcasted seed will sit atop compacted soil, where it will be vulnerable to wind, water, heat, and predation.

To improve soil structure and prepare a favorable seedbed for germination and establishment, compacted sites should be scarified or plowed. Scarification is a form of ripping that breaks up topsoil aggregates. This is accomplished by raking the soil surface with ripper shanks pulled behind a tractor, grader or bulldozer. In sites where the topsoil has been removed, ripping subsoils to a depth of six to 12 inches before adding topsoil is recommended. Disc plows are often harmful to soil structure and should not be used to mitigate compaction unless coarse clods, produced when the soil was worked while wet, dominate the site.

Seedbed preparation

Compacted soil requires seedbed preparation. The degree of seedbed preparation in other cases depends partly on the seeding method (See Step 9, "Determine a Seeding Method," p. 29), which is influenced by site accessibility, terrain and seedbed characteristics. Seedbed preparation is usually not necessary when drill seeding, but is strongly recommended when broadcast seeding or hay-mulch seeding. The ideal seedbed contains adequate safe sites. The ideal seedbed is also firm enough to prevent wind and water erosion and allow good seed-to-soil contact, yet loose enough for the seed to sprout and penetrate the soil. Seedbed firmness is ideal when, walking across it, footprints remain that are four inches deep.

Broadcasted seed will sit atop compacted soil, where it will be vulnerable to wind, water, heat, and predation.

A seedbed can be prepared through shallow chiseling, plowing, harrowing or dragging small chains. Plowing loosens the upper layer of soil. This increases the number of safe sites and facilitates germination and root extension. Plowing should be carefully considered, as it may permanently damage desired vegetation and facilitate erosion on slopes or fine-textured soils. Never deep plow on sites with invasive weeds. Deep plowing promotes nitrogen release, which favors heavy weed growth. Harrowing and raking are secondary tillage operations that use spiked or toothed cultivating implements to uniformly roughen the soil surface. Small chains function similarly. These methods can be used both before and following broadcast seeding to break up crusts or to lightly cover seeds. Light packing of the soil following broadcast seeding is beneficial for adequate seed-to-soil contact. The application of hydromulch is also beneficial following broadcast seeding.

Burned-area revegetation typically does not require seedbed preparation if the reseeding immediately follows fire. Ash created by a fire can provide an excellent seedbed. A fall-dormant broadcast seeding into the ash will cover and retain seeds. The moisture action over subsequent seasons will work the seeds into the soil while breaking down any hydrophobic soil layers. Frost heaving will also break down any ash crust layers that may have formed from fall rains before or after reseeding.

Soil amendments

Amendments are added to soils before or shortly after seeding to provide a better medium for plant growth. In some cases, altering the amount of nitrogen can assist establishment. Additions of soil microorganisms, when necessary, may also assist establishment.

Nitrogen fertilizers should only be used when soil tests reveal a gross deficiency. Fertilizers may also be necessary in mesic or moist sites when rapid growth and maximum production is desired with agronomic species such as tall fescue (*Lolium arundinacea*). The high nitrogen requirements of this non-native grass makes it well suited for use in mixtures with nitrogen-fixing legumes such as alfalfa.

Rarely is nitrogen needed for native species, especially late-seral grasses such as bluebunch wheatgrass (*Pseudoroegneria spicata* ssp. *spicata*). These grasses have minimal nitrogen requirements, having evolved in low-nutrient environments. In many revegetation cases, reducing the amount of available nitrogen in the soil can increase late-seral grass establishment by reducing weed competition. For this reason, when seeding late-seral native grasses in moderate- or high-nitrogen sites, consider a low rate seeding (< 20 lbs PLS/acre) with a sterile companion crop such as Regreen to sequester nitrogen. Nitrogen reduction will hinder the growth of invasive weeds while favoring establishment of the late-seral seeded species. Companion crops further favor seeded species by protecting seeds and soil from wind and water erosion, conserving soil moisture, moderating soil temperatures, and protecting seedlings.

The addition or reduction of nitrogen can significantly effect invasive weed growth. The reduction of soil nitrogen through cover crop sequestration can benefit native grasses, whereas the addition of non-essential nitrogen reduces important mycorrhizal activity (St. John 1997) and encourages heavy weed growth. In one southeastern Montana study, the main responses to nitrogen fertilization in a dry-land situation were increased annual grass or annual weed production and decreased plant diversity (Hertzog 1983). Nitrogen additions are not necessary when seeding native grasses unless a gross deficiency is present.

A sere is a step in the sequence of plant community succession where successive plants occupy an area from the initial stage to the climax.

Soil microorganisms process mulch and dead plant material into a form available for plant uptake, an essential component of nutrient cycling. Important microorganisms include bacteria, protozoa and fungi. Mycorrhizal fungi contribute to plant growth and survival in degraded habitats. These fungi develop a beneficial relationship with plants and are known to improve the phosphorus uptake, drought tolerance and pathogen resistance of host plants. These microorganisms also benefit nitrogen cycling, enhance the transport of water (improving drought resistance) and increase offspring quality, contributing to long-term reproductive success and fitness of the species (Kumar et al. 1999). Mycorrhizal inoculation of locally collected or salvaged nitrogen-fixing plants or nursery stock may benefit a project. If determined beneficial, place inoculum below the seedling at transplant stage or dip bareroot stock in adhesive-treated inoculum.

You can reestablish mycorrhizal fungi naturally by collecting the top litter layer from a local weed–free landscape and working it into the topsoil or by planting shrubs that can capture wind-blown topsoil and mycorrhizal spores.

Step 6 Reduce weed interference

Successful establishment of seeded species often depends on adequate soil moisture and significant reduction of invasive weed competition. When revegetating weed-infested sites, strategies are available to reduce weed competition for successful germination and establishment of seeded species. These strategies may include sequestering nutrients with cover or companion crops. Reducing the availability of nutrients to weeds can reduce weed interference with seeded species, especially late-seral native grasses. Sites high in such nutrients as nitrogen favor quick-growing, invasive weeds; sites with low nitrogen favor slow-growing, late-seral native grasses. Herron et al. (2001) found seeding cereal rye (*Secale cereale*), an early-seral cover crop, dramatically lowered nitrogen and shifted the competitive advantage from spotted knapweed to bluebunch wheatgrass. Fast-growing cover crops sequester soil nitrogen and reduce weed interference by depriving weeds of some of this resource. To reduce nutrients at sites with high soil nitrogen, consider planting an early-seral cover crop the year before revegetating with native, late-seral grasses.

Managing infestations with mowing or herbicides for the first couple of years prior to seeding (or longer) to weaken an infestation is recommended. This will significantly reduce competition for light, water and nutrient resources. For instance, mowing spotted knapweed can be effective in reducing seed production and weakening an infestation. Rinella et al. (2001) found mowing as a single management tool decreased spotted knapweed density by 85 percent when performed during the early bud stage. Integrating mowing with other management tools may further reduce weed density. Combining mowing with an appropriate herbicide applied one month after the last mowing cycle to the rapidly developing regrowth may be effective. Removing plants that have acclimated to frequent mowing by growing low to the ground can be accomplished through herbicide treatments or hand-pulling. Consider mowing and applying herbicide in a single, efficient entry with a wet-blade mower.

In cases where forbs were planted, herbicides should be carefully applied only to non-desired weeds or hand-pulled to avoid damage to the seeded forb species.

Another strategy to reduce weed interference is a fall-dormant no-till drilling operation preceded by a late-season non-selective herbicide application such as glyphosate to remove weeds and invasive grasses such as cheatgrass (*Bromus tectorum*). When cheatgrass is present, this strategy can substantially reduce competition for early-season moisture the following spring. When invasive forbs are the dominant component, a cost-effective revegetation strategy developed by Sheley et al. (2001b) may be considered, using picloram and a no-till drill with a single field entry (see text on following page).

"Single-entry" Revegetation

Weed control is often short-lived in areas dominated by noxious weeds because desired species are not available to occupy niches opened by weed control procedures. Weed-infested sites lacking an adequate understory of desired species require revegetation for successful long-term weed management (Borman et al. 1991). However, revegetation of weed-infested sites is often expensive because of the number of attempts required for success and the number of field entries needed to maximize the potential for seedling establishment (Sheley et al. 2001b).

The revegetation of weed-infested sites has customarily required multiple entries:

1) The site is tilled in late fall to loosen the soil and encourage germination of weed seeds.
2) A few weeks later, a non-selective herbicide is applied to control newly emerging weeds.
3) Following the herbicide application, fall dormant grasses are seeded with a no-till drill.
4) The following spring, the remaining weed seeds and seeded grasses germinate and emerge; with adequate spring precipitation, both weed and grass seedlings survive. If grass seedlings survive until midsummer, a broad-leaf herbicide is applied to reduce weed competition.

In short, successful revegetation of weed-infested sites can be expensive. By contrast, a "single-entry" approach can direct cost-effective and reliable revegetation. In one late-fall field entry, a residual broadleaf herbicide can be applied at the very time grasses are seeded with a no-till drill.

Sheley et al. (2001b) combined eight herbicide treatments and three grass species at two Montana sites infested with spotted knapweed. The best revegetation success resulted from the fall application of picloram at ½ or 1 pint per acre with 'Luna' pubescent wheatgrass (*Elytrigia intermedia* ssp. *Trichophorum*) as the seeded species. This cost-effective and reliable "single-entry" strategy can be a major component of many sustainable weed management programs.

Young grass seedlings can be sensitive to many herbicides. Although herbicide recommendations are beyond the scope of this document as selection and application are based on site specific conditions, some generalizations can be set forth. According to the USDA NRCS (2000), the application of bromoxynil at the three- or four-leaf grass stage enables early suppression of young broadleaf weeds; 2,4-D may be applied once the grass seedlings have reached the four- to six-leaf stage, or later. On the other hand, Sheley et al. (2001b) found the application of picloram at ½ or 1 pint per acre did not injure seeded grasses, even with the two- to three-year soil residual. Grass injury did occur, however, when picloram was applied at two quarts per acre. Contact local experts for herbicide recommendations and rates specific to your site conditions.

Step 7 Design a seed mix

When selecting species, varieties or cultivars, choose those most appropriate to the revegetation goals and environmental conditions of the site. Avoid purchasing preformulated wildflower seed mixes. A recent University of Washington study found 19 packets of wildflower seed mixes contained anywhere from three to 13 invasive species. Rather than purchasing preformulated mixes, buy certified wildflower seeds species by species—and make sure they are native to the region.

We strongly encourage the selection and use of native species to promote ecologic stability and plant community integrity. Native species are available for most any site needing revegetation. The USDA - NRCS *Plants National Database* at http://plants.usda.gov/ provides plant profiles with synonyms, classifications, distribution maps, images, and additional sources and references for plant species. This USDA-NRCS site also hosts VegSpec, a web-based decision support system that assists land managers in the planning and design of revegetation practices. This decision support system utilizes soil, plant, and climate data to select plant species that are site-specifically adapted, suitable for the selected practice, and appropriate for the purposes and objectives for which the revegetation is intended. Other helpful sources are the *Intermountain Planting Guide* published by USDA-ARS (2001) and *Restoring Western Ranges and Wildlands*, a three-volume guide published by USDA-Forest Service Rocky Mountain Research Station (2004).

> A native grass cannot typically compete in a mixture with introduced grasses. Avoid mixing native grasses with introduced grasses.

Determining an appropriate seed mix should initially be based on revegetation goals or management objectives of the area, such as to:

1) Improve rangeland forage production or rehabilitate degraded or disturbed areas;
2) Quickly reestablish vegetation to minimize erosion;
3) Establish species that can minimize weed invasion or reestablishment; and/or
4) Restore a healthy plant community.

Once revegetation goals have been determined, site characteristics such as soil attributes, precipitation, temperature and elevation confirm or further direct species selection. Local experts can assist in designing a proper seed mix that addresses species compatibility and avoids niche overlap to prevent using species that may be displaced over time.

Take care to ensure adequate species diversity in revegetation. Comfort and Wiersum (2000) advise several species of grasses, but not more than five, should be seeded to cover the range of site conditions and increase revegetation success. When developing a mix, consider species compatibility as seedling vigor varies by species. These vigorous species develop rapidly, often at the expense of other species in the mix. For instance, non-native tall wheatgrass (*Elytrigia elongata*), should be seeded alone, as it will completely dominate a site after four or five years.

Species characterized by slow-developing, non-aggressive seedlings, such as non-native Russian wildrye (*Psathyrostachys juncea)* and tall fescue, should also be seeded alone (USDA 1996). Birdsfoot trefoil *(Lotus corniculatus*), an introduced legume, is intolerant of competition from other plants and performs best alone (Smoliak et al. 1990). If weeds are present, competition-intolerant species should not be considered. Unless the site is to be grazed, avoid mixing tall-growing grasses with such shade-intolerant legumes as birdsfoot trefoil. Such grasses can suppress legume performance.

When purchasing seeds, ensure the mix is weed-free. To improve quality and establishment, purchase certified seeds. Only cultivated, named varieties such as 'Luna' and 'Canbar' can be certified. (Bags of such seed bear blue "certified seed" tags.) Certification guarantees the seeds have the same genetic potential to perform in the field as did the breeder seeds of the variety when it was first released for production. For instance, when purchasing certified ''Tegmar' intermediate wheatgrass (*Elytrigia intermedia* ssp. *intermedia*), you are sure to have dwarf intermediate wheatgrass plants to meet your revegetation goals.

Recent interest in native wildland seeds and a critical need for well-adapted native species for reclamation has prompted a seed certification class for such collections. The "Source Identified Class" verifies the species and origin of wildland seed harvests. Seeds that are harvested following approved guidelines and procedures are labeled with yellow certified seed tags, confirming the species and origin of the harvest by the certification agency.

A list of selected species based on desired season of rangeland use is provided in Table 1. Recommended native and introduced grasses, forbs, and shrubs are included.

Revegetation goals

1) *Improve rangeland forage production or rehabilitate degraded or disturbed areas*

A. *Rangeland improvement* Numerous native and non-native species are appropriate for rangeland improvement. Mixtures of species with differing palatability are usually not recommended, as some will be overgrazed while others are underutilized depending on time of grazing events. For instance, needle-and-thread grass (*Stipa comata*) is preferred less than other grasses. And the relatively low palatability of tall wheatgrass makes it necessary to have pastures fenced separately, giving livestock no forage alternative. Mixtures should be designed with careful attention to niche overlap to avoid reversion to a few species over time. A series of dryland pastures with one or more planted to spring-grazed species and others planted to summer or fall species may be an effective option (Holzworth et al. 2000). Because such sites may lack maximized niche occupation, frequent monitoring for weeds is necessary.

Consider pasture management and the ability of the species to supply forage when needed, and then design the mix to accommodate seasonal forage requirements. For instance, winterfat (*Krascheninnikovia lanata)* is one of the most valuable plants for maintaining animal

weight on winter range (Smoliak et al. 1990). Include a combination of shallow- and deep-rooted forbs and grasses that grow both early and late in the year to maximize resource competition in time and soil profile space throughout the year to guard against weed invasion.

Forage production can be enhanced with a mixture of productive cool-season grasses and a deep-rooted legume. This mix produces more high-quality forage than grass alone. For instance, orchardgrass (*Dactylis glomerata*) alone will yield an average of one to two tons per acre of hay, but can yield a maximum of two to three tons per acre when grown with clover or alfalfa. Also, the palatability and nutritive value of tall fescue is improved when it is grown with a legume (Smoliak et al. 1990). To avoid bloat, replace alfalfa with low-bloat legumes such as native vetches or sainfoin (*Onobrychis viciaefolia*), cicer milkvetch (*Astragalus cicer*) or birdsfoot trefoil. Following seeding, and if appropriate to the site, consider planting shrubs that can add vertical strata to the ecosystem and eventually enhance soil fertility, reduce evapotranspiration, increase nutrient cycling, add organic matter from litterfall and further improve soil structure (West 1989). The presence of shrubs may significantly increase the productivity of associated grasses as compared with shrub-free grass stands (Rumbaugh et al. 1982). Good winter protein and energy make sagebrush (*Artemisia* spp.) valuable winter forage. Bitterbrush (*Purshia tridentata*) and fourwing saltbush (*Atriplex canescens*) provide high year-round nutrition, but maximum plant performance is maintained when it is used as winter forage (Brown and Wiesner 1984).

B. Natural area rehabilitation Areas not managed for forage production, such as natural areas, should be seeded with native species to maintain ecologic stability and plant community integrity. Seeding non-native grass is not recommended. This will guard against their dominance, which could inhibit native community recovery and potentially alter the diversity of local plants.

When designing a seed mix for natural areas, including wetlands, use the local native landscape as reference for species selection based on occurrence and distribution. Germination success and plant hardiness may be increased because the seeds are local and well adapted to local conditions. Furthermore, the local landscape can provide species that may not be available commercially. Depending on current-year growing conditions, however, collected wildland seeds can sometimes have low viability. For instance, germination tests of Indian ricegrass (*Achnatherum hymenoides*) revealed over half the seeds lacked a developed embryo and were not capable of germination (Stoddart and Wilkinson 1938). To compensate for low viability, collecting large quantities of seeds is necessary. This can increase collection time and costs unless volunteer labor is available.

C. *Roadside rehabilitation* Roadside soil often has low fertility and depleted biological activity because of nutrient-poor construction fill materials. This condition reduces the establishment and persistence of vegetative stands (Claassen and Zasoski 1993) and limits revegetation success. To increase long-term success, amend with healthy topsoil to supply nutrients, plant propagules and mycorrhizal inocula. Topsoil should be added when it is unfit or altogether missing from roadsides. Before construction, plan a topsoil salvage and replacement operation, if appropriate.

After construction completion, quick application of seed is usually necessary given the likelihood of rapid invasive weed establishment along roadsides. In addition, the freshly scarified, roughened surface provides an excellent seedbed. When selecting plant materials, consider species' ability to adapt to the site, rapidly establish and self-perpetuate. Whenever practicable, select and distribute native species based on ecological criteria (Harper-Lore 2000). Native grasses such as Idaho fescue (*Festuca idahoensis*), sheep fescue (*F. ovina*), canby bluegrass (*P. canbyi*), and 'Nortran' tufted hairgrass (*Deschampsia caespitosa*) are short-growing and can significantly reduce costly roadside mowing maintenance.

Also consider the species' ability to minimize soil erosion and tolerate disturbance. Rhizomatous species with extensive root systems are a good choice. For instance, streambank and thickspike wheatgrass (*Elymus lanceolatus* ssp. *psammophilus* and ssp. *lanceolatus*, respectively) are strongly rhizomatous with excellent seedling vigor. These species are frequently used for erosion control. These species, however, are tall stature and may require regular mowing. Grass-like sedges, such as slenderbeak sedge (*Carex athrostachya*), dewey sedge (*C. deweyana*), and chamisso sedge (*C. pachystachya*), are demonstrating excellent results with roadside restoration efforts in Glacier National Park.

When revegetating roadsides it is difficult to recreate a native community in its entirety. It is still valuable, however, to use species that are major components of the targeted community type. Morrison (2000) states that dominant, prevalent (i.e., typically occurring most abundantly), and "visual essence" (i.e., having some unique, visually important trait within the community) species should be included. Implementing integrated roadside vegetation management practices that favor the seeded species is essential to long-term roadside revegetation success.

2) *Quickly reestablish vegetation to minimize erosion*

Sloped landscapes and drainages should be seeded with soil-stabilizing species to minimize erosion and sedimentation after drastic disturbances such as wildfires. Quick-establishing annuals provide immediate protection, but only for a year. Rhizomatous grasses and grasslike plants are ideal for erosion control because of their extensive networks of soil-stabilizing underground stems. 'Critana' thickspike wheatgrass, a native rhizomatous cultivar with very strong seedling vigor, is good for site stabilization in coarse soils. Blue wildrye is a native, cool-season bunchgrass commonly used in erosion-control seedings in forested sites where rapid slope or site stabilization is needed. Pacific aster, Rocky Mountain beeplant (*Cleome serrulata*), purple coneflower, yellow and white evening primrose (*Oenothera biennis* and *O. pallida*), 'Bandera' Rocky Mountain penstemon (*Penstemon strictus*),* and lacy phacelia *(Phacelia tanacetifolia*) are native forbs that perform well in disturbed areas, helping reduce erosion. Grass-like plants such as sedges, spikerushes (*Eleocharis* spp.), rushes (*Juncus* spp.), bulrushes (*Scirpus* spp.) and cattails (*Typha latifolia*) are helpful for erosion control in riparian areas.

Quick establishment is critical when selecting species to minimize soil erosion. Annual ryegrass (*Lolium multiflorum*) or small grains establish very quickly to provide rapid protection, yet are non-persisting. Regreen is a sterile, hybrid cross that reduces wind and water erosion, establishes quickly, and is non-persistent. Canada wildrye (*Elymus canadensis*) is a native, cool-season, perennial bunchgrass often included

in seed mixtures for rapid establishment of protective cover. Winter wheat (*Triticum aestivum*) is a good choice for protection and cover into the spring but can be moderately competitive to establishing perennials. Comfort and Wiersum (2000) recommend slender wheatgrass (*Elymus trachycaulus* ssp. *trachycaulus*), a quick-establishing native bunchgrass, at 20 to 40 percent of the seed mix for wildfire rehabilitation.

3) *Establish species to minimize weed invasion or reestablishment*

An effective seed mix consists of aggressive, quick-establishing grasses and forbs that occupy available niches without competing with each other. Pokorny (2002) suggested enhanced forb diversity and function may result in preferential use of site resource by desired species. For instance, spotted knapweed performed best at sites with low functional group diversity, especially when shallow- and deep-rooted native forbs were absent. This may demonstrate sites with a high functional diversity of native forbs might better compete with spotted knapweed and could resist weed invasion. It is highly recommended that the native forb component of a plant community be protected to resist weeds and maintain ecosystem stability. Once removed, this critical feature of plant communities is difficult and expensive to reestablish. Weed management strategies should always preserve existing and seeded native forbs.

For a plant community to be "weed-resistant," it must effectively and completely utilize all available resources. Design seed mixes that include shallow- and deep-rooted forbs and grasses that grow both early and late in the year to maximize any available niches. Cool-season species initiate growth in early spring. These species use soil resources available in the upper soil profile and begin seed production in early summer. Competitive, native, cool-season grasses include thickspike wheatgrass, slender wheatgrass, western wheatgrass (*Pascopyrum smithii*), and Canada wildrye. Non-native grasses highly competitive with weeds include several cultivars of pubescent wheatgrass (*Elytrigia intermedia* ssp. *trichophorum*), intermediate wheatgrass, hard fescue (*Festuca trachyphylla)* and 'Bozoisky-Select' Russian wildrye, owing to its long season of growth and extensive root system. Solid stands of meadow brome (*Bromus biebersteinii*), a non-native bunchgrass, are relatively resistant to weeds. Idaho fescue and 'Covar' sheep fescue are native, drought-tolerant, cool-season bunchgrasses that are strongly competitive with invasive weeds once established in mature stands.

When treating noxious weeds with herbicides, take care to prevent neighboring shrubs and forbs. Avoid broadcast herbicide treatments, unless necessary, as indicated by high weed density.

Competitive native forbs suitable for revegetation include blue flax (*Linum lewisii*), white yarrow (*Achillea millefolium*), Maximilian sunflower (*Helianthus maximiliani*), blanketflower (*Gaillardia aristata*), and fireweed (*Chamerion angustifolium*). Lacy phacelia is an aggressive native annual with good competitive abilities. Gayfeather (*Liatris virgata*), a native forb, was found to be a strong competitor with spotted knapweed (Pokorny 2002); check with seed suppliers on the availability of this species. Numerous other native forbs are available and suitable for revegetation efforts.

Deeply tap-rooted shrubs such as sagebrush, rabbitbrush (*Ericameria* spp.), bitterbrush or 'Wytana' fourwing saltbush used in the seed mix or as young plants can utilize resources from the lower soil profile throughout the growing season. Furthermore, shrubs may increase establishment of understory species. Call and Roundy (1991) summarized West (1989) in stating shrubs can:

- Positively affect water availability by intercepting water from light rains and snow
- Increase infiltration rate and water-holding capacity by improving soil structure through reducing raindrop impact and adding organic matter from litterfall
- Enhance soil fertility and seedbanks for plant establishment by catching wind-blown soil, seeds and mycorrhizal spores, and concentrate nutrients through absorption and fixation by roots; and
- Decrease understory temperatures that reduce evapotranspiration and increase nutrient cycling when shrub canopies were present.

4) Restore a healthy plant community

Weed-infested sites alter the structure, organization and function of ecologic systems (Olson 1999). A healthy plant community consisting of functionally diverse species is the key to sustainable invasive weed management as well as meeting other land use objectives.

The long-term management of a healthy plant community involves steady removal of weeds with replacement by desired plants. This replacement can occur naturally, when desired vegetation is adequate within the degraded site, or through artificial revegetation. Species selection for restoration of a desired or healthy plant community should be based on recommendations in the previous section to minimize weed invasion, as well as the intended use of the site.

It is imperative to protect existing native forbs within a weed-infested site during weed management. This may be difficult to accomplish since the most cost-efficient method of control is often through broadcast applications of herbicides that can injure or permanently damage existing native forbs. Instead, if practical, use herbicide spot treatments to protect remnant forbs.

Long-term maintenance that favors the seeded species will be necessary towards the development of a healthy plant community. The desired grass component should be managed to encourage strong vigor and growth, such as by avoiding heavy or untimely grazing practices. The forb component should be managed to encourage the highest levels of diversity, a condition that may be promoted by periodic prescribed burning.

Site Characteristics

Once species have been identified that meet revegetation goals and management objectives, site characteristics such as soil attributes, annual precipitation, soil moisture, temperature, and elevation need to be considered.

Soil Attributes

Soil texture, which is determined by the size and distribution of the particles comprising the soil, is an important characteristic that can direct species selection. Most seeded species prefer medium- to fine-textured soils. However, Indian ricegrass, a highly drought-tolerant native bunchgrass, is well adapted to sandy soils, and western wheatgrass, a native rhizomatous grass, does well on heavy clay soils. Loam soil texture is considered ideal, and consists of 45 percent sand, 35 percent silt and 20 percent clay. (See Figure 2, p. 19)

Determining the chemical properties of soil can be helpful in directing or confirming species selection and in identifying needed soil amendments. The chemical status of a soil also indicates its suitabilityfor plant survival and growth.

If you are planning a challenging revegetation project, contact local experts and consider testing the soil for:

1) *pH* The optimal range is 6.5 to 7.5. Use revegetation species adapted to highly acidic (pH <6) or highly alkaline (pH >8.4) soils in lieu of attempting to amend the soil with additions of sulfur, peat, lime or fertilizer. Grasses, grasslike species, forbs and shrubs adapted to saline-alkaline soils are footnoted in tables 2, 3 and 4.
2) *Electrical conductivity (EC)* This is a measure of soil salinity; the optimal range is 0 to 2 mmhos/cm soluble salts.
3) *Sodium adsorption ratio (SAR)* This is the proportion of the concentration of sodium ions to the concentration of calcium plus magnesium ions in the saturation paste; optimum is <6. When SAR rises above 12, serious physical soil problems arise and plants have difficulty absorbing water
4) *Organic matter* This is a measurement of the percent organic material and humus in the soil; optimum is >3%. Organic matter increases soil porosity, infiltration, water-holding capacity, nutrient reserves, and improves soil structure. The addition of organic matter such as compost can increase soil microorganism development and thereby enhance the establishment of seeded species.

You can roughly estimate the approximate amount of sand, silt and clay in soil by a simple method called “manual texturing.” The feel of the moist sample when rubbed between the thumb and forefinger determines the texture. If the soil sample is predominantly sand, it will feel very coarse and gritty. If it is predominantly silt, it will feel smooth or slippery to the touch. And if it is predominantly clay, it will feel sticky and fine in texture.

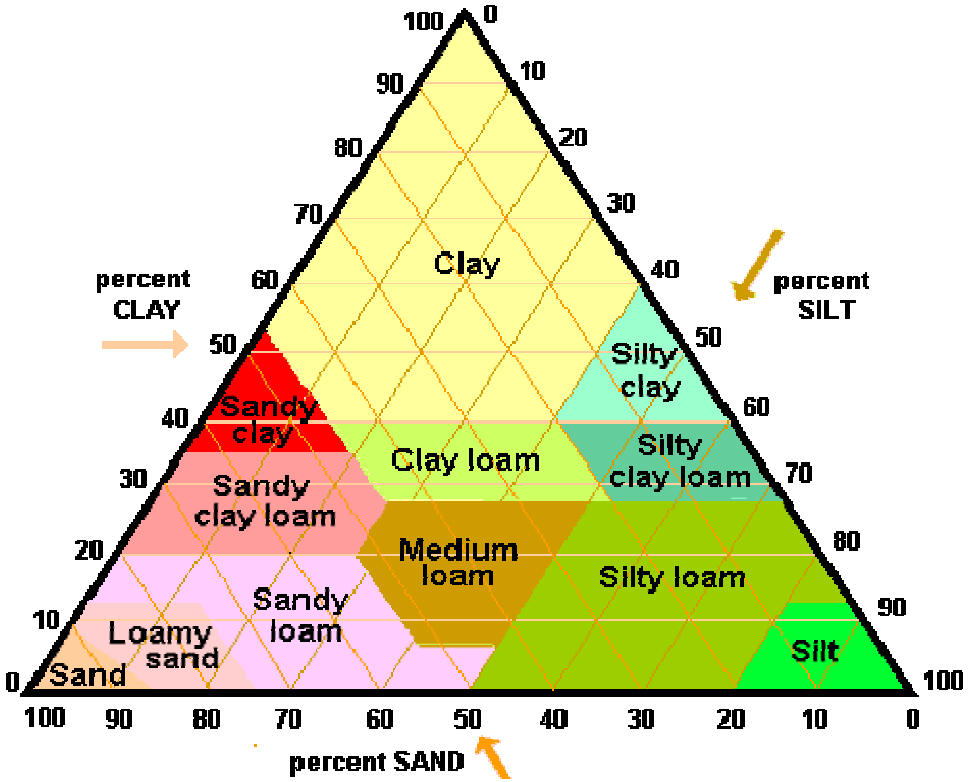

Figure 2. *The soil triangle illustrating the range in composition of sand, silt and clay for each soil textural class. The dotted line depicts a loam soil that has 45% sand, 35% silt and 20% clay content.*

Precipitation, soil moisture, temperature, and elevation of the site

Seeded species should be adapted to the annual precipitation and soil moisture level of the site. Temperature zone and elevation of the site should also be considered. Obtain the USDA Plant Hardiness Zone Map to consider species survival, especially for shrubs, based on average winter minimum temperatures, from your local USDA service center. Wildland seeds (native seeds collected from the local landscape) may have long-term resiliency, as they are locally adapted. Unfortunately, large quantities must often be collected to offset low seed viability. Custom-collecting by commercial harvesters is possible, and may be necessary for large projects when site-specific seed is desired or when preferred species are not commercially available. Seeds can be collected and used immediately for revegetation, or may be increased through cultivation and stockpiled to meet future demands.

Numerous species perform well on such high-soil-moisture sites as stream bottoms or wet meadow sites subirrigated for at least part of each growing season. Beardless wildrye (*Leymus triticoides*) is a native adapted to a wide variety of soils that are subirrigated, wet, or occur in annual precipitation zones greater than 18 inches. Other suitable natives are western wheatgrass and tufted hairgrass. Orchardgrass (*Dactylis glomerata*), meadow brome and tall fescue, although not native, are often recommended for irrigated pastures. Native sedges, spikerushes, rushes, bulrushes and cattails are grass-like species used extensively in riparian and wetland revegetation. Numerous native grasses, forbs, and shrubs are available for wetland/riparian revegetation projects. Planting greenhouse-grown plugs has demonstrated higher establishment rates than seeding or planting wildlings—plugs collected from wild populations (Hoag and Sellers 1995). Plugs should be planted when heat, light and water are greatest. Broadcast seeding of wetland/riparian areas is used primarily to increase overall species diversity. After seed broadcasting, do not cover seeds with soil; light and heat are needed for proper germination.

Many plants that have a large range vary considerably in height, growth habits, leafy characteristics and reproductive habits. Plants of the same species that display such variations are grouped into local ecological units associated with habitat differences. These local ecological plant groups are known as ecotypes: plants in the early stages of varietal development that lack the refined plant characters that come with breeding to fix desired characters. In practice, ecotypes are considered best adapted to areas no farther than 200 miles from their origin or point of collection.

Table 1. *Selected species for revegetation projects.*

Name	Cultivar	Preferred Soil Type	Minimum Ppt. (inches)	Pure Stand PSL Rate/Acre (pounds)	Notes
Native bunchgrasses--short to medium					
Indian ricegrass (*Achnatherum hymenoides*)	Nezpar, Paloma, Rimrock	sandy to loamy	8	12	Drought tolerant. Easy to moderate establishment, relatively short-lived. Useful in coarse soils on low-fertility sites. Highly palatable and nutritious.
Idaho fescue (*Festuca idaohensis*)	Joseph	silty-loamy to clayey	10-12	8	Moderately drought tolerant. Slow establishment. Poor seedling vigor. Good palatability.
Squirreltail (*Elymus elymoides*)	Sand Hollow	sandy to loamy	6	12	Short-lived. Fair seedling vigor. Becomes unpalatable at maturity. Often seeded as a mid-successional species. Competitive with cheatgrass and medusahead.
Sandberg's bluegrass (*Poa sandbergii*)	High Plains	sandy to clayey	8	4	Very drought tolerant. Slow establishment. Can withstand considerable grazing pressure.
Native bunchgrasses--medium to tall					
Mountain brome (*Bromus carinatus*)	Bromar	silty-loamy to clayey	12-16	15	Rapid establishment. Short-lived. Adapted to relatively moist soils. Good livestock forage value.
Tufted hairgrass (*Deschampsia caespitosa*)	Nortran	silty-loamy to clayey	20 (riparian)	2	Long-lived. Most common in moist sites and at higher elevations. Very palatable to livestock and wildlife.
Native bunchgrasses--medium to tall					
Canada wildrye (*Elymus canadensis*)		sandy	12	15	Rapid establishment. Short-lived. Prefers moist or periodically moist, well-drained sites. Good palatability, but poor grazing tolerance.
Prairie Junegrass (*Koeleria cristata*)		sandy	12	2	Drought tolerant. Easy establishment. Good-quality early spring forage.
Sand dropseed (*Sporobolus cryptandrus*)		sandy	10	2	Extremely drought tolerant. Moderate palatability. Prolific seed producer, tends to increase on poor condition rangelands. Seed should be scarified before planting.

Name	Cultivar	Preferred Soil Type	Minimum Ppt. (inches)	Pure Stand PSL Rate/Acre (pounds)	Notes
Native bunchgrasses--medium to tall (continued)					
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	Goldar, Secar, Anatone	silty-loamy to clayey	9	12	Drought tolerant. Moderate establishment. Adapted to most sites, including nonproductive sites.
Thurber's needlegrass (*Stipa thurberiana*)		loamy to clayey	9	10	Slow establishment. Seedlings are poor competitors. Palatable to livestock and wildlife.
Columbia needlegrass (*Stipa columbiana*)		silty-loamy to clayey	12	8	Slow establishment, but survival can be high. Tolerant of harsh environments. Occurs at higher elevations. Good palatability.
Native bunchgrasses--tall to very tall					
Blue wildrye (*Elymus glaucus*)	Arlington, Elkton	sandy to silty-loamy	12	10	Rapid establishment. Short-lived, but stands readily reseed themselves. Common on moist sites, but moderately drought tolerant.
Great Basin wildrye (*Elymus cinereus*)	Magnar, Trailhead	silty-loamy to clayey	8	11	Establishment requires 2-3 years. Not very competitive. Adapted to a wide variety of sites in winter-wet and summer-dry areas. Excellent winter forage and cover.
Native bunchgrasses--tall to very tall					
Slender wheatgrass (*Elymus trachycaulus*)	Primar, Pryor, Revenue, San Luis	sandy to clayey	16 (riparian)	12	Moderate drought tolerance. Rapid establishment. Short lived. Saline-tolerant. Useful where quick, native, non-aggressive perennial cover is desired.
Big bluegrass (*Poa ampla)*	Sherman	silty-loamy to clayey	8	5	Easy establishment. Intolerant of poorly drained soils or high water tables. Excellent palatability and stays green longer than other species.
Needle-and-thread (*Stipa comata*)		sandy to silty-loamy	10	14	Drought tolerant. Long lived. Useful for disturbed sites and winter forage.
Introduced bunchgrasses--short to medium					
Sheep fescue (*Festuca ovina*)	Covar, Durar	sandy to clayey	10-12	8	Drought tolerant. Slow establishment, but tenacious. Competitive, once established. Poor palatability to livestock, but used by wildlife.

Name	Cultivar	Preferred Soil Type	Minimum Ppt. (inches)	Pure Stand PSL Rate/Acre (pounds)	Notes
Introduced bunchgrasses--medium to tall					
Crested wheatgrass (*Agropyron cristatum*)	Douglas, Ephraim, Fairway	silty-loamy to clayey	10	8-12	Drought tolerant. East establishment. Long-lived. Useful where rapid establishment and early season for age is important.
Standard crested wheatgrass (*Agropyron desertorum*)	Hycrest, Nordan	sandy to clayey	10	10	Easy establishment. Similar to crested, but slightly more cold-, shade-, and moisture tolerant and productive.
Siberian wheatgrass (*Agropyron fragile*)	P-27, Vavilov	silty-loamy to clayey	8	8-11	Easy establishment. Similar to standard crested wheatgrass but more drought tolerant and palatable, later maturing, and performs better on lighter-textured soils. Seedling vigor may be low.
Meadow foxtail (*Alopecurus pratensis*)		silty-loamy to clayey	25 (riparian)	4-5	Slow establishment. Long lived. Useful for pasture and range improvement. Excellent palatability.
Timothy (*Phleum pratense*)	Climax, Clair	silty-loamy to clayey	16	9	Easy establishment. Adapted to moderately moist sites. Commonly planted as pasture or hay grass and for seeding riparian areas. Excellent palatability.
Introduced bunchgrasses--tall to very tall					
Tall wheatgrass (*Elytrigia elongata*)	Alkar, Jose, Orbit	silty-loamy to clayey	12	10-17	Drought tolerant. Easy establishment. Suitable for most saline sites. Low palatability.
Tall fescue (*Festuca arundinacea*)	Alta, Fawn, Kenmont, Goar	all soils except sandy	18	8	Slow establishment. Long lived. Tolerates wet, poorly drained sites. Good palatability and relatively tolerant of heavy grazing
Altai wildrye (*Leymus angustus*)	Prairieland, Pearle, Eejay	silty-loamy to clayey	18	15	Slow establishment. Extremely salt- and alkaline-resistant.
Russian wildrye (*Psathyrostachys juncea*)	Bozoisky, Swift, Mankota, Vinall	silty-loamy to clayey	12	7-10	Drought tolerant. Difficult establishment. Long lived. Excellent palatability and nutrition. Not adapted to cool, moist sites.

Name	Cultivar	Preferred Soil Type	Minimum Ppt. (inches)	Pure Stand PSL Rate/Acre (pounds)	Notes
Native rhizomatous grasses					
Streambank wheatgrass (*Elymus lanceolatus*)	Sodar	sandy to clayey	8	12	Drought tolerant. Moderate establishment. Short lived. Especially well suited for stabilizing silty to sandy soils on upland sites.
Beardless wildrye (*Leymus triticoides*)	Shoshone	sandy	10	20	Moderately drought tolerant. Difficult establishment. Saline tolerant.
Western wheatgrass (*Pascopyrum smithii*)	Rosana, Rodan, Arriba	silty-loamy to clay	10	16	Drought tolerant. Fairly easy to moderate esetablishment. Long lived.
Introduced rhizomatous grasses					
Creeping foxtail (*Alopecurus arundinaceus*)	Garrison, Retain	silty-loamy to clayey	25 (wet areas)	4	Moderate establishment. Long lived. Adapted to wet or periodically wet soils. Tolerates alkaline-saline soils. Very palatable and nutritious. Well suited for hay and pasture.
Newhy wheatgrass (*Elymus hoffmanii*)	Newhy	silty-loamy to clayey	10	14	Easy establishment. Adapted to moist soils including moderately saline sites.
Orchardgrass (*Dactylis glomerata*)	many	silty-loamy to clayey	18	8	Easy establishment. Medium to long-lived. Adapted to a wide variety of sites. Highly productive and palatable. 'Paiute' was selected for its drought tolerance.
Canada bluegrass (*Poa compressa*)	Reubens	silty-loamy to clayey	18	2	Able to grow in harsh sites. Useful to improving poor sites where other species are unable to grow.
Intermediate wheatgrass (*Elytrigia intermedia*)	Amur, Greenar, Oahe, Tegmar, Rush	silty-loamy to clayey	14	10-12	Moderately drought-tolerant. Easy establishment. Medium to long lived.

Name	Cultivar	Preferred Soil Type	Minimum Ppt. (inches)	Pure Stand PSL Rate/Acre (pounds)	Notes
Native forbs					
Rocky mountain penstemon (*Penstemon strictus*)	Bandera	sandy to silty-loamy	14	3-4	Widely adaptable. Ability to persist on rocky or sandy loam sites. Not recommended in areas with Lemhi penstemon, a sensitive plant, due to hybridization.
Palmer penstemon (*Penstemon palmeri*)		sandy to clayey	10	2-3	Does well on exposed and disturbed sites with well-drained sandy, gravelly soil. Drought and cold tolerant.
Firecracker penstemon (*Penstemon eatonii*)		sandy to loamy	10	1-3	Known for its winter hardiness, seed production, and wide adaptability.
Arrowleaf balsamroot (*Balsamorhiza sagittata*)		silty-loamy	12	7-15	Drought tolerant.
Blue flax (*Linum lewisii*)	Appar	sandy to silty-loamy	10	5	Drought tolerant. Easy establishment. Short lived, but will reseed itself.
White yarrow (*Achillea millefolium*)		sand to sandy	10	1	Drought tolerant. Aggressive.
Scarlet globemallow (*Sphaeralcea coccinea*)		sandy	8	2-4	Tolerates disturbance such as fire or disking. Hard seed coat often prevents germination.
Introduced forbs					
Alfalfa (*Medicago sativa*)	many	silty-loamy	12	15	Fair drought tolerance. Easy establishment
Cicer milkvetch (*Astragalus cicer*)	Lutana, Monarch, Oxley	silty-loamy	18	20-25	Fair drought tolerance. Slow establishment. Long lived. Cold hardy.
Birdsfoot trefoil (*Lotus corniculatus*)	Empire, Viking	silty-loamy to clayey	15	6	Slow establishment. Long lived. Grows best along and not in mixes.
Sainfoin (*Onobrychis viciifolia*)	Eski, Remont	silty-loamy	12	35-45	Drought tolerant. Easy establishment. Short lived. Alkaline tolerant.
Alsike clover (*Trifolium hybridum*)		clayey	32	8	Moderate ease of establishment. Short lived. Tolerates alkalinity more than other clovers.
Small burnet (*Sanquisorba minor*)	Delar	silty-loamy	10	20-24	Easy establishment. Long lived. Valuable forage for wildlife.
Forage kochia (*Kochia prostrata*)	Immigrant	wide range	6	1-2	Very drought tolerant. Seed viability is generally limited to one year. Competes well with invasive annuals.

Name	Cultivar	Preferred Soil Type	Minimum Ppt. (inches)	Pure Stand PSL Rate/Acre (pounds)	Notes
Native shrubs					
Sagebrush (*Artemisia* spp.)		sandy to clayey	8-12	varies	Drought tolerant. Many species and growth forms. Request seed harvested in similar environmental conditions. Important for forage and cover.
Fourwing saltbush (*Atriplex canescens*)	Wytana	silty-loamy to clay	8	13	Drought tolerant. Relatively easy to establish. Long lived. Salt tolerant.
Rabbitbrush (*Chrysothamnus* spp.)		sandy to clayey	8	varies	Easy establishment.
Bitterbrush (*Purshia tridentata*)	Lassen	sand to clayey	8	varies	Drought tolerant. High quality browse.
Curl-leaf mountain mahogany (*Cercocarpus ledifolius*)		silty-loamy	11	varies	Adapted to dry shallow to medium-deep soils on slopes and ridges from 2,000-9,000 ft. elevation. Important winter browse plant.
Shadscale (*Atriplex confertifolia*)		silty-loamy to clayey	4	varies	Medium to short lived. Often found in salty basins. May be difficult to establish due to seed dormancy.

Step 8 Assist Establishment

Seedling establishment is the most critical phase of revegetation (James 1992). Many factors can Influence establishment including variations in soil, site exposure and climate. Failures to establish are usually caused by a combination of factors; the most important are insufficient soil moisture and intense weed competition (Jacobs et al. 1998). Schoenholtz et al. (1992) states that early revegetation success is more a function of soil moisture than of soil nutrient availability, and Masters et al. (1996) states that invasive weed interference was the primary constraint to successful establishment of native plants.

Methods of enhancing establishment include:

a) Using species and selections adapted to local site conditions
b) Using high-quality, certified seed
c) Reducing weed competition through management or nutrient reduction with early-seral cover crops when planting native species
d) Inoculating seed or using locally collected legumes with proper bacteria to ensure maximum nitrogen fixation in sites lacking a healthy nitrogen cycle. This will improve phosphorus uptake, water transport, drought tolerance and resistance to pathogens. This may also increase offspring quality to contribute to long-term reproductive success and fitness of seeded species.
e) Heightening seedling survival by placing seeds using a drill seeder or preparing the seedbed before and after broadcast seeding and lightly packing the soil. (Consider applying hydromulch following broadcast seeding.) Avoid covering wetland/riparian species with soil; light is needed for proper germination.
f) Planting plugs to establish wetland/riparian grasslike species.
g) Using a land imprinter to form depressions in the soil; these depressions retain moisture at the surface longer than smooth soil surfaces. Soil depressions create good conditions for soil coverage of broadcasted seeds. The sides of the depression slough off and trap wind-blown particles.
h) Increasing seeding rates to:
   - Make desired species more competitive with invasive weeds. For instance, Velagala et al. (1997) found that increasing intermediate wheatgrass densities removed the competitive abilities of spotted knapweed;
   - Increase the likelihood that an adequate amount of broadcasted seeds find safe sites (Sheley et al. 1999), and
i) Adding small amounts of water to temporarily encourage establishment—but only in cases when natural precipitation has proved inadequate. (An initial watering is always recommended, however, after transplanting during the growing season.) Be aware that frequent watering may result in poor plant adaptation and only short-term success followed by failure once supplemental water is withdrawn. In one study, supplemental watering stimulated germination but had little lasting, long-term effect (Padgett 2000). Consider using commercial water-holding polymers and similar products during the establishment period to provide young plants with moisture.
j) Defer grazing by means of fencing or herding until vegetation is fully established, typically after two growing seasons. If palatable, slow-maturing shrubs are recovering, do not graze until the shrubs are able to produce viable seeds.

Treating seeds can also enhance establishment. Consider the following seed treatments when appropriate:

- **Seed priming** initiates the germination process, allowing it to progress to a certain point, then suspending it. The primed seeds are then ready to continue germination in the field when conditions are favorable. Seed priming is helpful in revegetation of weed-infested sites since the first seedlings to capture available resources have a competitive advantage (Harper 1980).
- **Seed fungicide** protects seeds from numerous soil-borne organisms. Consider this treatment in mesic environments, especially with slow-germinating forbs. Even small amounts of litter may harbor pathogens that reduce germination and seedling survival when soil moisture and surface relative humidity increase following rainfall (Call and Roundy 1991).
- **Seed stratification** "fools" seeds into germinating by mimicking normal environmental conditions. There are numerous dormancy types and dormancy breaking strategies. Many upland species such as beardless wildrye and Indian ricegrass need cold stratification to break dormancy and germinate. Most wetland/riparian seeds should be planted during fall dormancy or cold-stratified in a proper medium, usually distilled water and sphagnum moss, for 30 days at 32–36°F.
- **Seed scarification** with acid or mechanized scarification methods improves germination of seeds with considerable dormancy such as Indian ricegrass, beardless wildrye, sweetvetch (*Hedysarum boreale*), prairie clover (*Dalea* spp.) and sumac (*Rhus* spp.) among them.
- **Seed coating** with growth regulators such as cytokinin or diatomaceous earth can improve seedling establishment (Greipsson 1999).

Mulching

A mulch cover protects soil and seeds from erosion by wind and water, conserves soil moisture, and moderates soil temperatures.

Hay mulch Native, certified weed-free hay is a beneficial mulch containing a small amount of nitrogen from leaves, flowers and seed heads. Native hay may also contain seeds of native plants, if harvested with mature seeds. McGinnies (1987) found volunteer stands developed in cases where hay mulch contained a large amount of seed. As a result, more diverse communities can be developed on sites mulched with native hay than on sites mulched with other products. Native hay harvests typically include needle-and-thread grass, western wheatgrass and bluebunch wheatgrass. When attempting to sow needle-and-thread grass, the long awns can prove problematic. These long awns become useful appendages in hay mulches, however, by working the seeds into the ground which improves germination (Smoliak et al. 1990). Mulches are used for short-term protection on moderate (3:1) to flat slopes. Use enough hay to completely cover the soil. To avoid losing it to the wind, pliable mulch can be crimped into the soil or trampled briefly by livestock. Another option is to use an organic tackifier, a glue that breaks down into natural byproducts.

Stubble mulch crops Sterile forage sorghums, Sudangrass (*Sorghum sudanese*) or forage millets are planted the growing season prior to permanent seeding. After crop maturation, native seeds are sown into the residual standing dead material. Standing stubble traps snow, improving soil moisture during the critical germination phase.

Companion crops Fast-growing, non-persisting annuals or short-lived native perennials such as mountain brome, slender wheatgrass, Canada wildrye and blue wildrye, or non-native perennial ryegrass (*Lolium perenne*) are seeded with perennial grasses to protect soil and the young, slower establishing perennial seeded grasses. Sterile hybrids such as Regreen and triticale were developed specifically for use as cover or companion crops. Regreen and triticale establish rapidly, do not persist or reseed into successive years and are completely out-competed by the seeded species. Triticale is often used as a companion crop when maximum forage is desired while slower-developing perennials establish. Avoid using cereal rye as a companion crop; it is very competitive and may spread to surrounding sites.

Hydromulch (hydraulic mulch) Hydromulch is comprised of virgin wood fibers or recycled paper mixed into a water slurry and sprayed onto the ground. Long wood fibers intertwine with one another to form a rigid bond. Excellent erosion protection is provided when hydromulch is applied with a tackifier. Recycled paper mulch decomposes quickly and provides good protection on relatively flat slopes. It is particularly useful in conjunction with quick-establishing vegetation or following broadcast seeding.

Bonded fiber matrix Bonded fiber matrix is a sprayed-on mat consisting of a continuous layer of elongated fiber strands held together by a water-resistant bonding agent. A continuous cover is needed to create the integrated shell. Hire a certified contractor who knows how to apply the material appropriately; if it is applied too thickly it can prevent penetration by seedling shoots.

Erosion control blankets Usually composed of woven organic material such as straw or coconut fiber, these blankets are designed to allow seed germination and to permit stems to grow through and above the mat. Increase seeding rates if light-dependent species are being sown under blankets or mulch. As the fabric ages it becomes incorporated into the soil and decomposes. The erosion-controlling mat is replaced by established vegetation. Mats are expensive but highly effective, and for steep slopes (3:1 and greater) that require long-term protection, they are sometimes the only viable option.

Conditions for successful establishment

Successful establishment may require all of the following conditions:

- -Seed placement in favorable microsites
- -Precipitation adequate to stimulate germination
- -Recurrent precipitation for seedling establishment
- -Low Levels of herbivory, and
- -Absence of competition during establishment

Adapted from Nobel (1986)

Step 9 Determine a seeding or planting method

The most common seeding methods are drilling, broadcasting, imprinting, hay mulch seeding, and hydroseeding. "Island" planting, plugging, and sprigging place whole plants or rhizomes. Plugging is used to establish wetland/riparian plants. Sprigging is used in saline-alkaline soils with rhizomes as plant propagules. Which seeding method is used depends on site accessibility, and terrain, seedbed characteristics, and species/seed characteristics.

Drill seeding

A non-rocky site accessible to equipment should be seeded with a no-till drill. This is a tractor-pulled machine that opens a furrow in the soil, drops seeds in the furrow at a specified rate and depth, and rolls the furrow closed. This method is preferred becausee seed depths and seeding rates are closely controlled and seed-to-soil contact is high, directly enhancing seedling establishment and revegetation success. Ideal seeding depths range from ¼ inch for small seeds to about ½ to one inch for large seeds. Seeding depth varies with site characteristics that influence soil moisture. Chief among them are soil texture, site exposure and aspect. Although drill seeding can enhance seedling establishment, some shortcomings should be recognized:

- The plants that germinate develop in rows resembling a crop rather than a native plant community.
- Long, narrow seeds are difficult to plant because they become bridged within the drill.
- Some species require shallow placement in the soil while others require deeper placement. As a result, two separate seeding operations may be needed when planting a mix. Alternatively, drop tubes can be pulled for broadcasting.
- Seeds of various sizes will separate in the seed container. Very small seeds vibrate to the bottom of the seed box and fall from the box faster than larger seeds. Adding a carrier such as cracked corn or rice hulls, vermiculite, or perlite, can mitigate the size or weight segregation of seeds by dampening vibrations in the seed box. Adding a carrier also controls the flow of problematic seeds with long awns (like needle-and-thread grass) or light and hairy or feathery seeds (like creeping foxtail or meadow foxtail [*Alopecurus pratensis*]). These seeds form large bunches that interfere with the fall of individual seeds from the boxes into the seeding tubes (Munshower 1994).
- Drill furrows can enhance soil erosion from water flow unless seeding is performed along slope contour.

Broadcast seeding

Broadcasting is a commonly used method on steep, rocky or remote sites inaccessible to equipment. Aircraft can seed inaccessible areas burned by wildfire. Small areas can be broadcast-seeded with a hand spreader, whereas large commercial spreaders can seed substantial areas.

The addition of hydromulch over broadcasted seed can enhance establishment

Seedbed preparation is recommended prior to broadcast seeding. On accessible sites, dragging small chains or harrowing and raking can roughen and loosen the soil surface. Roughening creates safe sites, ensuring proper seed placement for enhanced germination and establishment. Roughen the soil surface again following seeding and, if possible, lightly roll or pack the soil. The addition of hydromulch over broadcast seed can enhance establishment.

If seedbed preparation is not feasible, doubling or tripling the broadcast seeding rate appropriate for drill seeding or plowed-ground seeding will be necessary to make sure an adequate amount of seed finds safe sites for germination. Consider introducing short-term livestock trampling so hoof action can push the seeds into the soil.

Broadcast seeding of wetland/riparian species is used not as a primary means of revegetation but as a method to increase overall species diversity. When broadcast seeding, do not cover or pack the seeds with soil as wetland plant seeds need plentyof heat and light for germination. Consider plantingplugs of wetland/riparian species as the primary revegetation method to ensure long-term success.

Hydroseeding

Hydroseeding is a form of broadcast seeding in which the seeds are dispersed in a liquid under pressure. The hydroseeder consists of a water tanker with a special pump and agitation device to apply the seed under pressure in water that may include mulch or other additives. In some cases, the seed-germination and establishment results of hydroseeding are less satisfactory than drill or broadcast seeding since the seed does not always make good seed-to-soil contact. Hydroseeding onto a freshly roughened or disturbed site, however, assists with necessary seed-to-soil contact. Hydroseeding is usually the only practicable method for seeding slopes 3:1 or steeper.

The addition of mulch can enhance soil protection. Albaledejo et al. (2000) found hydroseeding with the application of vegetal mulch or humic acids or both reduced soil runoff and soil loss up to 98.5 percent on two 40 percent slopes. An increase in the density of plant cover was observed seven months after the hydroseeding treatments.

Land imprinting

Imprinting uses heavy, textured rollers to make imprints in the soil surface, aiding water infiltration and soil aeration. The imprints work as precipitation catch basins, enhancing water accumulation for improved seed germination. On accessible sites, imprinting can be used in conjunction with broadcast seeding. Seed can be broadcast in front of the imprinter and pressed firmly into contact with the soil. Small seeds are typically broadcast behind the imprinter so splash erosion covers seed in the depressions without burying them too deeply in the soil. Imprinters fitted with seed bins can be stand-alone seeding devices.

Hay mulch seeding

Hay mulch seeding entails spreading seed-containing hay over a prepared seedbed. Hay mulch seeding is useful becausee the hay is both the seeding method and mulch. However, becausee each species produce seed at a slightly different time, many species can be absent from or underrepresented in any given hay harvest. Hay should be cut when the important species are at an optimal stage of maturity and spread during the optimal seeding time for the dominant or preferred species within the hay. Spreading hay by hand is practicable on small sites, but chopper-shredders that shred and apply the hay are better for larger sites. To avoid loss to wind, hay can be crimped into the soil with machinery, pushed into the soil by the livestock trampling, or held down upon the soil with an organic tackifier.

"Island" planting

Planting nursery stock can complement reseeding and increase overall revegetation success through rapid plant establishment. Planting mature stock circumvents the susceptible and critical seed germination and establishment stages. Purchased stock can be costly. However, planting fewer individuals in "islands" where central, established stands of plants can reproduce and eventually spread throughout the area can reduce costs. The effects of such islands will be long-term; an immediate increase in the number of non-seeded species resulting from this practice should not be anticipated.

Areas can be "island seeded" by using a drill to sow wide strips. Over time, the seeded strips spread into the unseeded areas. Carefully monitor for weeds in unseeded areas until vegetation is established.

Areas can be "island"-seeded by using a drill seeder to seed wide strips. Over time, the seeded strips spread into the unseeded areas. Careful monitoring for weeds in the unseeded areas until vegetation is established is important.

Island-planting shrubs as overstory plantings can complement a revegetated site. The ability of shrubs to increase water availability through moisture interception, enhance soil fertility, reduce evapotranspiration, increase nutrient cycling, add organic matter from litterfall and improve soil structure (West 1989) increases establishment of understory species.

Plugging

Establishing wetland/riparian plants from seeds is usually difficult because site hydrology must be carefully controlled and precise amounts of heat, light and water are needed. Planting plugs circumvents the susceptible and critical seed germination and establishment stages. Hoag and Sellers (1995) state that planting plugs to revegetate wetland areas is preferred to broadcast-seeding or collecting wildlings (see Step 11, Transplanting, p. 33). Greenhouse-grown plugs of wetland/riparian grasses and grass-like species should be planted on 18- to 24-inch centers (Hoag 2000), which translates to about 11,000 plugs per acre (Comfort and Wiersum 2000). Over time, the plants spread into the unplanted areas.

In Idaho, plugs have been successfully planted from April through late October. Spring planting is generally preferred over fall planting since spring-planted plugs will have a longer establishment period. Fall planting may result in lower establishment success because of the shorter growing season and damage from frost heaving (Hoag 2000). Wetland/riparian plants favor warm temperatures, long days and ample water.

Control of site hydrology is important during planting and establishment. A detailed description is provided in *Harvesting, Propagating, and Planting Wetland Plants* (Hoag 2000), available from NRCS service centers.

Sprigging

Sprigging involves planting rhizomes at a depth of three to four inches. Specialized equipment for digging and planting sprigs is commercially available. Plants can be established by sprigging at slightly higher salinity levels than by seeding because the rhizomes are more salt-tolerant than seedlings and can be placed below the highest concentration of salts in the soil profile (USDA 1996). Once established, rhizomatous grasses will continue to spread. The lack of an available sprig source and equipment are the main limitations to this method.

Step 10 Calculate seeding rate

Depending on the species, seeding rates are typically 20 to 50 viable seeds per square foot. The actual rates vary depending on many factors, among them weed interference, differences in seedling vigor, site conditions and the components of a mix. When a species is used as a component of a mix, adjust to percent of mix desired. Use the recommended amount of pure live seed (PLS) found in tables 2 through 5. Consider increasing rates 30 percent for irrigated sites, doubling rates when seeding a severely burned area (80 seeds per square foot for perennial grasses), and doubling or tripling rates when seeding to compete with invasive weeds or if broadcast- or hydroseeding. Increasing seeding rates adds expense to a project, but such an investment may work to ensure establishment and long-term revegetation success.

When designing a seed mix, calculate separately the number of pounds of PLS of each species and then divide by the number of species in the mixture. Then take the pounds per acre and multiply by the total acres to be seeded. For example, for a mix of four grasses to be seeded on ten acres, divide the pounds per acre for each species by 4 and then multiply by 10. (For slender wheatgrass: 12 lbs per acre/4 species x 10 acres = 30 lbs.) seeding rates for timothy are 8–10 pounds PLS per acre when seeded alone and 4–5 pounds PLS per acre when seeded with another species, usually a legume.

Pure live seed is a measure describing the percentage of a quantity of seed that will germinate; PLS equals the percent purity times percent germination. Multiply the purity percentage by the percentage of total viable seed (germination plus dormant), then divide by 100 to calculate the PLS content of a given seed lot. Because the PLS measurement factors in quality, purchasers can compare the quality and value of different seed lots. Consider this example:

	Seed lot A	Seed lot B
Cost/lb. (bulk)	$1.75	$2.00
Percent purity	80	95
Percent germination	75	90
Percent PLS	55	82

Seed lot A might appear to be the better value because its cost is only $1.75 per bulk pound, whereas the cost for seed lot B is $2.00 per bulk pound. However, the quality of seed lot A is far inferior to seed lot B. To properly compare the value, a purchaser would calculate the cost per PLS pound by dividing the bulk cost by the percent PLS (PLS cost = bulk cost x 100/percent PLS). The calculation shows seed lot B is the better value at $2.44 per PLS pound; seed lot A costs $3.18 per PLS pound. Precise ordering of seed based on PLS allows purchasers to get full value for the money they spend on seed.

When designing a seed mix, the percent of each species desired in the mixture needs to be determined. Multiply *the percent desired in the seed mix* times *the pounds of PLS recommended per acre* to get the *PLS mix per acre*.

The following example, adapted from Hoag (2003), shows the calculation of seeding rates for mixed seed:

GIVEN:

Of the desired seed mix, 85% will be bluebunch wheatgrass. This lot of seed has a 90% PLS. The recommended seeding rate is 12 lbs. The remaining 15% of the mix will be small burnet. This lot of seed has an 85% PLS. The recommended seeding rate is 20 lbs. PLS per acre. Thus—

(Bluebunch 85%) x (12 lbs. PLS/acre) = 10.2 lbs. PLS/acre mixed
(Small burnet 15%) x 20 lbs. PLS/acre = 3.0 lbs. PLS/acre mixed

DETERMINE:

Amount of bulk seed (mixed) per acre using the formula above

SOLUTION:

Bluebunch: 10.2 PLS/90% PLS = 11.3 lbs. bulk mixed/acre
Small burnet: 3.0 lbs. PLS/85% PLS = 3.5 lbs. bulk mixed/acre

Determining Bulk Rate for Drill-Seeding

Hoag (2003) states that when seeding the recommended PLS seeding rate using a drill, the bulk rate of seeding needs to be determined since the material in the seed lot cannot be removed. To calculate pounds of bulk seeding per acre, divide pounds of PSL at the recommended rate per acre by the percent PLS.
For example, if the recommended seeding rate for Hycrest crested wheatgrass is 10 pounds PLS per acre and the PLS is calculated to be 80%, the bulk rate needed to seed the recommended PSL is determined thus:

10 PLS/**0.080** PLS = **12.5 lbs.** ***bulk seeding rate per acre***

Step 11 Transplanting

Because planting circumvents the susceptible seed germination and establishment stages, planting local ecotypes can complement reseeding and increase overall revegetation success by providing rapid plant establishment. Local ecotypes can be obtained as salvaged, locally collected, or containerized plants propagated by seeds. Sometimes planting is the only feasible method of establishing certain plants. For instance, seeds of many shrubs may germinate only occasionally, establish very poorly or grow slowly under natural conditions (Munshower 1994).

Although sometimes difficult to attain, successful transplantation of salvaged or locally collected native plants ensures the preservation of local native gene pools and ecotypes. Propagation by seeds in containers, however, can attain the same purpose and have demonstrated much more success. Planting bareroot stock can also be considered. To increase establishment success and reduce weed interference, plant dormant during late winter or early spring. Planting during dormant periods helps plants withstand planting rigors and increases the chances that adequate moisture will be available during the onset of active growth.

Some plants tolerate transplanting better than others. Rough fescue (*Festuca scabrella*), a native bunchgrass, can tolerate transplanting. Native plants growing in disturbed areas have been found to be particularly well suited for transplanting (Goeldner 1995). Native plants to consider include purple three-awn (*Aristida purpurea*), Pacific aster, Rocky Mountain beeplant, lance-leaved coreopsis, fireweed and yellow and white evening primrose. Plants with taproots and extensive root systems are least likely to tolerate transplanting. To increase transplantation success over the growing period, water individuals at the time of transplanting and consider occasional and temporary short-term watering. Also consider adding finished compost during planting to reduce transplant shock and increase plant survival, especially on lower-fertility, dry, sandy soils (Atthowe 2001).

Planting fewer individuals in islands where a central, established stand of plants can reproduce and eventually spread throughout the area can reduce time, effort, and costs of planting. Island-planting containerized shrubs can complement a revegetated site and increase establishment of understory species.

Transplanting wild wetland/riparian plants, known as wildlings, can be considered. Consider transplanting wildlings when the plants are easy to propagate by adventitious roots or sod (i.e., willows and cottonwoods), and when they are small. Make sure the wildlings are placed in a wet, low water stress environment. Planting herbaceous species plugs of greenhouse grown material may have a much higher establishment rate and spread faster and further than transplanting wildlings or straight seeding. Transplanting wetland plants, however, which can be done successfully because of their sturdy root systems, may be considered a useful and viable revegetation method. When removing wetland plants, dig no more than 14 inches of plant material from a four-foot, two-inch area and do not dig deeper than five or six inches (Hoag 2000). Leaving the soil on the removed plants ensures the mycorrhizae remain intact, which increases establishment success.

Step 12 Determine the best time to revegetate

The right time to seed depends on the species being seeded and the soil texture. Warm-season species are commonly seeded during late spring or early summer. Fall-dormant seedings are common with cool-season species or when mixtures of grass, legumes, forbs and shrubs are used (Brown and Wiesner 1984). Dormant seedings should occur after the soil temperature has fallen below 55°F for a consistent one- to two-week period. This period is usually during late fall (i.e., late October and early November) just before the soil freezes, when temperatures and moisture remain low enough to prevent germination before the spring (Cash 2001). Dormant seedings are essential for many cool-season species that require cold stratification. Beardless wildrye, Indian ricegrass, and other grass and forb species require cold. Indian ricegrass needs exposure to at least 30 days of cold soil to meet its stratification requirements (Brown and Wiesner 1984). When conditions are not adequate for a fall-dormant seeding, early spring seedings may capitalize on late snows and early rains. Plant wetland/riparian plugs during June, when warm temperatures, long days and adequate water prevail.

Soil texture can influence the timing of seeding. For instance, when seeding cool-season species on heavy- to medium-textured soils, consider a very early spring seeding. On medium- to light-textured soils, consider a late fall seeding (USDA 2000). Generally, a late fall-dormant seeding is best for all cool-season species regardless of soil texture; the cold stratification requirement of many cool-season species will be satisfied during the winter months.

Late-summer planting—prior to mid-August—of cool-season species should only be done only if supplemental water is available from irrigation or as stored soil moisture. With irrigation, planting can occur from spring until mid-August; allow for emergence four to six weeks before first frost (Cash 2001).

Planting or transplanting tree and shrub seedlings should be done during fall or early spring dormancy to increase planting success. Seeding directly into the ash layer immediately after a fire is the best time to seed burned areas. Contact local experts for recommendations on optimal seeding times specific to your site.

Step 13 Monitor success

Proper site monitoring identifies problems that could prevent or interfere with a successful revegetation project. This cost-effective component can identify problems such as:

- Unexpected successional changes that shift species composition or abundance;
- The invasion or reestablishment of weeds from remnant roots or from an existing seedbank;
- Preferential foraging by wildlife;
- Erosion that can damage plant materials and the soil base;
- Small areas of revegetation failure (repair with new seed or plants and mulch); and
- Unfavorable moisture.

Monitoring can identify and rectify these problems in time to allow for successful revegetation. These problems can be partially prevented by:

- Reducing weed interference before, during and after seeded species establishment
- Removing weeds. The first year or two of a project may be entirely dedicated to weed removal if the site is moderately to heavily infested with invasive weeds
- During and after establishment, hand-pulling or spot-spraying weeds with herbicides to avoid damaging naturally occurring or seeded forbs
- Providing temporary water until seedlings are established when adequate precipitation does not occur. Then, if the species were properly matched to site conditions, the plants are on their own (Harper-Lore 2000)
- Erecting protective fencing to mitigate the threat of selective grazing by local wildlife; and
- Using mulch to protect seeds, prevent soil erosion and conserve soil moisture.
- Monitoring can range from quick visual inspection to an in-depth study of species composition, distribution and density. Monitoring frequency will depend on project goals and site conditions. For example, a site prone to low moisture, high erosion or weed invasion should be monitored frequently.

Step 14 Long-term management

Long-term revegetation success requires continuous monitoring and evaluation for timely adjustments to maintain the desired plant community. Money and effort spent on revegetation will be wasted unless management practices favor the seeded species. Long-term maintenance includes proper and careful weed management such as frequently monitoring the site and the adjacent area to detect and eradicate new weeds early and thus avoid weed spread. Long-term maintenance also includes allowing seed to set and disperse to perpetuate and maintain stands. Evaluate management practices at least annually, and modify when necessary.

If grazing is the intended use of the site, further management will be necessary. Encourage seeded species growth and vigor to extend the productive life and economic returns of seeded pastures. Encouraging seeded species growth and vigor also limits resources for invasive weed establishment and growth. A grazing management plan should be designed to encourage desired species. For instance, Indian ricegrass is highly palatable and nutritious and regarded as very valuable winter forage. However, overgrazing has resulted in its virtual elimination from many rangeland systems (Smoliak et al. 1990). The following methods benefit desired plants, enhancing and promoting a healthy rangeland system:

> Money and effort spent on revegetation will be wasted unless management practices favor the seeded species.

- ***Fence seeded pastures separately*** from native rangeland and seedings of different species or mixtures based on differences in maturity, palatability, and grazing tolerance among species. For instance, Russian wildrye has excellent year-round palatability and nutrition and should be fenced to guard against overuse.
- ***Implement multi-species grazing*** Domestic sheep assist in the successional process towards a perennial grass community by usually avoiding grasses and instead, applying grazing pressure on native forbs and non-native weeds. When domestic sheep graze alongside cattle, grazing pressure is equalized across rangeland plants. Glimp (1988) found on moderately stocked rangelands, one ewe per cow could be added without reducing cattle production.
- ***Defer grazing*** until seeded species are well established, usually after two growing seasons. Bitterbrush seedlings should not be grazed until the plants reach a height of eight to ten inches, which usually takes three to four years.
- ***Avoid heavy grazing*** by determining and implementing proper stocking rates and grass utilization levels. Heavy grazing stops growth and reduces grass vigor by affecting carbon fixation. Even aggressive-growing non-native grasses cannot tolerate close and continuous grazing. Such grazing puts the grazed plant at a great disadvantage in competing for resources with an ungrazed weed. In eastern Washington, Sheley et al. (1997) found the establishment of diffuse knapweed (*Centaurea diffusa*) was enhanced only when defoliation of the native bluebunch wheatgrass exceeded 60 percent, suggesting defoliation beyond this level reduced the grass's competitiveness.
- ***Alter the season of use*** Avoid grazing the same plants at the same time year after year.

- ***Beware close grazing*** Close grazing during fall green-up can be very damaging to all grass species. Avoid grazing cool-season grasses from early August (30–45 days prior to average first frost) until the first "killing" frost in mid-October—a frost with several successive days of temperatures around 25°F. This period of rest allows roots to replenish reserves for winter survival and early spring growth.
- ***Rotate livestock*** among pastures to allow plant recovery before re-grazing the pastures. Recovery time depends on the species, weather and soil fertility. Plants with abundant leaves remaining after grazing will recover more quickly than closely grazed plants. A minimum recovery period of 21 to 30 days is usually needed when growing conditions are optimal in spring. Recovery periods of two to three months may be required after grazing in summer or early fall (Holzworth et al. 2000). Winterfat (*Eurotia lanata*) performs especially well under deferred rotation grazing.
- ***Outline the movement of livestock*** throughout the year.
- ***Minimize bare ground*** by promoting plant litter accumulation to prevent weed seeds from reaching the soil surface.

Regular range monitoring should be undertaken to determine the efficacy of the grazing program in maintaining the desired plant community. Range monitoring includes detecting changes in desired plant cover and noting such surface conditions as litter accumulation and exposed soil. To permit implementation of needed adjustments in a timely manner, annual evaluations are essential.

Because perennial grass and forb seed often lies dormant in the soil until climate conditions are appropriate for germination, significant results of a seeding project can take three to five years.

Conclusion

Revegetation is helpful and often necessary for speeding natural recovery and mitigating or preventing soil erosion and invasive weed establishment and growth. However, revegetation necessity should be based on the abundance of desired plants and propagules at the site. Revegetation is also helpful in cases where rangeland improvement is desired.

Numerous steps should be considered and implemented in a thoughtful way to increase the likelihood of a successful revegetation project. Often these steps include planned events such as topsoil and vegetation salvage and replacement operations or the implementation of significant weed management plans to reduce weed interference on seeded species. Weed management plans should also encourage the preservation of native forbs for ecosystem stability and sustainable weed management. Successful revegetation also includes determining appropriate species based on revegetation goals, environmental conditions, and site characteristics as well as utilizing the most appropriate seeding method at the proper time. Soil amendments, seed treatments and mulching are used to assist seeded species establishment. Monitoring the revegetated site is necessary to quickly identify problems for timely correction. Long-term management of the site should favor the seeded species.

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