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GERALD MARKS

Revegetation Guidelines for Western Monta
Considering Invasive Weeds

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Revegetation Guidelines for Western Montana: Considering Invasive Weeds

Kim Goodwin *Project Specialist, Montana State University-Bozeman*

Roger Sheley *Rangeland Weed Ecologist, Oregon State University*

Gerald Marks *Montana State University Extension Agent, Missoula County*

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On the cover and frontispiece: line drawing of
Western wheatgrass (*Pascopyrum smithii*)
Hitchcok-Chase Collection of Grass Drawings
Courtesy of the Hunt Institute for Botanical Documentation
Carnegie Mellon University, Pittsburg
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note to the preview edition

The authors welcome readers' comments and suggestions and other responses to this publication. Please direct them to—

Kim Goodwin, Project Specialist
Land Resources & Environmental Sciences
P.O. Box 173120
Montana State University
Bozeman MT 59717–3120

kgoodwin@montana.edu
(406) 994–6749

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Preface

Major portions of western Montana's landscape become degraded and disturbed every day. As noxious weeds invade weed-free areas and displace desired vegetation towards monotypic stands, these areas become further degraded year by year. Disturbances can be natural, such as floods and fires, or strictly human-induced, such as road and construction sites, utility line trenches and long-term improper grazing. Eventually, some of these disturbances may naturally recover, but it may be many years before desired plants become established. Conversely, these areas may never naturally recover where invasive weeds establish first, preventing the ability of native plants to establish, grow and reseed. Furthermore, these weeds have the potential to spread into adjacent healthy landscapes where local biodiversity is threatened, nutrient and water cycling is altered, wildlife and livestock forage is diminished and soil erosion and stream sedimentation are increased.

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 work to prevent weed invasion and reestablishment. Revegetation should only occur when necessary, as determined by the abundance of desired plants and propagules at the site. Revegetation is 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 western Montana, west of the Continental Divide. 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 revegetation projects.

The authors' objective is to help improve revegetation success by providing practical and effective revegetation concepts and methods to establish a desired plant community or return sites to conditions as similar as practicable to the pre-degraded, pre-disturbed state. Depending on your situation, this process can entail many steps: salvaging resources, protecting key plant-community components, preparing the site appropriately, reducing weed interference, designing a proper seed mix, seeding using the most effective method. Establishment should be monitored to identify problems that could prevent or interfere with successful revegetation. Following establishment, proper vegetation management that favors the seeded species will be necessary. This includes long-term maintenance of the desired plant community and deterring future establishment and growth of invasive weeds.

KIM GOODWIN
ROGER SHELEY
GERALD MARKS

Missoula
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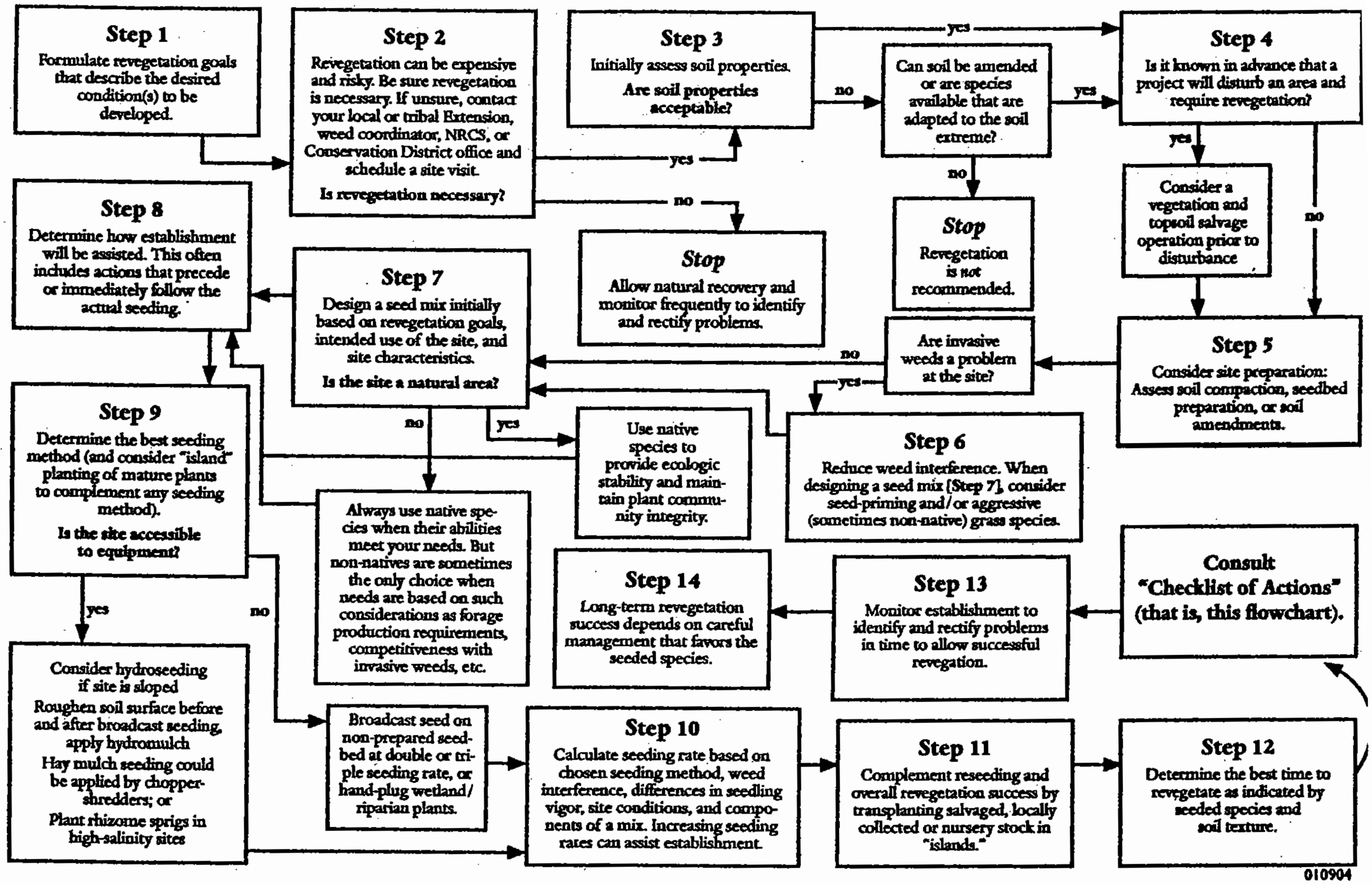
Checklist of Actions



Step I
Make a Goal Statement

Historically, pest management has evolved for cropping systems and has focused on controlling pests. Today, many land managers focus weed management simply 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 used and managed. Invasive weeds must be considered in establishing revegetation goals. This implies that just killing weeds 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 that is relatively invasion-resistant while meeting such other land use objectives as forage production or wildlife habitat development or recreation land maintenance (Sheley et al. 1996).

A healthy, weed-resistant plant community comprises a diverse group of species that maximize niche occupation. A diverse community captures a large proportion of the resources in the system, which preempts 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 must 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 that native forbs compete better with spotted knapweed (*Centaurea maculosa*) than grassses since native forbs and non-native invasive forbs (e.g., spotted knapweed) are in the same functionally similar plant group. Maintaining native forb functional groups such as shallow- and deep-rooted forbs for ecosystem maintenance and invasion resistance could be a primary objective of land managers. Such ecologic knowledge is important in formulating goal statements that direct the establishment of desired plant communities for sustainable land management.

> A *niche* is a habitat that contains attributes necessary for a plant or animal to live. An available niche for a plant could be bare ground with suitable resources.

> *Functional groups* of plant species are similar in form and share the same ecological role.

Goal statements describe the desired conditions to be developed. For instance, the goal statement of the Missoula County Weed Management Plan (*draft 2002*) is to "minimize the impact of noxious weeds through the use of sound ecological practices." Revegetation goal statements might include the following:

Step 1

- 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.

Step 2
Determine the necessity of revegetation

Revegetation should only be implemented when necessary. Included are cases where rangeland improvement is desired to accommodate seasonal forage requirements and in cases where quick groundcover is needed to minimize or preclude erosion. Revegetation is also necessary in cases where desired plants and propagules are inadequate at the site to meet various land use objectives, such as to minimize noxious weed invasion and establish 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 and maintains forage resources is essential. Often this includes seeded pastures that can supply nutritious forage at times during the year when other sources are inadequate or unavailable. Revegetating to meet this need and improve rangelands is often necessary.

Erosion control

Revegetation is necessary to reduce the impact of excessive erosion and speed natural recovery. Planned disturbance activities involving bare slopes often require revegetation in combination with mulch, netting or erosion control blankets for wind and water protection and to assist germination and establishment. Prior to a planned disturbance, many projects require a topsoil or vegetation salvage operation where topsoil containing plant propagules or whole plants and blocks of native sod are removed, set aside, and replaced. Wildfire-affected areas also may require revegetation to guard against erosion in special cases involving high severity burns, stream corridors and slopes above 15 percent (see "Revegetating After Wildfires," overleaf).

> 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. Determine the necessity of revegetation based on this advantage.

Desired plant introduction

Weed-infested sites with inadequate desired plant canopy cover (figure 1, p. 7), usually of less than 20 percent, typically require revegetation with competitive plants to meet various land-management goals.
(See figure 1 for how to determine canopy cover.) 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).

Revegetation after wildfire

Revegetation is recommended in some burned areas as a result of wildfire. Contact your local Extension, USDA Natural Resource Conservation Service or Conservation District office to schedule a site visit and an assessment of revegetation necessity, which is usually performed through a seed survey. Revegetating only when necessary will avoid suppressing the recovering native plant community and conserve limited resources.

Revegetation following wildfire depends on many factors. Among them are these:

- **Burn severity** A high-severity fire can permanently damage desired plants and propagules, greatly reducing natural recovery potential. Runoff increases on slopes due to hydrophobic (water-repellent) soils and lack of vegetation to absorb and use rainfall. Lack of competitive plants favors noxious weed invasion and aggressive reestablishment. Revegetation is sometimes recommended for high burn severity sites especially when slopes are present or noxious weeds are a serious threat.
- **Slope** Runoff increases due to lack of vegetation and soil erosion can result. Moderate burn severity slopes above 15 percent usually require quick protection with annual ryegrass (*Lolium multiflorum*) or small grains. Stabilize surface movement with hay mulch held by netting or an organic tackifier. Slopes benefit from cross-slope log erosion barriers or contour scarification when hydrophobic soils occur. Slash filter windrows at toe-slopes are beneficial at further stabilizing soils.
- **Proximity to drainages** Revegetate channels to mitigate serious erosion during increased flows and to filter sedimentation from runoff. For quick temporary cover and protection, annual ryegrass at 10 pounds per acre or small grains at 20 pounds per acre are frequently seeded within 50 feet of drainage channels, regardless of burn severity. Installing temporary check structures in ephemeral drainages is also beneficial.
- **Pre-burn noxious weed cover** Sites with inadequate desired plant cover prior to the burn as a result of noxious weed displacement should be considered for revegetation regardless of burn severity (Goodwin and Sheley 2001). (Such inadequate cover may be between 20 and 30 percent, the higher percentage the consequence of additional burned-site disturbances such as increased nitrogen, which favors invasive weed colonization.) Revegetation will typically be necessary given moderate to high weed cover coupled with lack of competitive plants and such fire-produced disturbances as increased nutrients and high light conditions.
- **Exposed soil** Such areas as new roads, firebreaks and embankments, including cut-and-fill slopes, should be revegetated. During wildfire rehabilitation, consider replacing soil that was pushed aside during firebreak development. By replacing this topsoil, revegetation may not be necessary, for the soil will likely contain an adequate amount of plant propagules. Replace this topsoil as soon as possible and with a minimum number of machine passes.

* * *

Fast-growing, non-persisting annuals such as annual ryegrass or barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*) varieties are often seeded as cover crops with perennial grasses in wildfire-affected areas. The cover crop establishes quickly to protect soil and young, slower-establishing perennial grasses. Planting conifer seedlings is beneficial in speeding natural recovery and ultimately providing shade to suppress noxious weed invasion and growth. *-Adapted in part from* Comfort and Wiersum (2000)

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. 2001). Weed density should be significantly reduced to reduce weed interference on seeded species. This may require effective infestation management for the first couple of years or longer, to weaken an infestation and significantly reduce competition for light, water and nutrient resources to benefit desired species. In all cases of weed management, strongly consider protecting and enhancing the growth and vigor of native forbs through careful spot treatment of herbicides or hand-pulling weeds, if appropriate. Unnecessary broadcast herbicide treatments will injure or permanently damage a remnant or remaining native forb component. If entirely removed, this critical feature could be impossibly difficult and expensive to reestablish. Furthermore, an intact native forb community seems to be vital to long-term weed management success because forbs may compete with invasive weeds better than grasses do, and provide better plant community invasion resistance (Pokorny 2002).

With good weed management, weed-infested sites with more than 20 percent desired vegetation canopy cover do not usually require revegetation. In such cases, adequate desired plants are present to direct natural revegetation. Desired grasses and forbs steadily occupy open niches made available by removed weeds.

Fig. 1. *Canopy cover* is the area of ground covered by the vertical projection of the outermost perimeter of the natural spread of plant foliage. Small openings within the canopy are included.

To determine the general 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 the hoop and let it land flat on the ground.

3.) Visually estimate the percentage of ground covered by the canopy, as shown above, of desired vs. non-desired plants. (Do not count plants—this will give you density.)

4.) Repeat, randomly tossing the hoop throughout the site and visually estimating the canopy cover of desired vs. non-desired plants, at least ten times.

5.) Add the desired plant percentages and divide by 10—or by or the number of times the hoop was tossed—to determine the *average desired plant canopy cover.*

Again, the importance of protecting native forbs cannot be overstated. To avoid injury to this key ecosystem component, weeds should be removed through careful spot treatment with herbicides or by hand-pulling.

Step 2

Use this chart to determine whether revegetation is likely to succeed based on soil properties without the addition of amendments.

Soil parameter	**Ideal condition**	**Acceptable range**	**My soil's properties** — **(Insert the properties of your soil)**	**My soil: Yes or No** — **(Are your soil's properties within the acceptable range?)**
Bulk density (gm/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		
Sodium adsorption ratio	< 6	– ? –		

Step 3
Determine the likelihood of successful revegetation

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

The decision index on the opposite page provides an initial assessment of soil properties found in most NRCS county soil surveys. Soil testing, although usually not necessary, also provides more accurate and site-specific information. (See Step 7, Site Characteristics, p. 40, for additional information on soil properties and successful revegetation.)

Contact your county or reservation Extension office, weed coordinator or local NRCS office if your soil properties are outside the acceptable range. Proceed with Step 4 if your soil properties are acceptable.

Step 4
Salvage vegetation and topsoil prior to planned disturbances

Consider preserving or salvaging the vegetation that was on the site before the onset of the disturbance. If it is known in advance that a project will disturb an area and require revegetation, salvaging or taking steps to preserve existing plants and seeds that are already adapted to the site is recommended to avoid permanently losing this resource and to supplement the revegetation process (see Step 11, Transplanting, p. 55). For instance, blocks of the existing native sod can be removed and set aside and replaced after the work has been completed. The addition of such missing major functional groups as forbs should be considered as appropriate to revegetation goals.

Deeper subsoils are often salvaged to increase the amount of material available for covering a larger area. In these cases, separating topsoil from subsoil is recommended. Lower soil materials should be stored separately and marked to distinguish them from true topsoil and then should be re-spread first before the topsoil is replaced as the uppermost layer.

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

In addition to salvaging vegetation, also consider salvaging healthy topsoil. And in wildfire cases, plan on replacing soil that was pushed aside for firebreak development. Found in the upper six to 12 inches of the soil profile, topsoil contains microorganisms (bacteria, fungi, protozoa, etc.), earthworms and insects. Topsoil also contains living, pre-adapted plant propagules such as seeds, plant fragments, and whole plants—valuable revegetation resources. Biological activity in this zone cycles soil nutrients and 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 (e.g., containing high noxious weed cover) should not be salvaged; instead, it should be removed and replaced with healthy topsoil.

Avoid damaging topsoil by keeping the soil alive, noxious weed–free and protected until it can be returned to the site. Salvage topsoil during a fall operation and while it's moist (not wet) to avoid depressing seedling recruitment. Store it in shallow piles less than two feet high, exposing as much soil to air as possible (to avoid anaerobic conditions that can damage microorganism numbers) and for as brief a period as possible. A study in Yellowstone National Park showed that topsoil stripped and replaced within 90 days retains viable populations of mycorrhizae fungi, but topsoil stored over a winter lost most of its mycorrhizal propagules (Williams 1991). Rokich et al. (2000) found that stockpiling topsoil for one or three years demonstrated substantial, significant declines in seedling recruitment—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 or triticale, sterile hybrid crosses between common wheat and tall wheatgrass (*Triticum aestivum* × *Elytrigia elongata*) and common wheat and cereal rye (*T. aestivum* × *Secale cereale*), respectively. Monitor the stored topsoil often and remove noxious 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 an assurance that the area will be revegetated within a few days. If the volume of topsoil is limited, consider concentrating the returned topsoil in small pockets to allow increased retention of the biological activity of the soil (Claassen and Zasoski 1993). How-ever, if you have enough topsoil, spread it at least six inches deep. Redente et al. (1997) found that a thin layer of topsoil spread to this thickness was sufficient for the establishment and continued productivity of vegetation at a northwest Colorado mine site. Deeper topsoil depths (12, 18 and 24 inches) were found to be associated with plant communities dominated by grasses. Shallow topsoil depths supported plant communities that were more diverse and had significantly greater forb production and shrub density.

Mycorrhizal fungi are essential to nutrient cycling, and greatly influence long-term revegetation success.

A topsoil salvage operation is recommended, along with integrated roadside vegetation management, for long-term roadside revegetation success (Appendix B, p. 65.) Biologically inactive and nutrient-poor construction fill materials 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 is made up of organic material, air spaces and different-sized clumps and particles of sand, silt, and clay. A loss of soil structure, such as from compaction or excessive tillage, or tillage when soil is too wet, negatively affects soil processes. Compaction limits the ability of water to percolate through the soil and, by reducing the number of air spaces within the soil, reduces roots/air exchange.

roadcast seed will just sit
op *compacted* soil, where it
ill be vulnerable to wind,
ater, heat and predation.

To improve soil structure and prepare a proper seedbed for adequate seed-safe sites, seriously compacted sites should be scarified or plowed. Scarification is a form of ripping that breaks up breaking up topsoil aggregates by raking the soil surface with ripper shanks that are typically 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.

Seedbed preparation

The necessity of seedbed preparation depends on the seeding method (See Step 9, "Determine a Seeding Method," p. 49), influenced by site accessibility and terrain and seedbed characteristics. Seedbed preparation is usually not necessary when drill seeding, but is strongly recommended when broadcast seeding or hay-mulch seeding. Generally, the ideal seedbed is firm enough so the seed will be in contact with the soil and the soil will not be easily washed or blown away, but loose enough for the seed to sprout and penetrate the soil. The ideal seedbed includes adequate seed-safe sites that provide conditions for germination and resources for growth.

A seedbed can be produced through shallow plowing, harrowing or dragging small chains. Plowing loosens the upper layer of soil, increasing the number of seed-safe sites and facilitating seedling germination and root extension. Plowing should be carefully considered, for it may permanently damage any desired vegetation and can facilitate erosion on slopes or fine-textured soils. Always avoid deep plowing on sites with invasive weeds; it promotes nitrogen release, which favors heavy weed growth. If plowing is absolutely necessary, shallow-plowing just the upper two inches of soil is recommended. Disc plows are often harmful to soil structure and should not be used as a means of mitigating compaction unless coarse clods, produced when the soil was worked while wet, dominate the site.

Harrowing and raking, secondary tillage operations that use spiked or toothed cultivating implements, uniformly roughen the soil surface. So does the dragging of small chains. These methods are generally employed to break up crusts or to lightly cover seeds; it is recommended these methods be used both before and following broadcast seeding. Light packing of the soil following broadcast seeding is beneficial.

Burned-area revegetation typically does not require seedbed preparation if the reseeding immediately follows fire. Ash left by a fire can provide an excellent seedbed. A fall-dormant broadcast seeding into the ash will cover and retain seeds. The wet/dry, freeze/thaw action of moisture over subsequent seasons will work the seeds into the soil while also 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. Harvesting fire-killed trees is often implemented to prepare a site for revegetation (if necessary) and to reduce falling tree hazards and reduce disease—and to provide income to offset fire losses.

Soil amendments

Amendments are added to soils before or shortly after seeding to provide a better medium for plant growth. In many cases, the addition or reduction of nitrogen can enhance establishment. Additions of soil microorganisms can also enhance seeded species establishment.

Nitrogen fertilizers should only be used when a soil test has revealed a gross deficiency or in mesic sites when agronomic species such as tall fescue (*Festuca arundinacea*) are seeded when rapid growth and maximum production is desired. Smooth brome (*Bromus inermis*) may require nitrogen fertilizer if the soil is not sufficiently fertile (Smoliak et al. 1990). The high nitrogen requirements of these non-native grasses make them 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*); see box overleaf. 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 interference. For this reason, when seeding late-seral native grasses such as bluebunch wheatgrass in moderate- or high-nitrogen sites, consider seeding a sterile cover crop such as Regreen or triticale that can quickly sequester nitrogen. This nutrient reduction will hinder the growth of noxious weeds while favoring the late-seral seeded species.

> A *sere* is a step in the sequence of plant community succession where successive plants occupy an area from the inititial stage to the climax. (See Appendix C.)

Cover crops further favor seeded species by providing quick protection to seeds and soil from erosion by wind and water, conserving soil moisture from the effects of wind and sun, and moderating soil temperatures.

Step 5

The addition or reduction of nitrogen can have significant effects on noxious weed growth. The reduction of soil nitrogen through cover crop sequestration can benefit native grasses. The addition of non-essential nitrogen reduces important mycorrhizal activity (St. John 1997) and encourages heavy weed growth that overwhelms slower-growing natives. In a southeastern Montana study, the main responses to nitrogen fertilization in a dry-land situation were increased annual grass or annual weed production and decreased diversity (Hertzog 1983). Avoid nitrogen additions when seeding native grasses.

> A healthy functioning nitrogen cycle is essential to long-term revegetation success.

> Legumes form symbiotic relationships with bacteria that convert atmospheric nitrogen into plant-available nitrogen. Seed companies can inoculate legume seed with an appropriate species of bacteria to ensure maximum nitrogen fixation.

Soil microorganisms process mulch and dead plant material into a form available for plant uptake, essential for 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 known to improve phosphorus uptake, drought tolerance and resistance to pathogens. 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 can be highly beneficial to a project. 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 noxious 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 the elimination or significant reduction of invasive weed competition or interference. When revegetating weed-infested sites, strategies are available to reduce weed competition for resources that seeded species require for germination and successful establishment.

These strategies may include managing infestations with herbicides or grazing domestic sheep or, for the first couple of years prior to seeding (or longer), mowing to weaken an infestation and significantly reduce competition for light, water and nutrient resources. For instance, mowing spotted knapweed can be effective in preventing seed production and weakening an infestation. In a Montana State University study, mowing as the single management tool decreased spotted knapweed density by 85 percent when performed during the early bud stage (Rinella et al. 2001). A further reduction in density may be anticipated when integrating mowing with other management tools. Combining mowing with an appropriate herbicide applied one month after the last mowing cycle to the rapidly developing regrowth can be effective. Removing plants that have acclimated to frequent mowing by growing prostrate or low to the ground can be accomplished through herbicide treatments or hand-pulling. Consider mowing and applying a herbicide in a single, efficient entry with a wet-blade mower (see Appendix B, p. 65).

> Harper (1980) notes seed priming is helpful in revegetation of weed-infested sites since the first seedling to capture resources has a competitive advantage. (See Step 8, p. 45)

> 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.

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 (1999) found that 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 in sites with high soil nitrogen, consider planting an early-seral cover crop the year before revegetating with native, late-seral grasses.

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

Step 6

remove noxious 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. (2001) has proved successful. It uses picloram and a no-till drill in a single field entry (see text box opposite).

Young grass seedlings can be sensitive to many herbicides. Universal recommendations for herbicides are beyond the scope of this document. However, some generalizations can be set forth. According to the USDA Natural Resources Conservation Service (2000), the application of bromoxynil at the three- or four-leaf 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. (2001) 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. But grass injury did occur when picloram was applied at two quarts per acre. Contact your county or reservation Extension agent or weed coordinator for herbicide recommendations specific to your site.

Always follow herbicide label instructions regarding safe handling and application rates.

"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 (Borman et al. 1991) for successful long-term weed management. 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. 2001).

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

1.) The site is tilled in late fall to loosen the soil surface and encourage germination of weed seeds.

2.) A few weeks later, a non-selective herbicide (glyphosate) is applied to manage newly emerging weeds; the combination of tillage and herbicide reduces weed-seed density and weed competition the following spring.

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 broadleaf herbicide (2,4-D) 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. (2001) 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.

Step 7
Design a seed mix

Because every site is unique seed mixes should be customized to the revegetation goals, soils and environmental conditions of the site. When selecting species, varieties or cultivars, choose those that are most appropriate for your site's conditions. If a preferred variety is not available, make sure the second-choice seed originated within a 500-mile radius of the site to be revegetated to ensure adaptation (Comfort and Wiersum 2000). 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 buy preformulated mixes, buy wildflower seeds species by species—and make sure they are native to the region.

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

Certified seed meets high genetic purity and germination standards with a very low weed content.

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
4.) Restore a healthy plant community.

* * *

Once revegetation goals have been determined, site characterist such as soil attributes, precipitation, temperature and elevation confirm or further direct species selection. Local USDA Natural Resources Conservation Service field officers or county and reservation Extension agents and weed coordinators are go sources of information on environmental and establishment re quirements. They can assist in designing a proper seed mix tha addresses species compatibility and avoids niche overlap to prevent purchasing seeds that may be displaced over time.

Take care to ensure adequate diversity in revegetation. Comfort and Wiersum (2000) advise that several species of grasses should be seeded to cover the range of site conditions and increase revegetation success (see table 5, p. 36, for recon mended mixes by zone for western Montana). When develop ing a mix, avoid niche overlap and consider species compatib ity as some species have very good seedling vigor. These speci develop rapidly, often at the expense of other species in the seed mix. For instance, tall wheatgrass (*Elytrigia elongata*) an smooth brome, both non-natives, should be seeded alone, for each 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 in any case grows 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 seed, ensure that the mix is weed-free. To improve both quality and establishment results, specify certified seed. Only cultivated, named varieties such as 'Luna' and 'Canbar' can be certified. (Bags of such seed bear blue "certified seed" tags.) Certification guarantees that the seed has the same genetic potential to perform in the field as did the breeder seed 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 or land-management objectives.

Recent interest in native wildland seeds has prompted a seed certification class for such collections. The "Source Identified Class" verifies the origin and ecotype of a wildland seed harvest. Seed that is harvested following the approved guidelines and procedures for the Source Identified Class comes with yellow certified seed tags that affirm that the location of the seed harvest was verified by the certification agency.

A list of selected species based on desired season of rangeland use is provided in table 1, overleaf. Recommended native grasses and grasslike species are listed in table 2, pp. 22–25. A list of non-native grasses for typical projects is provided in table 3, pp. 26–29. And selected forb and shrub species are listed in table 4, pp. 30–35.

Revegetation goals

1. Improve rangeland/forage production or rehabilitate degraded or disturbed areas

A. ***Rangeland improvement*** Many 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. For instance, needle-and-thread grass (*Stipa comata*) is preferred less than other grasses, and the relatively low palatability of reed canarygrass (*Phalaris arundinacea*) makes it necessary to have pastures fenced separately, giving livestock no alternative. Mixtures should be designed with careful attention to niche overlap to avoid reversion to a few species over time. Some find that the

Table 1. Season of use for selected western Montana forage species
Adapted from Holzworth et al. (2000) *and* Brown and Wiesner (1984)

Native	Spring	Summer	Fall	Winter	Non-native
Sandberg bluegrass Big bluegrass Canby bluegrass Sheep fescue	●				Siberian wheatgrass
Blue wildrye		●			
Bluebunch wheatgrass Beardless wheatgrass Streambank wheatgrass Thickspike wheatgrass Canada wildrye Mountain bromegrass Prairie junegrass Sand dropseed Reed canarygrass Prairie coneflower Prairie clover (*fall grazing possible*) Northern sweetvetch Smooth or oakbrush sumac	●	●			Timothy Tall wheatgrass Intermediate wheatgrass
Idaho fescue	●	●	●		Newhy hybrid wheatgrass Pubescent wheatgrass Orchardgrass Smooth brome Alfalfa Sainfoin
Basin wildrye Needle and thread grass Snowberry	●			●	
		●	●		Birdsfoot trefoil Cicer milkvetch
Winterfat Bitterbrush Western wheatgrass		●	●	●	
	●			●	Crested wheatgrass
Fourwing saltbush (*best if used as winter forage only*)	●	●	●	●	Russian wildrye Meadow brome Small burnet
Sunflower			●	●	
Slender wheatgrass Indian ricegrass	●	●		●	

best option is to create a series of dryland pastures with one or more planted to spring grazing species and others planted to summer or fall species (Holzworth et al. 2000). Because such sites may lack maximized niche occupation, frequent monitoring for weeds is encouraged.

Consider the use of the pasture and the ability of the species to supply forage when needed (table 1, left) and design the mix to accommodate seasonal forage requirements. For instance, winterfat (*Eurotia lanata*) is one of the most valuable plants for maintaining weights of adult animals on winter range (Smoliak et al. 1990). Guard against weed invasion by including a combination of shallow- and deep-rooted forbs and grasses that grow both early and late in the year to maximize niche occupation in time and soil profile space throughout the year.

Enhanced forage can be provided with a simple mixture of productive cool-season grasses and a deep-rooted legume. This mix will produce more high-quality forage than grass seeded alone. For instance, smooth brome mixed with properly nodulated alfalfa produces yields of hay three times those produced from smooth brome alone. Orchardgrass (*Dactylis glomerata*) grown alone will yield an average of one to two tons per acre of hay, but when it is grown with clover or alfalfa, yields of two to three tons per acre may be expected. Similarly, 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. Excellent pasture can be developed using cicer milkvetch, a competitive legume, with creeping foxtail (*Alopecurus arundinaceus*) on wet meadows or irrigated pastures.

Following seeding, consider planting appropriate shrubs that can 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 used for grazing, such as natural areas, should be seeded with native species that provide ecologic stability and maintain plant community integrity. Avoiding the seeding of non-native grasses will guard against their dominance, which could inhibit native community recovery and the potentially alter the diversity of local plants.

When designing a seed mix for natural areas, including wetlands, the local landscape or nearby wetlands are good references for species selection based on species occurrence and distribution. Because the seeds are local and thus well adapted to local environmental conditions, germination success and plant hardiness may be increased. Furthermore, the local landscape can provide species that may not be available commercially. However, depending on current-year growing conditions, collected wildland seed can sometimes have low viability. For instance, germination tests of Indian ricegrass (*Achnatherum hymenoides*) revealed that often over half the seeds lack a developed embryo and hence could not germinate (Stoddart and Wilkinson 1938). To offset this disadvantage, the collection of large quantities is required, which can increase collection time and costs unless those costs can be compensated through volunteer labor.

> When treating noxious weeds with herbicides, care should be taken to protect neighboring shrubs and forbs.Avoid broadcast herbicide treatments. unless necessary, as indicated by high weed density.

> Hard fescue (*Festuca longifolia*) is a non-native, cool season bunchgrass with massive, fibrous, shallow roots. This grass is very competitive and excellent at controlling erosion. Establishment is slow but persistent. Consider seeding with a cover or companion crop (see Step 8, p.45).

C. Roadside rehabilitation (see Appendix B, p. 65) Roadsides often have low fertility and depleted biological activity. This reduces the establishment and persistence of vegetative stands (Claassen and Zasoski 1993) and limits long-term revegetation success. To

increase long-term success, healthy topsoil additions will [*Continued from p. 21*] serve as a source of nutrients, plant prop-

[*continued on p. 37*]

Table 2. Native grasses and grasslike species (all cool-season perennials unless stated) recommended for western Montana revegetation projects

Name	Cultivar	Growth form	Preferred soil type	Minimum precipitation (*inches*)	Erosion control	Pure stand PLS rate/ acre* (*pounds*)	Notes
Bunchgrasses— **Short to short-medium bunchgrasses—**							
Indian ricegrass (*Achnatherum hymenoides*)	Rimrock, Nezpar; Paloma	Short bunchgrass	Sand to sandy	8	Good	12	Drought tolerant. Easy to moderate establishment, relatively short-lived. Useful in coarse soils on droughty, low-fertility sites. Highly palatable and nutritious.
Idaho fescue (*Festuca idahoensis*)	Joseph	Short bunchgrass	Silty-loamy to clayey	10	Good	8	Moderately drought-tolerant. Slow establishment. Poor seedling vigor. Mature stands are strongly competitive. Good palatability to wildlife and livestock.
Sheep fescue (*Festuca ovina*)	Covar, Durar; Quatro	Short bunchgrass	Sandy to clayey	10	Very good	10	Drought-tolerant. Slow but persistent establishment. Provides excellent and attractive ground cover. 'Covar' is an aggressive competitor. Poor palatability to livestock but used by wildlife.
Meadow barley[1,2] (*Hordeum brachyantherum*)	——	Short-medium bunchgrass	Silty-loamy to clayey	16	Good	15	Tolerates standing water for short periods. Palatable and saline tolerant.
Alpine timothy[2] (*Phleum alpinum*)	——	Short-med. bunchgrass	Clay	16 (or wet areas)	Good	2	Prefers poorly drained mountain meadow soil. Good forage for livestock and wildlife because it stays green throughout most of the summer.
Canby bluegrass (*Poa canbyi*)	Canbar	Short bunchgrass	Silty-loamy	10	Good	4	Drought-tolerant. Slow establishment. Highly palatable, early-season forage that outcompetes weedy spring annuals.
Sandberg bluegrass (*Poa sandbergii*)	High Plains	Short bunchgrass	Sandy to clayey	8	Poor	4	Drought-tolerant. Slow establishment. Productive on poor sites. Good competitiveness with weeds.
Medium to medium-tall bunchgrasses—							
Mountain brome (*Bromus marginatus*)	Bromar	Medium-tall bunchgrass	Silty-loamy to clayey	16	Very good	19	Rapid establishment, short-lived. Adapted to relatively moist soils, including thin, infertile sites. Intolerant of high water tables. Useful for soil stabilization. Good palatability.
Tufted hairgrass[2] (*Deschampsia caespitosa*)	Norcran	Medium bunchgrass	Silty-loamy to clayey	20 (or riparian)	Good	2	Most common on moist sites. 'Norcran' is used for low maintenance ground cover. Very palatable to livestock and wildlife.

1. Adapted to saline and/or alkaline soils 2. Requires wetland/riparian habitat or performs well in standing water or periodic flooding
* Based on pure stand; see Step 10, "Calculate seeding rate," p. 53, to determine mix rates and special cases involving increased rates

Table 2. Native grasses and grasslike species, *cont'd*

Name	Cultivar	Growth form	Preferred soil type	Minimum precipitation (*inches*)	Erosion control	Pure stand PLS rate/ acre* (*pounds*)	Notes
Medium to medium-tall bunchgrasses, *cont'd*							
Canada wildrye (*Elymus canadensis*)	——	Medium-tall bunchgrass	Sandy	12	Very good	15	Rapid establishment; short-lived. Prefers moist or periodically moist, well drained sites. Good palatability poor grazing tolerance.
Rough fescue (*Festuca scabrella*)	——	Medium-tall bunchgrass	Silty-loamy to clayey	12	Good	10	Most common in prairies and open woods. Establishes on a wide variety of soil types. Excellent forage for cattle and horses; good forage for wildlife.
Prairie junegrass (*Koeleria cristata*)	——	Medium bunchgrass	Sandy	12	Good	2	Drought-tolerant. Easy establishment. Useful where early season forage is desired and erosion is not a severe problem. Not tolerant of heavy early season grazing.
Bluebunch wheatgrass (*Pseudoroegneria spicata* ssp. *spicata*)	Goldar, Secar	Medium-tall bunchgrass	Silty-loamy to clayey	10	Good	8–12	Drought-tolerant. Moderate establishment. Adapted to most sites including thin, nonproductive soils.
Nuttal alkaligrass[1] (*Puccinellia airoides*)	Quill	Medium bunchgrass	Clayey	15 (or moist soils)	Fair	4	Valuable species for reseeding marshes, alkali basins, or other waterways; occasionally survives in standing water.
Tall to very tall bunchgrasses—							
Blue wildrye (*Elymus glaucus*)	Arlington; Elkton	Tall bunchgrass	Sandy to silty-loamy	12	Excellent	10	Rapid establishment, short-lived. The attractive blue-green foliage adds value to landscaping projects where slope stabilization is needed.
Slender wheatgrass[1] (*Elymus trachycaulus* ssp. *trachycaulus*)	Primar, Pryor, Revenue, San Luis	Tall bunchgrass	Sandy to clayey	16 (or riparian)	Very good	12	Moderate drought tolerance. Rapid establishment, short-lived. Saline-tolerant and adapted to a wide range of sites. Useful where quick, native, non-aggressive perennial cover is desired.
Basin wildrye (*Leymus cinereus*)	Trailhead, Magnar	Very tall bunchgrass	Silty-loamy to clayey	8	Good	11	Drought-tolerant. Slow establishment. Adapted to a wide variety of sites in winter-wet and summer-dry areas. Provides excellent winter forage.
Big bluegrass (*Poa ampla*)	Sherman	Tall bunchgrass	Silty-loamy to clayey	8	Good	5	Easy establishment. Excellent palatability and stays green later than other species. Intolerant of poorly drained soils or high water tables.
Needle and thread (*Stipa comata*)	——	Tall bunchgrass	Sandy to silty-loamy	10	Good	14	Drought-tolerant. Long-lived. Good palatability before seed set but preferred less than other grasses. Useful for disturbed sites and valuable winter forage.

1. Adapted to saline and/or alkaline soils 2. Requires wetland/riparian habitat or performs well in standing water or periodic flooding
* Based on pure stand; see Step 10, "Calculate seeding rate," p. 53, to determine mix rates and special cases involving increased rates

Table 2. Native grasses and grasslike species *cont'd*

Name	Cultivar	Growth form	Preferred soil type	Minimum precipitation (*inches*)	Erosion control	Pure stand PLS rate/ acre* (*pounds*)	Notes
Rhizomatous— **Short to short-medium rhizomatous—**							
Arrowgrass[1,2] (*Triglochin maritima*)	——	Short-med. rhizomatous	Clayey	(Wet areas)	Good	5	Grasslike perennial adapted to saline/alkaline wet areas; poisonous to livestock
Medium to medium-tall rhizomatous—							
Streambank wheatgrass (*Elymus lanceolatus* ssp. *psammophilus*)	Sodar	Medium-tall rhizomatous	Sandy to clayey	8	Excellent	12	Drought-tolerant. Moderate establishment, short-lived. Especially well suited for stabilizing highly erosive silty to sandy soils on upland sites.
Mannagrass[2] (*Glyceria* spp.)	——	Medium-tall rhizomatous	Clayey	18 (or wet areas)	Good	12	Adapted to stream banks, marshes, and wet areas.
Beardless wildrye[1] (*Leymus triticoides*)	Shoshone	Medium-tall rhizomatous	Sandy	10	Very good	20	Moderately drought-tolerant. Difficult establishment. Saline-tolerant and suited for erodable, poorly drained soils. Very palatable; useful for improving saline range.
Western wheatgrass[1] (*Pascopyrum smithii*)	Rosana; Rodan, Arriba	Medium-tall rhizomatous	Silty-loamy to clay	10 (or riparian)	Poor	16	Drought-tolerant. Fairly easy to moderate establishment, long-lived. Useful for slightly saline, erosive soils where long-lived hardy vegetation is desired and rapid establishment is not.
Bluebunch wheatgrass (*Pseudoroegneria spicata* ssp. *inermis*)	Whitmar	Medium rhizomatous	Silty-loamy	13–15	Good	12	Fair establishment, long-lived. Intolerant of poor drainage, high water tables and spring flooding.
Tall rhizomatous—							
American sloughgrass[2] (*Beckmannia syzigachne*)	Egan	Tall rhizomatous	Silty-loamy to clayey	25 (or wet areas)	Excellent	19	*Annual* or short-lived perennial (4–5 years) adapted to wet sites. 'Egan' developed for erosion control in seasonally wet areas.
Bluejoint reedgrass[2] (*Calamagrostis canadensis*)	Sourdough	Tall rhizomatous	Silty-loamy to clayey	18 (or wet areas)	Very good	4	Easy establishment. Adapted to wetland and riparian sites. 'Sourdough' developed for ability to establish easily and for soil stabilizing characteristics.
Thickspike wheatgrass (*Elymus lanceolatus* ssp. *lanceolatus*)	Bannock, Critana, Schwen-dimar	Tall rhizomatous	Sandy to clayey	8	Excellent	12	Drought-tolerant. Easy to fair establishment, long-lived. Good year-round palatability.

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Table 2. Native grasses and grasslike species, *cont'd*

Name	Cultivar	Growth form	Preferred soil type	Minimum precipitation (*inches*)	Erosion control	Pure stand PLS rate/ acre* (*pounds*)	Notes
Grass-like species—							
Sedge[2] (*Carex* spp.)	——	Bunchgrass or rhizomatous	Clayey	(Wet areas)	Good	2–7	Adapted to wet meadows, saturated soils, or shallow water. (Nebraska sedge, *C. nebraskensis*, is more xeric than other Carices.)
Spikerush[1,2] (*Eleocharis* spp.)	——	Short rhizomatous	Clayey	(Wet areas)	Excellent	12	Easy establishment. Occurs in wet saline-alkaline soils. Useful for quick stabilization.
Rush[1,2] (*Juncus* spp.)	——	Short or tall rhizomatous	Clayey–clay	12 (or wet areas)	Good	12	Prefers saturated soils but can tolerate drought periods. Useful for restoring wetland and riparian areas.
Bulrush[1] (*Scirpus* spp.)	——	Medium-tall rhizomatous	Clayey	(Wet areas)	Very good	20	Adapted to wet meadows, marshes, standing water or wet muddy soils. Prefers alkaline soils.
Cattail[2] (*Typha latifolia*)	——	Tall rhizomatous	Clayey	(Wet areas)			Occurs in and around wet areas. Widely adapted and can become aggressive. Excellent cover for wildlife.
Warm-season grasses— Bunchgrasses							
Purple three-awn (*Aristida purpurea*)	——	Short-med. bunchgrass	Sandy	10	Good	6	Easy establishment. Provides good forage before going to seed. Useful for disturbed areas.
Alkali sacaton[1] (*Sporobolus airoides*)	Salado	Medium bunchgrass	Silty-loamy to clayey	6	Fair	3	Difficult establishment; long lived. Prefers mostly lower, slightly moist alkaline flats with high water tables (4–8 ft.) of frequent flooding. Medium palatability.
Sand dropseed (*Sporobolus cryptandrus*)	——	Medium bunchgrass	Sand to sandy	10	Very good	2	Drought-tolerant. Easy establishment. Winter hardy, with good palatability but preferred less than other grasses. Useful for rapid establishment in sandy sites. Good in a mix with slow-establishing species.
Rhizomatous—							
Inland saltgrass[1,2] (*Distichlis stricta*)	——	Short-med. rhizomatous	Clayey to clay	8	Poor	10	Adapted to wet, saline-alkaline sites. Useful for unusually saline areas. Usually grows with alkali sacaton and prairie cordgrass. Often established vegetatively by sodding.

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Table 3. Non-Native grasses recommended for western Montana revegetation projects (all cool-season unless noted otherwise
Note: **Native grasses [see Table 2] are advised when they're capable of meeting revegetation goals [See Step 1]**

Name	Cultivar	Growth form	Preferred soil type	Minimum precipitation (inches)	Erosion control	Pure stand PLS rate/ acre* (pounds)	Notes
Annuals—							
Annual ryegrass (*Lolium multiflorum*)	Gulf	Tall annual	Silty-loamy	10	Very good	16–35	Annual, quick and easy establishment. Highly palatable to livestock and wildlife.
Regreen (wheat × tall wheatgrass) (*Triticum aestivum* × *Elytrigia elongata*)	—	Medium-tall bunchgrass	Silty-loamy	12	Excellent	20–40	Annual or short-lived perennial sterile hybrid cross. Used as a soil stabilizer and cover crop. Quick and easy establishment; does not persist or reseed. Will be entirely out-competed by more desired species. Drought-tolerant.
Triticale (wheat × cereal rye) (*Triticum aestivum* × *Secale cereale*)	Spring and winter varieties	Tall annual	Silty-loamy to clayey	12	Very good	60–100	Annual, quick and easy establishment. Good forage production and highly palatable. Often used when maximum forage is desired while slower perennials establish.
Bunchgrasses— **Short to short-medium bunchgrasses—**							
Hard fescue (*Festuca longifolia*)	Durar, Serra, Crystal	Short bunchgrass	Sandy to clayey	16	Very good	10	Moderately drought-tolerant. Slow but persistent establishment, long-lived. Well suited for low fertility, upland or hilly sites. Used for low-maintenance cover. Poor palatability and nutrition.
Meadow fescue[2] (*Festuca pratensis*)	—	Short bunchgrass	Sandy to clayey	18	Good	10	Slow establishment. Adapted to cool moist regions. Useful in pasture blends and riparian areas. Extremely palatable.
Medium to medium-tall bunchgrasses—							
Crested wheatgrass[1,3] (*Agropyron cristatum*)	Douglas, Ephraim, Fairway	Medium-tall bunchgrass	Silty-loamy to clayey	10	Very good	8–12	Drought-tolerant. Easy establishment, long-lived. Useful where rapid establishment and early season forage is important. Good palatability when green.
Standard crested wheatgrass[1,3] (*Agropyron desertorum*)	Hycrest, Nordan	Medium-tall bunchgrass	Sandy to clayey	10	Very good	10	Easy establishment. Similar to crested wheatgrass but slightly more cold-, shade-, and moisture-tolerant and productive.

1. Adapted to saline and/or alkaline soils 2. Performs well in standing water or periodic flood irrigation
3. Aggressive grasses that can be invasive. Use is recommended in cases where strong plant competition with invasive weeds is needed; avoid use in natural areas.
* Based on pure stand – see Step 10, "Calculate seeding rate," p. 53, to determine mix rates and special cases involving increased rates

able 3. Non-Native grasses *cont'd*

lame	Cultivar	Growth form	Preferred soil type	Minimum precipitation (*inches*)	Erosion control	Pure stand PLS rate/ acre* (*pounds*)	Notes
ledium to medium-tall bunchgrasses, *cont'd*							
iberian wheatgrass[1,3] (*gropyron fragile* ssp. *bericum*)	P-27, Vavilov	Medium bunchgrass	Silty-loamy to clayey	8	Very good	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.
leadow foxtail[1,2] (*llopecurus pratensis*)	——	Medium-tall bunchgrass	Silty-loamy to clayey	25 (or wet areas)	Good	4–5	Slow establishment, long-lived. Adapted to wet, poorly drained sites and tolerant of saline-alkaline soils. Useful for irrigated pastures. Nutritious and palatable.
erennial ryegrass (*olium perenne*)	Tetraploid	Medium-tall bunchgrass	Silty-loamy to clayey	12	Very good	15–35	Rapid establishment, short-lived. Useful for pasture and range improvement. Excellent palatability.
imothy[3] (*hleum pratense*)	Climax; Clair	Medium bunchgrass	Silty-loamy to clayey	16	Good	8–10	Easy establishment. Adapted to moderately moist sites. Commonly planted as pasture or hay grass and for seeding riparian areas. Excellent palatability.
all to very tall bunchgrasses—							
all wheatgrass[1] (*lytrigia elongata*)	Alkar, Jose, Orbit	Very tall bunchgrass	Silty-loamy to clayey	12	Good	10–17	Drought-tolerant. Easy establishment. Suitable for most saline sites and some subirrigated cases. Low palatability.
all fescue[1] (*estuca arundinacea*)	Alta, Fawn, Kenmont, Goar	Tall bunchgrass	All soils except sandy	18	Good	8	Slow establishment; long-lived. Tolerates wet, poorly drained sites. Useful for pasture, good palatability and relatively tolerant of heavy grazing.
ltai wildrye[1] (*eymus angustus*)	Prairieland, Pearle, Eejay	Tall bunchgrass	Silty-loamy to clayey	18	Very good	15	Slow establishment. Extremely salt- and alkaline-resistant.
ussian wildrye[1] (*Psathyrostachys juncea*)	Bozoisky, Swift, Mankota, Vinall	Tall bunchgrass	Silty-loamy to clayey	12	Poor	7–10	Drought-tolerant. Difficult establishment, long-lived. Useful for somewhat saline sites where severe erosion is not a problem. Palatability and nutrition are excellent year-round. Well suited as a pasture grass. Not adapted to cool, moist sites.

1. Adapted to saline and/or alkaline soils 2. Performs well in standing water or periodic flood irrigation
3. Aggressive grasses that can be invasive. Use is recommended in cases where strong plant competition with invasive weeds is needed; avoid use in natural areas.
* Based on pure stand – see Step 10, "Calculate seeding rate," p. 53, to determine mix rates and special cases involving increased rates

Table 3. Non-Native grasses *cont'd*

Name	Cultivar	Growth form	Preferred soil type	Minimum precipitation (*inches*)	Erosion control	Pure stand PLS rate/ acre* (*pounds*)	Notes
Rhizomatous— **Medium to medium-tall rhizomatous—**							
Creeping foxtail[1,2] (*Alopecurus arundinaceus*)	Garrison, Retain	Medium-tall rhizomatous	Silty-loamy to clayey	25 (or wet areas)	Good	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.
Meadow brome[1] (*Bromus biebersteinii*)	Regar, Fleet, Paddock	Medium weakly rhizomatous	Silty-loamy to clayey	16 (or irrigated)	Good	12–17	Good drought tolerance. Easy establishment, long-lived. Very productive: Starts growth in early spring, ripens by early summer and produces abundant late-summer and fall regrowth. Highly palatable when green. Excellent winter hardiness.
Orchardgrass[3] (*Dactylis glomerata*)	Many	Medium-tall rhizomatous	Silty-loamy to clayey	18 (or irrigated)	Poor	8	Easy establishment, medium to long-lived. Adapted to a wide variety of sites. Highly productive and palatable, grazing tolerant. 'Paiute' was selected for its drought hardiness.
Newhy hybrid wheatgrass[1] (*Elymus hoffmanii*)	Newhy	Medium weakly rhizomatous	Silty-loamy to clayey	10	Good	14	Easy establishment. Adapted to moist soils including moderately saline sites. Useful on both irrigated and non-irrigated pasture and rangelands.
Canada bluegrass (*Poa compressa*)	Reubens	Medium rhizomatous	Silty-loamy to clayey	18	Good	2	Able to grow in harsh sites including shallow, infertile soils. Useful for improvement of poor sites where more palatable and productive species are unable to establish.
Fowl bluegrass[2] (*Poa palustrus*)	——	Medium-tall weakly rhizomatous	Silty-loamy to clayey	> 18	Fair	3	Adapted to meadows and moist open areas. Useful for irrigated pastures.

1. Adapted to saline and/or alkaline soils 2. Performs well in standing water or periodic flood irrigation
3. Aggressive grasses that can be invasive. Use is recommended in cases where strong plant competition with invasive weeds is needed; avoid use in natural areas.
* Based on pure stand – see Step 10, "Calculate seeding rate," p. 53, to determine mix rates and special cases involving increased rates

Table 3. Non-Native grasses *cont'd*

Name	Cultivar	Growth form	Preferred soil type	Minimum precipitation (*inches*)	Erosion control	Pure stand PLS rate/ acre* (*pounds*)	Notes
Tall rhizomatous—							
Redtop[1,2] (*Agrostis alba*)	Streaker	Tall rhizomatous	Silty-loamy to clay	20 (or wet areas)	Excellent	1	Prefers moist or moderately wet sites. Tolerates acidic and nutritionally poor soils and periodic flooding. Used as pasture hay.
Smooth brome[3] (*Bromus inermis*)	Lincoln, Manchar, Carlton	Tall rhizomatous	Sandy to clayey	15 (or irrigated)	Good	8–12	Moderately drought-tolerant. Rapid establishment, short-lived. Winter hardy. Requires fertile soils. Best suited for hay production. Commonly used for pasture.
Intermediate wheatgrass (*Elytrigia intermedia* ssp. *intermedia*)	Amur, Greenar, Oahe, Tegmar, Rush	Tall rhizomatous	Silty-loamy to clayey	14	Excellent	10–12	Moderately drought-tolerant. Easy establishment, medium to long-lived. Sites should not be subject to prolonged drought or severe combinations of extreme cold and lack of snow cover.
Pubescent wheatgrass[1] (*Elytrigia intermedia* ssp. *trichophorum*)	Greenleaf, Luna, Mandan, Topar	Tall rhizomatous	Sandy to clayey	12	Very good	12–14	Moderately drought-tolerant. Easy establishment, long-lived. Well suited for stabilizing slightly saline soils. Not winter hardy; use is limited to less harsh sites.
Reed canarygrass[2,3] (*Phalaris arundinacea*)	—	Tall rhizomatous	Silty-loamy to clayey	16 (or wet areas)	Very good	5–10	Moderately drought-tolerant. Difficult establishment, long-lived. Useful on poorly drained, non-saline sites where erosion control is needed. Competitive and aggressive. Low palatability.
Warm-season grasses—							
Sudangrass (*Sorghum sudanese*)	Many	Medium-tall bunchgrass	Silty-loamy to clayey	14	Good	30–50	Annual preferring warm and moist soils. Often used in stubble mulch crops.

1. Adapted to saline and/or alkaline soils 2. Performs well in standing water or periodic flood irrigation
3. Aggressive grasses that can be invasive. Use is recommended in cases where strong plant competition with invasive weeds is needed; avoid use in natural areas.
* Based on pure stand – see see Step 10, "Calculate seeding rate," p. 53, to determine mix rates and special cases involving increased rates

Table 4. Selected forbs (selection based on revegetation goals) and shrubs for western Montana revegetation projects (native unless noted otherwise)

Name	Cultivar	Soil type	Minimum precipitation (*inches*)	Pure stand PLS rate/acre* (*pounds*)	Notes
Forbs— **Annuals—**					
Marsh Indian paintbrush[1,2] (*Castilleja exilis*)	—	Clayey	12	1	Prefers wet, saline or alkaline meadows. Recommended for sites with high water tables, heavy soils, and high pH.
Rocky Mountain beeplant (*Cleome serrulata*)	—	Silty-loamy to clayey	16	10–16	Recommended for short-term stabilization in disturbed areas. Attracts bees and butterflies.
Plains coreopsis (*Coreopsis tinctoria*)	—	Silty-loamy	12	2	Drought-tolerant. Blooms June to September. Found along roadsides, fields, and meadows.
Lacy phacelia (*Phacelia tanacetifolia*)	—	Silty-loamy	10	2–8	Aggressive in growth, adapted to a wide range of soils. Good for erosion control.
Drummond phlox (*Phlox drummondii*)	—	Silty-loamy	12	6–8	Blooms May to October in fallow fields, open woods, roadsides and prairies.
Perennial— **Short perennial forbs—**					
Sulfur buckwheat (*Eriogonum umbellatum*)	—	Sandy to silty-loamy	10	4–7	Drought-tolerant. Common on dry rocky slopes, mountain meadows, and alpine ridges. Requires well drained soils.
Rocky Mountain iris[2] (*Iris missouriensis*)	—	Silty-loamy to clayey	16	15–30	Useful where moisture is plentiful.
White evening primrose (*Oenothera pallida*)	—	Sandy to silty-loamy	12	4	Blooms May to September, good erosion control.
Medium perennial forbs—					
White yarrow[2] (*Achillea millefolium*)	—	Sand to sandy	10	1	Drought-tolerant, aggressive species widely used for erosion control and landscaping. Useful to wildlife, not palatable to livestock.
Columbine (*Aquilegia* spp.)	—	Sandy to clayey	16	3–7	Moderate to high moisture requirements. Most columbines bloom June to August.

Table 4. Selected forbs and shrubs *cont'd*

Name	Cultivar	Soil type	Minimum precipitation *(inches)*	Pure stand PLS rate/acre* *(pounds)*	Notes
Medium perennial forbs, *cont'd*					
Butterfly flower (*Asclepias tuberosa*)	—	Sandy to silty-loamy	24	7–12	Drought-tolerant. Showy perennial that attracts butterflies. Blooms June to September.
Pacific aster (*Aster chilensis*)	—	Sandy to clayey	12	2	Somewhat drought-tolerant. Blooms July to October. Often found in disturbed habitats. Good erosion control.
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	—	Silty-loamy	12	7–15	Drought-tolerant. Blooms May to July along open hillsides, grasslands, sagebrush and in open pine forests. Provides valuable spring forage for deer and elk.
Splitleaf Indian paintbrush (*Castilleja rhexifolia*)	—	Silty-loamy	10	1	Occurs within wooded areas and meadows and on open, rocky slopes.
Aspen daisy (*Erigeron speciosus*)	—	Sandy to silty-loamy	16	1	Blooms June to September. Found on open moist slopes, along streams, and under aspens, spruce and fir.
Blanketflower (*Gaillardia aristata*)	—	Sandy to silty-loamy	10	6–10	Fairly drought-tolerant and suitable for use in mixtures for erosion control.
Northern sweetvetch (*Hedysarum boreale*)	—	Silty-loamy	14	15–25	Drought-tolerant. Productive and palatable to wildlife and livestock.
Blue flax (*Linum lewisii*)	Appar	Sandy to silty-loamy	10	5	Drought-tolerant. Easy establishment, short-lived. Adapted to well drained soils. 'Appar' has outstanding vigor and competitiveness.
Yellow evening primrose (*Oenothera biennis*)	—	Sandy	14	2	Blooms July and August. Found in disturbed areas. Good for erosion control.
Prairie coneflower (*Ratibida columnaris*)	—	All types	16	2	Drought-tolerant, showy species common on gentle slopes, roadsides and grassy prairies, especially on well drained limestone soils. Good nutrition and palatability to livestock.
non-native Small burnet (*Sanguisorba minor*)	Delar	Silty-loamy	10	20–24	Easy establishment, long-lived. 'Delar' is winter hardy, moderately drought-tolerant. Valuable forage for livestock and wildlife in late winter and early spring.
Munro globemallow (*Sphaeralcea munroana*)	—	Sand to sandy	12	4–8	Drought-tolerant. Blooms May to August along roadsides, sandy washes, abandoned fields and other exposed areas.

Table 4. Selected forbs and shrubs *cont'd.*

Name	Cultivar	Soil type	Minimum precipitation *(inches)*	Pure stand PLS rate/acre* *(pounds)*	Notes
Medium perennial forbs, *cont'd*					
Golden banner[2] (*Thermoopsis montanus*)	—	Silty-loamy	16	20–40	Blooms May to August in Montana meadows and moist woods or along streams. Persists on wet soils or sites that are wet early but dry out in summer.
Mules ears (*Wyethia amplexicaulis*)	—	Silty-loamy to clayey	14	16	Drought-tolerant. Occurs on rangeland, hillsides, open woods, dry meadows and moist draws. Blooms May to July.
Tall perennial forbs—					
New England aster[1,2] (*Aster novae-angliae*)	—	Silty-loamy to clayey	16	2	Prefers wet thickets, stream banks, and meadows. Tolerates saline soil. Blooms August to October.
Lance-leaved coreopsis (*Coreopsis lanceolata*)	—	Sandy to silty-loamy	14	8–10	Blooms May to August. Prefers sandy or rocky soil. Establishes well on disturbed sites. Uses include roadside or waste area plantings.
Purple coneflower (*Echinacea purpurea*)	—	Silty-loamy	12	7–12	Fairly drought-tolerant. Establishes on wide range of soil types. Commonly included on roadsides for erosion control and beautification.
Fireflower (*Epilobium angustifolium*)	—	Silty-loamy	8	0.5	Blooms June to September. Occurs in rich moist soil in open woods, prairies, hills, along streams and disturbed ground. Aggressive and persistent.
Wild geranium[2] (*Geranium viscosissimum*)	—	Silty-loamy	14	10–12	Prefers moist meadows, along streams, or open slopes at high elevations.
Maximilian sunflower (*Helianthus maximiliani*)	—	Silty-loamy to clayey	14	6–10	Moderate drought tolerance. Moderate ease of establishment. Rhizomatous and very competitive.
Rocky Mountain penstemon (*Penstemon strictus*)	Bandera	Sandy to silty-loamy	14	3–4	Blooms May to June. Widely adaptable. Fibrous root system and ability to persist on rocky or sandy loam sites. To avoid hybridization, not recommended in areas with Lemhi penstemon (*Penstemon lemhiensis*), a sensitive plant.
Purple verbena (*Verbena stricta*)	—	Silty-loamy	12	4–6	Drought-tolerant. Blooms June to September. Grows in exposed areas. Used for roadside stabilization.
Forbs: Legumes—					
» » NON-NATIVE Cicer milkvetch (*Astragalus cicer*)	Lutana, Monarch, Oxley	Silty-loamy	18	20–25	Fair drought tolerance. Slow establishment, long-lived. Cold hardy. Performs well on poor, infertile soils. Useful for erosion control and as a nonbloat forage and hay mix.

1. Adapted to saline and/or alkaline soils 2. Requires wetland/riparian habitat or performs well in standing water or periodic flooding

* Seeding rate for pure stands; forbs and shrubs are most commonly planted as a mixture component rather than a pure stand (see Step 10, "Calculate seeding rate," p. 53)

Table 4. Selected forbs and shrubs *cont'd*

Name	Cultivar	Soil type	Minimum precipitation (*inches*)	Pure stand PLS rate/acre* (*pounds*)	Notes
Forbs: Legumes, *cont'd*					
» » NON-NATIVE Birdsfoot trefoil[1] * (*Lotus corniculatus*)	Empire, Viking	Silty-loamey to clayey	15	6	Slow establishment, long-lived. Adapted to wet and poorly drained sites; cold hardy; acid-, alkaline- and saline-tolerant. Useful for erosion control and as a nonbloat forage. Grows best alone and not in mixes.
Lupine (*Lupinus* spp.)	——	Silty-loamey to clayey	12–16	10–24	Generally found on dry, open or shaded sites.
Alfalfa[§] (*Medicago sativa*)	Many	Silty-loamy	12	15	Fair drought tolerance. Easy establishment. Widely used for pasture and rangeland.
» » NON-NATIVE White or yellow sweetclover[1 § †] (*Melilotus* spp.)	Many	Silty-loamy to clayey	10	15	Drought- and alkaline-tolerant. Easy establishment. Cold hardy. Valuable in disturbed sites for soil improvement. *Can be invasive/aggressive.*†
Sainfoin[1 §] (*Onobrychis viciaefolia*)	Eski, Remont	Silty-loamy	12	35–45	Drought-tolerant. Easy establishment, short-lived. Typically used in pasture mixes for short rotations. Highly palatable, nonbloat, winter hardy, and alkaline tolerant.
Prairie clover (*Petalostemum* spp.)	Kaneb	All types	14	6–8	Long-lived. White prairie clover (*Petalostemum candidum*) is an excellent legume for erosive sites where productive, palatable, nutritious forage is desired. 'Kaneb' purple prairie clover (*P. purpureum*) has superior vigor, height and stand development.
» » NON-NATIVE Alsike clover[1] (*Trifolium hybridum*)	(Tetraploid or diploid)	Clayey	32	8	Moderate ease of establishment, short-lived. Adapted to cool and moist sites. Cold hardy and shade intolerant. Tolerates alkalinity more than other clovers. Used in hay and pasture.
Vetch (*Vicia* spp.)	Lana	Silty-loamy	12–18	40	Easy establishment, most short-lived. Hairy vetch (*V. villosa*) is a drought-tolerant annual. Highly palatable and nutritious. Hairy and wooly pod vetch (*V. dasycarpa*) is often used as green manure crop, cover, or pasture.
Shrubs— **Small shrubs—**					
Winterfat (*Ceratoides lanata*)	Hatch	Sandy to silty-loamy	6	8	Very drought-tolerant. Slow establishment, long-lived. Adapted to all soil textures on flats, slopes and ridges to 10,000 ft. Extremely palatable to livestock and wildlife.

1. Adapted to saline and/or alkaline soils 2. Requires wetland/riparian habitat or performs well in standing water or periodic flooding
* Seeding rate for pure stands; forbs and shrubs are most commonly planted as a mixture component rather than a pure stand (see Step 10, "Calculate seeding rate," p. 53)
§ Request a copy of the free MontGuide, "Alfalfa Variety Selection," Publication No. MT199303, from your county or tribal Montana State University Extension office
† White or yellow sweetclover should not be used in natural areas because it can be invasive/aggressive

Table 4. Selected forbs and shrubs *cont'd*

Name	Cultivar	Soil type	Minimum precipitation (*inches*)	Pure stand PLS rate/acre* (*pounds*)	Notes
Shrubs: Small shrubs, *cont'd*					
Fringed sagebrush (*Artemisia frigida*)	——	Silty-loamy	6	(Varies)	Attractive rhizomatous, mat-forming sub-shrub occurring from 3,000 – 8,000 ft, usually on thin, dry soils. Fair palatability to livestock.
Prairie sage (*Artemisia ludoviciana*)	Summit	Sandy to silty-loamy	10	(Varies)	Rhizomatous half-shrub adapted to a wide variety of soils from 2,500 – 9,000 ft. Establishes quickly and easily, even on harsh sites. Fair forage value to livestock.
Medium shrubs—					
Sagebrush (*Artemisia* spp.)	Gordon Creek	Sandy to clayey	8–12	(Varies)	Drought-tolerant. Many species and growth forms available from tall shrubs to mat-formers. Request seed harvested in similar environmental conditions. Important for forage and cover and winter livestock browse.
Fourwing saltbush[1] (*Atriplex canescens*)	Wytana	Silty-loamy to clay	8	13	Drought-tolerant. Moderate ease of establishment, long-lived. Useful where a salt-tolerant plant is needed as a soil stabilizer and a high quality winter forage for livestock and wildlife to 8,500 ft. Not tolerant of high water tables. Adaptability is dependent on seed origin.
Rabbitbrush (*Chrysothamnus* spp.)	——	Sandy to clayey	8	(Varies)	Easy establishment. Occurs on all soil textures on a wide variety of sites. Moderately palatable.
Redosier dogwood[2] (*Cornus stolonifera*)	——	Silty-loamy to clayey	24	(Varies)	Thicket-forming deciduous shrub. Prefers sites along streams from 2,500 – 9,000 ft. Berries provide valuable forage for birds.
Bitterbrush (*Purshia tridentata*)	Lassen	Sand to clayey	8	(Varies)	Drought-tolerant. Useful soil stabilizer where high quality browse is needed to 8,500 ft. Valuable to livestock and wildlife.
Sumac (*Rhus* spp.)	——	Sand to silty-loamy	8–10	(Varies)	Drought-tolerant. Useful for stabilizing coarse soils. Valuable cover for wildlife and berries are important winter forage for birds. Adapted to well drained sites from 5,000 – 7,500 ft.
Currant[2] (*Ribes* spp.)	——	Silty-loamy	12–14	(Varies)	Golden currant (*R. aureum*) adapted to fertile, moist sites from 3,500 – 8,000 ft. Wax currant (*R. cereum*) and mountain gooseberry (*R. montigenum*) prefers drier sites from 2,500 – 9,500 ft and 7,000 – 11,500 ft, respectively. Berries important for wildlife.
Rose[2] (*Rosa* spp.)	——	Silty-loamy	10–16	(Varies)	Nootka rose (*Rosa nutkana*) occurs on wetter sites than Woods rose (*R. woodsii*). Occur from 3,500 – 9,000 ft in elevation. Berry-like "hips" provide important forage for wildlife.
Snowberry (*Symphoricarpos* spp.)	——	Silty-loamy	10–14	(Varies)	Drought-tolerant. Prefers moderate to well drained soils, useful for stabilizing erosive soils. Common and mountain snowberry (*Symphoricarpos aus* and *S. oreophilus*) prefer 5,000 – 8,000 ft and 5,000 – 10,000 ft, respectively. Good forage for livestock and wildlife.

Table 4. Selected forbs and shrubs *cont'd*

Name	Cultivar	Soil type	Minimum precipitation *(inches)*	Pure stand PLS rate/acre* *(pounds)*	Notes
Shrubs: Large shrubs—					
Rocky Mountain maple (*Acer glabrum*)	——	Silty-loamy	20	(Varies)	Found on mountain slopes and along streams from 4,000 to 10,000 ft. elevation. Important to wildlife for cover and forage.
Saskatoon serviceberry (*Amelanchier alnifolia*)	——	Sandy to clayey	11	(Varies)	Moderately drought-tolerant; long-lived. Prefers upland sites and along streams up to 9,000 ft. Useful for erosive soils on moist sites. Provides good wildlife and livestock forage.
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 to 9,000 ft. elevation. Excellent palatability to wildlife; important winter browse plant.
Chokecherry[1,2] (*Prunus virginiana*)	——	Sandy to silty-loamy	15	(Varies)	Drought-tolerant. Moderate ease of establishment. Prefers m oist or seasonally moist sites from 4,500–9,000 ft. Leaves are poisonous to cattle and sheep. Tolerates saline soils. Useful for erosion control. Valuable cover and forage for wildlife.
Elderberry[2] (*Sambucus* spp.)	——	Silty-loamy	12–18	(Varies)	Blue elderberry (*S. coerulea*) and red elderbery (*S. racemosa*) prefer moist soils to 9,000- ft. ComMon along streams.

1. Adapted to saline and/or alkaline soils 2. Requires wetland/riparian habitat or performs well in standing water or periodic flooding
* Seeding rate for pure stands; forbs and shrubs are most commonly planted as a mixture component rather than a pure stand (see Step 10, "Calculate seeding rate," p. 53)

Table 5. Recommended native grasses for western Montana by zone* [*adapted from* Comfort and Wiersum (2000)]

Zone 1 : Dry, warm site *(Note: this zone is typically very susceptible to noxious weeds): open grasslands and woodland benches, at low elevations on all aspects and on south- and west-facing slopes at higher elevations*	**Pure stand PLS rate (lbs/ac@40 seeds/sq ft)****
Grass or grasslike species	
Slender wheatgrass	12
Thickspike or streambank wheatgrass	12
Bluebunch wheatgrass	12
Beardless bluebunch wheatgrass	12
Big bluegrass	2
Canada wildrye	15
Sheep fescue	3

Native tree/shrub species Trees: ponderosa pine-west, Douglas fir-west; Shrubs <4′: snowberry, woods rose, bitterbrush, skunkbush sumac; Shrubs >4′: mountain mahogany, mockorange, chokecherry

Zone 2 : Moist, warm site *Moderate environments receiving more precipitation than dry, warm sites. Found on north- and east-facing slopes on lower elevation, all aspects at mid-elevations, and on south- and west-facing aspects at higher elevations*	**Pure stand PLS rate (lbs/ac@40 seeds/sq ft****
Grass or grasslike species	
Slender wheatgrass	12
Thickspike or streambank wheatgrass	12
Beardless bluebunch wheatgrass	12
Big bluegrass	2
Mountain brome	27
Canada wildrye	15
Sheep fescue	3

Native tree/shrub species Trees: ponderosa pine-west, Douglas-fir-west, western larch; Shrubs <4′: snowberry, Woods rose, currant; Shrubs >4′: serviceberry, Rocky Mountain maple

Zone 3: Moist, cool site *Found predominately on north- and east-facing slopes at mid-elevations and on all aspects at high elevations*	**Pure stand PLS rate (lbs/ac@40 seeds/sq ft****
Grass or grasslike species	
Slender wheatgrass	12
Beardless bluebunch wheatgrass	12
Big bluegrass	2
Tufted hairgrass	1
Mountain brome	27
Sheep fescue	3

Zone 4 : Riparian areas *Stream bottoms, wet meadows: these sites are subirrigated for at least a portion of each growing season*	**Pure stand PLS rate (lbs/ac@40 seeds/sq ft****
Grass or grasslike species	
Slender wheatgrass	12
Western wheatgrass	16
Tufted hairgrass	1
Tufted hairgrass	1
	plugs/acre
Native sedges	11,000
Native rushes	11,000

Native tree/shrub species Trees: black cottonwood, quaking aspen, Engelmann spruce; Shrubs <4′: snowberry, Woods rose; Shrubs >4′: native willows, red-osier dogwood, chokecherry, mockorange Rocky Mountain maple, water birch, alder, serviceberry

* The addition of native forbs is recommended when herbicide spot-treatment of noxious weeds or hand pulling is appropriate

** Based on pure stand. See Step 10, "Calculate seeding rate," p. 53, to determine mix rates and special cases involving increased rates agules and mycorrhizal inocula. These should be added when topsoil is unfit or is altogether missing from roadsides. Before construction, plan a topsoil salvage and replacement operation when roadside topsoil is healthy and noxious weed–free.

After completion of roadside construction, application of seed may or may not be necessary depending on the amount of desired plant propagules in the replaced topsoil. Delayed application of seed is not advised given the likelihood of rapid noxious weed establishment along roadsides. When selecting plant materials, consider species' ability to adapt to the site, to rapidly establish and to self-perpetuate. Whenever practicable, select and distribute native species for ecological reasons (Harper-Lore 2000). Native grasses such as Idaho fescue (*Festuca idaho-ensis*), sheep fescue (*F. ovina*), sandberg bluegrass (*Poa sandbergii*), canby bluegrass (*P. canbyi*), and 'Nortran' tufted hairgrass (*Deschampsia caespitosa*) are short-growing and can significantly reduce roadside mowing maintenance.

Also consider species' ability to guard against soil erosion. Consider rhizomatous species with extensive root systems that are tolerant of roadside disturbance (Tyser et al. 1998). For instance, streambank and thickspike wheatgrass (*Elymus lanceolatus* ssp. *psammophilus* and ssp. *lanceolatus*, respectively), both strongly rhizomatous with excellent seedling vigor, are frequently used for erosion control. Blue wildrye (*Elymus glaucus*) is a native perennial bunchgrass highly desirable for use in erosion-control seedings. However, these species are not short-growing and may require mowing maintenance.

When revegetating roadsides it is difficult to recreate a native community in its entirety. Still, incorporating key species within vegetation types appropriate to the site is recommended. 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. Selected native forbs that perform well along roadsides include Pacific aster (*Aster chilensis*), lance-leaved and plains coreopsis (*Coreopsis lanceolata* and *C. tinctoria*), purple coneflower (*Echinacea purpurea*), Drummond phlox (*Phlox drummondii*), and purple verbena (*Verbena stricta*). 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; such seeding often follows wildfires. Quick-establishing annuals can provide immediate protection, but only for a year. Grasses and grasslike plants that reproduce through rhizomes are ideal for erosion control because of their extensive networks of soil-stabilizing underground stems. 'Critana' thickspike wheatgrass, a native rhizomatous cultivar that has very strong seedling vigor, is good for site stabilization. Blue wildrye is a native, cool-season bunchgrass commonly used in erosion-control seedings where 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 and as erosion control species. 'Ephraim' crested wheatgrass (*Agropyron cristatum*), a non-native bunchgrass, is a variety selected for its rhizomatous growth habit. This wheatgrass is well suited for soil stabilization, but its use in natural areas is not advised given its aggressive and invasive characteristics. Grass-like plants such as sedges (*Carex* spp.), spikerushes (*Eleocharis* spp.), rushes (*Juncus* spp.), bulrushes (*Scirpus* spp.) and cattails (*Typha latifolia*) are helpful for erosion control in riparian areas.

See table 2, pp. 22–25, and table 3, pp. 26–29, for other recommended species characterized by soil-stabilizing growth forms.

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 and are non-persisting. Regreen and triticale are sterile, hybrid crosses that reduce wind and water erosion and are also quick establishing and non-persisting. Canada wildrye (*Elymus canadensis*) is a native cool-season perennial bunchgrass that is often included in seed mixtures for its rapid establishment of protective cover. 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 in wildfire-affected cases. Winter wheat (*Triticum aestivum*) is a good choice for protection and cover into the spring but can be moderately competitive to establishing perennials.

3. *Establish species that can minimize noxious weed invasion or reestablishment*

An effective seed mix should avoid niche overlap and contain a functional diversity of aggressive, quick-establishing grasses and forbs that can occupy available niches. (Do not include forbs if broadcast treatment of broadleaf herbicides is anticipated.) Carpinelli (2000) found that a diverse, well-established plant community might better resist weed invasion than a less diverse community. Pokorny (2002) states that enhancing forb functional group diversity, or enhancing the number of functional groups, might preempt resources, thus making resources less

* Care should be taken to avoid hybridization with Lehmi penstemon (*Penstemon lemhiensis*), a sensitive plant that is imperiled in Montana. Call the Montana Natural Heritage Program at **(406) 444-5354,** then press **2**, for information on recorded occurrences of this plant in your area. Avoid seeding Rocky Mountain penstemon if Lehmi penstemon occurs in your area.

available to an invader. And Pokorny (2002) found that spotted knapweed performed best at sites with low levels of functional group diversity, especially when shallow- and deep-rooted native forbs were absent. This demonstrates that sites with a high functional diversity of native forbs are most competitive with spotted knapweed and most likely to resist invasion and establishment. It is highly recommended that the native forb component of a plant community be protected and enhanced to resist weeds and maintain ecosystem stability. Once removed, this critical feature of plant communities is difficult and expensive to reestablish. Careful weed management should aim to preserve native forbs.

For a plant community to be "weed-resistant," it must effectively and completely utilize resources temporally and spatially. Designing a seed mix that includes shallow- and deep-rooted forbs and grasses that grow both early and late in the year will maximize niche occupation in time and soil profile space. Cool-season species initiate growth in late winter. In early spring these species use soil resources available in the upper soil profile and begin seed production in early summer. Selected native cool season grasses include thickspike wheatgrass, slender wheatgrass, western wheatgrass (*Pascopyrum smithii*), sandberg bluegrass and Canada wildrye. These grasses are competitive with weeds and in fact may prove good weed suppressors.

Idaho fescue and 'Covar' sheep fescue are native drought-tolerant cool-season bunchgrasses that are aggressive and strongly competitive once established in mature stands. Non-native grasses that are highly competitive with weeds include 'Luna' pubescent wheatgrass (*Elytrigia intermedia* ssp. *trichophorum*), hard fescue (*Festuca longifolia*) and, owing to its long season of growth and extensive root system, 'Bozoisky' Russian wildrye. Solid stands of meadow brome (*Bromus biebersteinii*), a non-native bunchgrass, are relatively resistant to weeds. Competitive native forbs suitable for revegetation include 'Appar' blue flax (*Linum lewisii*), white yarrow (*Achillea millefolium*), Maximilian sunflower (*Helianthus maximiliani*), blanketflower (*Gaillardia aristata*), and fireflower (*Epilobium angustifolium*). Lacy phacelia is an aggressive native annual that may have good competitive abilities. Pokorny (2002) states that gayfeather (*Liatris punctata*), a native forb, is a very strong competitor with spotted knapweed; check with seed suppliers on the availability of this species. Numerous other native forbs are available and suitable for revegetation efforts.

Incorporating deep–tap-rooted shrubs such as sagebrush, rabbitbrush (*Chrysothamnus* spp.), bitterbrush or 'Wytana' fourwing saltbush in the seed mix or as young plants can further make use of resources from the lower soil profile throughout and late in the growing season. Furthermore, the addition of shrubs can enhance establishment of understory species by increasing water availability, infiltration rates and water-holding capacities, and soil fertility and seedbanks. Shrubs also increase establishment of understory species by concentrating nutrients and decreasing understory temperatures that reduce evapotranspiration and increase nutrient cycling (West 1989).

Step 7

4. ***Restore a healthy plant community***

Weed-infested sites alter the structure, organization and function of ecologic systems (Olson 1999). The development of a healthy plant community comoprising functionally diverse species is the key to sustainable invasive weed management while meeting other land use objectives such as forage production, wildlife habitat development, or recreational land maintenance (Sheley et al. 1996).

The development of a healthy plant community involves long-term management that includes steady removal of individual weeds with replacement by desired plants. This replacement can occur as natural revegetation, when desired vegetation cover and propagules are adequate within the infestation, or through artificial revegetation efforts. Species selection to restore a desired or healthy plant community should follow recommendations in the previous section and other recommendations specific to the site's intended use.

* * *

It is imperative to protect the remnant native forb component within the weed-infested site during weed management. This may be difficult to do, for often the preferred choice of infestation management is broadcast herbicide treatments that often injure or permanently damage remaining native forbs. Instead, site-specific methods such as herbicide spot treatments should be developed and carefully employed to protect remnant forbs.

Forb protection within weed-infested sites is important not only because forbs are vital to ecosystem stability but because forbs have demonstrated strong competitive abilities against invasive weeds (Pokorny 2002) and may be key to successful long-term weed management.

After the development of a healthy plant community, long-term maintenance that favors the seeded species will be needed. The desired grass component should be managed to encourage strong vigor and growth, such as by avoiding heavy grazing practices, and the forb component should be managed to encourage the highest levels of diversity, such as through periodic prescribed burning.

Site Characteristics

Once species have been selected to meet revegetation goals and management objectives, site characteristics such as soil attributes and the precipitation, soil moisture, temperature, and elevation can confirm species selection.

Soil attributes

Soil texture, which is determined by the size of the particles that comprise 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. Optimal soil texture is usually loam comprising 45 percent sand, 35 percent silt and 20 percent clay. (See figure 2, right. And see the text box below the figure to determine your soil type. For large or challenging projects, consider obtaining a soil survey map from your local USDA Natural Resources Conservation Service field office.)

Testing the chemical properties of soil can be helpful in directing or confirming species selection and in suggesting any soil amendments. And testing can indicate the suitability of a given soil for plant survival and growth.

If you're planning a challenging revegetation project, you should test area soil for:

1.) *pH* The optimal range is 6.5 to 7.5. Seeded species adapted to highly acidic (pH <6) or highly alkaline (pH >8.4) soils should be used instead of attempting to amend the soil with additions of sulfur, peat, lime or fertilizer. Grasses, grass-like species, forbs and shrubs adapted to saline-alkaline soils are listed in tables 2, 3 and 4.

2.) *Electrical conductivity* This is a measure of soil salinity;

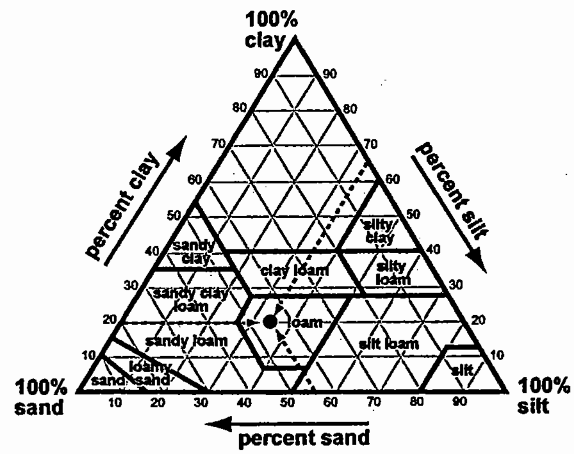

Fig. 2. Soil textural triangle illustrating the range in composition of sand, silt and clay for each soil textural class. The dotted line depicts a loam soil that has 45% sand, 35% silt and 20% clay content.

Manual texturing

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.

the optimal range is 0 to 2 mmhos/cm soluble salts.

3.) *Sodium adsorption ratio* This is the proportion 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.

Step 7

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 and 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.

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

Seeded species should be adapted to the precipitation and moisture level of the soil. Temperature zone and elevation of the site should also be addressed. See table 5, p. 36, for recommended grass species by western Montana zone.

Wildland seeds, seeds collected from the local landscape, are locally adapted and can have excellent establishment and long-term resiliency. But large quantities must be collected to offset the disadvantage of low seed viability. Custom-collecting is commercially available, and may be indicated for large projects when site-specific seed is desired or when preferred species are not available in the marketplace. Seeds can be collected and used immediately, or may be increased through cultivation—"grown out" to meet future needs.

Numerous species perform well on such high-soil-moisture or riparian/wetland sites as stream bottoms or wet meadows that are 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 or wet or occur in precipitation zones greater than 18 inches. Among other suitable natives are wheatgrass, western wheatgrass, tufted hairgrass and reed canarygrass. Orchardgrass (*Dactylis glomerata*), meadow brome and tall fescue, although not native, are often recommended for irrigated pastures in Montana. Smooth brome is another non-native that is less frequently recommended for irrigated pastures. Other non-native grasses that perform well in irrigated pastures are listed in table 3, pp. 26–29.

Native sedges, spikerushes, rushes, bulrushes and cattails are grass-like species used extensively in riparian and wetland revegetation projects because of their aggressive root systems and wildlife habitat value. Numerous native grasses, forbs, and shrubs are available for wetland/riparian revegetation projects; see tables 2 and 4. Planting greenhouse-grown plugs has shown higher establishment over seeding or planting wildlings—plugs collected from wild populations (Hoag and Sellers 1995). Plugs

Native vs. non-native species selection

Many land managers interested in wide adaptability, easy establishment, forage production and competitiveness with noxious weeds are shifting from seeding such introduced grasses as crested wheatgrass to reestablishing native species to restore or maintain native ecosystems' genetic and ecological integrity. This shift is based on social values that are changing as a result of advances in ecological knowledge.

The benefits of using natives include—

- **Erosion control** Many native grasses and forbs have rhizomes or deep and fibrous root systems that help prevent soil erosion. Blue wildrye can provide quick erosion control. Streambank and thickspike wheatgrass, both strongly rhizomatous grasses with excellent seedling vigor, are also used for erosion control. 'Bandera' Rocky Mountain penstemon, developed for its fibrous root system, is often included in reclamation seed mixes for its ability to control erosion.

- **Vegetation management** Short-growing native grasses such as Idaho fescue, sandberg bluegrass, canby bluegrass, and 'Nortran' tufted hairgrass reduce roadside mowing maintenance.

- **Ecology and aesthetics** Native plants can maintain ecological stability and establish a more natural setting. In a Glacier National Park study, Tyser et al. (1998) found the use of natives for roadside revegetation to be preferable for ecological and aesthetic reasons.

- **Resiliency** Natives represent a genetic product of an environment and are adapted to the means and extremes of an area. Natives can maintain excellent performance under a variety of conditions and demonstrate fewer boom-or-bust responses to environmental extremes than some introduced species (Brown and Wiesner 1984). For instance, non-native crested wheatgrass can perform well in an average rainfall year, but drought in combination with other environmental conditions severely limits its performance. Many native grasses and forbs—see table 2, pp. 22–25, and table 4, pp. 30–35—are resilient to drought, and replacement plantings should be rare.

- **Improved water quality** Fertilizers and other agricultural runoff into surface water is greater with sod or common turfs than from deep-rooted native grasses, such as slender wheatgrass.

Many non-native grasses are competitive with noxious weeds. However, selected native grass species can also be effective competitors. High-seral native bunchgrasses such as Idaho fescue and 'Covar' sheep fescue compete well with noxious weeds and such invasive grasses as cheatgrass on degraded sites. Thickspike wheatgrass, slender wheatgrass, western wheatgrass and Canada wildrye are also competitive.

Adapted in part from Harper-Lore, 2000

Step 7 should be planted during summer, when heat, light and water are greatest. Broadcast seeding of wetland/riparian areas is used primarily to increase overall species diversity. Following seed broadcast, avoid covering seeds with soil; light and heat are needed for proper germination.

ECOTYPES

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.

Step 8
Assist establishment

Seedling establishment is the most critical phase of revegetation (James 1992). However, variations in soil, site exposure and climate can hinder this vulnerable phase. 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) stated that early revegetation success is a function more of moisture than of soil nutrient availability, and Masters et al. (1996) stated that weed interference was the primary constraint to successful establishment of native plants.

Enhancing establishment can increase revegetation success. Avenues of enhancing establishment include:

a) Using species adapted to local site conditions and using high-quality, certified seed.

b) Reducing or eliminating weed interference through herbicide treatments or early-seral cover crops that work to reduce the availability of soil nitrogen.

c) Inoculating seed, nursery stock locally collected or salvaged legumes with proper bacteria to ensure maximum nitrogen fixation that can contribute to a healthy nitrogen cycle. This will improve phosphorus uptake, water transport, drought tolerance and resistance to pathogens, and by increasing offspring quality will contribute to long-term reproductive success and fitness of seeded species.

d) Heightening seedling survival by preparing the seedbed before and after broadcast seeding and lightly packing the soil. (Consider the application of hydromulch following broadcast seeding to enhance establishment.) Avoid covering wetland/riparian species with soil; light is needed for proper germination. (Alternatively, if the site is accessible to equipment, place seeds at the proper depth using a no-till drill.)

> In mesic environments, even small amounts of litter may harbor pathogens that reduce germination and seedling survival when soil moisture and soil surface relative humidity increase following rainfall (Call and Roundy 1991); consider seed fungicide treatments in these environments.

e) Planting plugs to establish wetland/riparian grasslike species. Hoag (1994) found that revegetation with planted plugs had higher establishment rates and spread faster and further as compared with revegetation with seeds or wildlings.

f) 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 broadcast seeds. Their sides slough off and trap wind-blown particles.

g) Increasing seeding rates to:

- Enhance desired species competitive interaction with noxious weeds. For instance, Velagala et al. (1997) found that increasing intermediate wheatgrass densities removed the effect of spotted knapweed on intermediate wheatgrass where interspecific interference occurred;

Step 8

- Increase the likelihood that an adequate amount of broadcast seeds find safe sites (Sheley et al. 1999), and
- Compensate for a lack of understanding of plant/site relationships (Vallentine 1989).

h) Adding small amounts of water temporarily to encourage establishment—but only in cases when natural precipitation has proved inadequate. (However, an initial watering is recommended after transplanting during the growing season.) Be aware that frequent watering may well 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.

i) Deferring grazing by means of fencing or herding until vegetation reaches establishment, 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 may also enhance the establishment phase of revegetation. Consider the following seed treatments when appropriate.

Seed priming initiates the germination process, allows it to continue to a certain point, then suspends it. The primed seed is 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 seedling to capture resources has a competitive advantage (Harper 1980).

Seed fungicide protects seeds from numerous soil-borne organisms. Consider this treatment in mesic environments.

Seed stratification. Cold stratification "fools" seeds into germination mode by mimicking the winter environmental conditions the seeds would be subject to in the natural environment. Many upland species such as beardless wildrye and Indian ricegrass need cold stratification to reduce seed dormancy and improve germination. Most wetland/riparian seeds should be cold-stratified in a proper medium, usually distilled water and sphagnum moss, for 30 days at 32–36°F.

Seed scarification Seeds with considerable dormancy—Indian ricegrass, beardless wildrye, sweetvetch (*Hedysarum boreale*), prairie clover (*Petalostemum* spp.) and sumac (*Rhus* spp.) among them—benefit from acid or mechanized scarification of the seed coat. This treatment greatly improves germination.

Seed coating Seeds coated with such growth regulators as cytokinin or diatomaceous earth can improve seedling establishment (Greipsson 1999).

Mulching

Providing an immediate mulch cover can protect soil and seeds from erosion by wind and water, conserve soil moisture from the effects of wind and sun, and moderate soil temperatures. The following mulches can enhance germination and establishment:

Hay mulch Native certified weed-free hay is a beneficial mulch that contains a small amount of nitrogen from leaves, flowers and seed heads. Native hay can also contain seeds of native plants if harvested with mature seeds present. McGinnies (1987) found that 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 can typically include needle-and-thread grass, western wheatgrass and bluebunch wheatgrass. When attempting to seed needle-and-thread grass, the long awns can prove problematic. However, these long awns become useful appendages in hay mulches by working the seed into the ground, improving 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 mulch to the wind, if it is still pliable it can be crimped into the soil to avoid excessive breakage or trampled short-term by livestock. Or an organic tackifier, a glue that breaks down into natural byproducts, can be applied.

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.

Cover or 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, a cross between common wheat and tall wheatgrass, and triticale, a cross between common wheat and cereal rye (*Triticum aestivum* x *Secale cereale*), 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 cover crop; it is very competitive and may aggressively spread to surrounding sites.

Seed can be planted by mulching with native hay. This is the most effective seeding method for problematic seeds, such as needle-and-

Hydromulch (hydraulic mulch) Hydromulch is 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 used with a tackifier. Recycled paper mulch will decompose quickly and provide good protection on relatively flat areas. 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 of seedling shoots.

Erosion control blankets Usually composed of woven organic material such as straw or coconut fiber, these blankets are designed to let seeds germinate and to permit stems to grow through and above the mat. 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 need long-term protection they're sometimes the only choice.

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 Noble (1986)

Step 9
Determine a seeding method

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

Drill seeding

A non-rocky site that is 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 since seed depths and seeding rates are closely controlled and the seed-to-soil contact is high, directly enhancing seedling establishment and revegetation success. Ideal seeding depths are about ¼ inch for small seeds and about ½ to 1½ inches for large seeds. Seeding depth varies with site characteristics that influence soil moisture, chief among them as soil texture, site exposure and aspect. (For specific depth recommendations, contact your local Extension office or USDA Natural Resources Conservation Service or Conservation District field office.)

> The soil should be firm when drill-seeding to allow for proper depth of seed placement.

Although drill seeding can enhance seedling establishment, some shortcomings should be recognized:

- The plants that germinate develop in rows that resemble a crop rather than a native plant community.
- Wetland/riparian species require plenty of light and heat to germinate. These plants should not be drill-seeded. Their seeds need to remain on top of a moist soil surface, as they will if broadcast-seeded.
- Long, narrow seeds such as those of smooth brome are difficult to plant because they become bridged within the drill.
- Because some species require shallow placement in the soil while others require deeper placement, two separate seeding operations may be needed when planting seed mixes.
- Seeds of various sizes will separate in the seed container prior to soil deposit. 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 sand, cracked corn or rice hulls can mitigate the size or weight segregation of seeds by dampen-

ing 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).

Step 9

- Drill furrows can favor soil erosion from water flow unless seeding is performed along slope contour.

Broadcast seeding

Broadcasting is a commonly used seeding method. It is commonly utilized on steep, rocky or remote sites that are inaccessible to equipment. Aircraft can seed inaccessible areas such as those burned by wildfire. Small areas can be broadcast-seeded with a hand spreader; commercial spreaders can seed larger areas.

The addition of hydromulch over broadcast 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 seed-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.

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

Broadcast seeding of wetland/riparian species is used not 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; wetland plant seeds need plenty of heat and light for good germination. Consider planting plugs 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. Even so, hydroseeding is usually the only practicable method for seeding slopes 3:1 or steeper.

The addition of mulch can enhance soil protection. Albaledejo (2000) found that 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 anthropic (that is, severely man-modified) steep 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 that aid water infiltration and soil aeration. The imprints work as small precipitation catchbasins that enhance 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 that 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 since the hay is both the seeding method and mulch that prevents soil erosion, conserves moisture and moderates soil temperatures. However, since each species produces 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 trampling hooves of livestock, or held down upon the soil with an organic tackifier.

"Island" planting

Planting nursery stock selected for the environmental, physical and chemical characteristics of a site 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 nonseeded species resulting from this practice should not be anticipated.

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

Island-planted 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 seed is usually difficult because site hydrology must be carefully controlled and precise amounts of heat, light and water are needed. Planting plugs skirts the susceptible and critical seed germination and establishment stages. Hoag and Sellers (1995) state that planting plugs to revegeteate wetland areas is preferred to broadcast-seeding or collecting wildlings (see Step 11, Transplanting, p. 55). Greenhouse-grown plugs of wetland/riparian grasses, grass-like species and forbs and shrubs should be planted on 18- to 24-inch centers (Hoag 2000), which works out to about 11,000 plugs per acre (Comfort and Wiersum 2000). Over time, the plants will spread out 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 lots of water.

In Montana, June may be the best time to plant plugs.

Control of site hydrology is important during planting and establishment. A detailed description is provided in *Harvesting, Propagating, and Planting Wetland Plants* (Hoag 2000; Riparian/Wetland Project Information Series No. 14), available from USDA Natural Resources Conservation Service field offices across the state.

Sprigging

Sprigging is the planting of 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 are placed below the highest concentration of salts on the soil surface (USDA 1996). Once established, rhizomatous grasses will continue to spread. The availability of a sprig source and proper equipment are the main limitations on 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, known 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. Wetland/riparian species as plugs should be planted on 18- to 24-inch centers (Hoag 2000). 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 trebling rates when seeding to compete with noxious weeds or if broadcast- or hydroseeding. Increasing seeding rates adds expense to a project, but this good 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 a mix of four grasses to be seeded on ten acres, for example, 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.) Common 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 in pastures.

Pure live seed is a measure that describes the percentage of a quantity of seed that will germinate; PLS equals the percent purity times percent germination. Multiplying 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 (adapted from Granite Seed Company [2000] and used here with permission):

	Seed lot A	*Seed lot B*
Cost/lb. (bulk)	$1	$1.50
Percent purity	75	95
Percent germination	60	80
Percent PLS	45	76

Step 10

Seed lot A might appear to be the better value because its cost is only $1 per bulk pound, whereas the cost for seed lot B is $1.50 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 that seed lot B is the better value at $1.97 per PLS pound; seed lot A costs $2.22 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 PLS at the recommended rate per acre by thepercent 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 percent, the bulk rate needed to seed the recommended PLS is determined thusly:

10 PLS/.080 PLS = 12.5 lbs *bulk seeding rate per acre*

Step 11
Transplanting

Because transplanting circumvents the susceptible and critical seed germination and establishment stages, transplanting salvaged or locally collected plants can complement reseeding and increase overall revegetation success by providing rapid plant establishment. Sometimes transplanting is the only feasible method of establishing certain plants. For instance, seeds of many shrubs may germinate only occasionally, establish very poorly or reveal slow growth rates in the natural environment (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. To increase success, reduce weed interference and transplant during periods of early spring or late fall dormancy. Transplanting during dormant periods can ensure that plants will withstand transplantation rigors and 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, fireflower and yellow and white evening primrose. Plants with taproots and extensive root systems are least likely to tolerate transplanting. To heighten transplantation success when performed during growing periods, 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 in lower-fertility, lighter, droughty soils (Atthowe 2001).

> Island-planting of salvaged or collected plants can introduce an adapted native seed source into a site.

Planting fewer individuals in islands where a central, established stand of plants can reproduce and eventually spread throughout the area can reduce the time and effort costs of transplanting salvaged or local native plants. Island-planted salvaged or locally collected shrubs can complement a revegetated site.

Such overstory plantings may increase establishment of understory species. Call and Roundy (1991) summarized West (1989) in stating that shrubs can—

• Positively affect water availability by intercepting water from light rains and snow

Step 11 • 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.

* * *

Transplanting wild wetland/riparian plants (i.e., wildlings) is often implemented, but planting plugs is preferred; as Hoag (1994) states, plugs have higher establishment rates and spread faster and further than transplanting or straight seeding. However, transplanting wetland plants, which can be done successfully because of their sturdy root systems, is 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 that the mycorrhizae remain intact, which increases establishment success. To avoid transporting weed seeds from collections made at weed-infested sites, wash the soil from plants and inoculate them with mycorrhizae, and to minimize shock, plant the collected plants as soon as possible.

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, blue flax and many other grass and forb species require cold, and 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 your county or tribal Extension office, an office of the USDA Natural Resources Conservation Service or a Conservation District office for recommendations on optimal seeding times specific to your site.

Avoid problems

The following specification tips can help prevent or mitigate common problems:

- Order uncommon seeds and plants early
- Require local origin seed and seedlings
- Don't plant seed too deep when using a convential grass drill
- Don't skip weed control steps to save time on a project

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 (See Appendix C, p. 69, for information on succession and successful revegetation)
- The invasion or reestablishment of noxious 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 noxious weeds
- During and after establishment, hand-pulling or spot-spraying noxious 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 a protective 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 site conditions. For example, a site prone to low moisture, high erosion or weed invasion should be monitored frequently.

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Step 14
Long-term management

Long-term revegetation success requires continuous monitoring and evaluation for timely adjustments to maintain the developed plant community. 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 them when necessary.

If grazing is the intended use of the site, further management will be necessary. This includes implementing grazing practices that 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—a plan that encourages 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:*

- ***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 weeds. When domestic sheep are grazed with cattle, a grazing balance is facilitated. Glimp (1988) found that 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.

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

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

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* See Holzworth et al. (2000) for in-depth recommendations on proper grazing management.

Step 14

• ***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 that the establishment of diffuse knapweed (*Centaurea diffusa*) was enhanced only when defoliation of the native bluebunch wheatgrass exceeded 60 per cent, suggesting that defoliation beyond this level reduced the grass's competitiveness.

Winterfat (*Eurotia lanata*) performs especially well under deferred rotation grazing.

• ***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).

• ***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 but is not limited to detecting changes in desired plant cover and noting such surface conditions as litter accumulation and exposed soil. To permit the making of any needed adjustments in a timely way, annual evaluations are essential.

Conclusion

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

Numerous steps must be 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 judicious weed management plans that 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 and 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.

Appendix A
Montana Noxious Weed List

Noxious weeds in Montana fall into three groups—Categories 1, 2 and 3.

Category 1 noxious weeds are currently established and generally widespread in many counties of the state. These weeds are capable of rapid spread and render land unfit or greatly limit beneficial uses. Weeds in this category are the third-highest management priority in Montana.

- Canada thistle (*Cirsium arvense*)
- field bindweed (*Convolvulus arvensis*)
- whitetop/hoary cress (*Cardaria draba*)
- leafy spurge (*Euphorbia esula*)
- Russian knapweed (*Acroptilon repens*)
- spotted knapweed (*Centaurea maculosa*)
- Dalmatian toadflax (*Linaria dalmatica*)
- St. Johnswort (*Hypericum perforatum*)
- sulfur (erect) cinquefoil (*Potentilla recta*)
- common tansy (*Tanacetum vulgare*)
- oxeye daisy (*Chrysanthemum leucanthemum*)
- houndstongue (*Cynoglossum officinale*)
- diffuse knapweed (*Centaurea diffusa*)

Category 2 noxious weeds have recently been introduced into the state or are rapidly spreading from their current sites. These weeds are capable of rapid spread and invasion, rendering land unfit. They are the second-highest management priority in Montana.

- Dyers woad (*Isatis tinctoria*)
- meadow hawkweed complex (*Hieracium pratense, H. floribundum, H. piloselloides*)
- purple loosestrife or lythrum (*Lythrum salicaria, L. virgatum,* and any hybrids)
- tall buttercup (*Ranunculus acris*)
- tansy ragwort (*Senecio jacobea*)
- tamarisk [saltcedar] (*Tamarix* spp.)
- orange hawkweed (*Hieracium aurantiacum*)

Category 3 noxious weeds have not been detected in the state or are to be found only in small, scattered localized infestations. These weeds are known pests in nearby states, are capable of rapid spread, and render land unfit. They are the highest management priority in the state. As of January 2004, there were three such weeds:

- yellow starthistle (*Centaurea solstitialis*)
- rush skeletonweed (*Chondrilla juncea*)
- common crupina (*Crupina vulgaris*)

Appendix B
Roadside revegetation

Roadside revegetation sometimes has but limited long-term success because many roadside sites have low fertility and depleted biological activity. Their poor nutrient cycling capacity results in inadequate retention of natural or amended nutrients, reducing the establishment and persistence of vegetative stands (Claassen and Zasoski 1993).

A properly implemented topsoil salvage and replacement operation greatly enhances the long-term success of roadside vegetation reestablishment. Topsoil contains potentially valuable microorganisms, invertebrates and living plant propagules. Biological activity in this zone cycles soil nutrients and increases nutrient availability, aerates the soil, maintains soil structure, and increases soil water-holding capacity. Topsoil additions can serve as a source of nutrients and mycorrhizal inoculum for revegetation of biologically inactive and nutrient-poor construction fill materials. Reapplication of healthy topsoil that has been properly stored during construction enhances revegetation success and promotes establishment of a persistent vegetative cover. Claassen and Zasoski (1993) state that when the volume of topsoil is limited, concentrating topsoil in small pockets to allow increased retention of the biological activity of the soil is recommended, as opposed to spreading the topsoil thinly over the entire surface of the site. However, Redente et al. (1997) found that after ten growing seasons a thin layer of topsoil (six inches) was sufficient for the establishment and continued productivity of vegetation at a northwest Colorado mine site. Deeper topsoil depths (12, 18 and 24 inches) were associated with a plant community dominated by grasses. Shallower topsoil depths supported plant more diverse communities that had significantly greater forb production and shrub density.

Following construction completion, application of seed may or may not be necessary depending on the amount of desired plant propagules in the replaced topsoil. Given the likelihood of rapid noxious weed establishment, especially along roadsides, delay is not advised if seeding is needed. When selecting plant materials, consider the ability of the species to adapt to the site, rapidly establish and self-perpetuate. Also consider species' abilities to produce extensive root systems that guard against soil erosion. Many rhizomatous species are tolerant of roadside disturbances (Tyser et al. 1998).

Whenever practicable, select and distribute native, short-growing species, both for ecological reasons and to reduce long-term mowing maintenance (Harper-Lore 2000).

Although it is hard to recreate a native community in its entirety, incorporating key species within vegetation types appropriate to the site is recommended. Morrison (2000) states that dominant species, prevalent species (i.e., species typically occurring most abundantly) and "visual essence" species (i.e., species presenting a visually important trait within the community) should be included. As with any successful revegetation effort, vigilant monitoring to quickly identify noxious weeds and other problems for timely correction will be necessary. And integrated roadside vegetation management practices that favor the seeded species are essential.

Integrated roadside vegetation management

With western Montana roadsides occupying thousands of acres, state and county road departments are large-scale vegetation managers. Roadsides should be managed cost-effectively to protect the public investment with minimal negative impacts on the environment. Integrated roadside vegetation management (IRVM) accomplishes this by establishing and maintaining long-term, low-maintenance, self-sustaining roadside plant communities. These plant communities can maintain, restore and enhance roadside functions while resisting nuisance and noxious weed encroachment by reducing weed habitat. Management tactics are site-specific and herbicides are used only when necessary. Again, roadside monitoring and evaluation are critical for proper implementation of a successful IRVM plan.

An IRVM plan directs the development and maintenance of healthy, functionally diverse and self-sustaining roadside plant communities. Such communities allow for reduced herbicide use because few resources are available to potential invaders. To encourage growth and vigor in roadside vegetation and further maximize resource competition with weeds, avoid chemical mowing and mechanically mow roadsides only when necessary.

The IRVM Process

This is the National Roadside Vegetation Management Association's definition of IRVM:

IRVM is a decision-making and quality management process for maintaining roadside vegetation that integrates the following:

- **Needs of local communities and highway users**
- **Knowledge of plant ecology (and natural processes)**
- **Design, construction, and maintenance considerations**
- **Government statues and regulations, and**
- **Technology with cultural, biological, mechanical, and chemical pest control methods to economically manage roadsides for safety plus environmental and visual quality.**

Chemical mowing

Chemical mowing is the application of non-selective herbicides in broadcast fashion to the roadside. It works to suppress growth of roadside vegetation. But because this practice can permanently damage desired vegetation, it is not recommended. Once declared far less disruptive to the roadsides and more economical than the mowers it replaced, in fact chemical mowing results in the virtually unrestrained spread of some noxious and nuisance weeds (Callicot and Lore 2000). And the permanent damage inflicted on desired vegetation leads to high-maintenance, unhealthy roadsides that are prone to noxious and nuisance weed invasions (and that thus need repeated herbicide applications) and erosion.

Mechanical mowing

Mechanical mowing is an important part of roadside maintenance. Proper mowing of certain roadsides furthers safety by maintaining adequate sight distances for motorists and clear zones for use by errant vehicles. However, in many cases mowing is done indiscriminately or too often. This wastes public resources and can negatively affect desired vegetation, resulting in high-maintenance roadsides. Encourage the growth and vigor of desired roadside vegetation by mechanically mowing roadsides only when necessary (Goodwin et al. 2000).

For reasons of safety, to maintain adequate sight distances and clear zones, it may be necessary to mechanically mow roadsides along state or county roads, especially those that have underdeveloped shoulders. During the active growing season, mow to a height of eight inches. This will promote desired vegetative vigor and continued resource capture. When mowing during the dormant period, which for most cool-season grasses comes after mid-July, mowing to two inches is acceptable; grasses are tolerant of short mowing during dormancy.

It is not necessary to mechanically mow roadsides when the road—an interstate highway, say—has a wide, developed shoulder or for aesthetic purposes.

Minimize disturbances associated with road construction to help limit weed dispersal into adjacent native communities (Tyser et al. 1998).

Mowing and weeds

Besides affecting the competitive vigor of desired vegetation, improper timing of mechanical mowing can also facilitate the spread of noxious weeds. This can occur when roadside maintenance crews mow roadside weeds, usually with flail mowers, after the weed seeds have matured. By the same token many maintenance crews, more out of habit than proved need, mow healthy roadside communities before seed maturation. This inhibits desired plant seed dispersal for next year's stand and the flail mowers expose the soil for the weed seed, providing a competitive advantage for the weeds and cultivating even more weeds that will need to be sprayed in the future. Activities that give weeds an opportunity to spread must be avoided and prevented (Callicot and Lore 2000).

However, by favoring desired plant growth and decreasing the competitive vigor of weeds, properly timed mechanical mowing can be an effective weed management tool. Proper timing of mowing is based primarily on the growth stage of the weeds and secondarily on the growth stage of the desired plants (Sheley et al. 2001).

The most effective time to mow noxious weeds is when the desired plants are dormant and the weeds have reached the flowering stage, well before seed production. Mowing at this time can encourage unrestricted growth and seed production of desired plants and weaken the weeds while preventing them from producing seed. Long-term repeated mowing of weeds after they have invested a large amount of energy in bolting (when the stem extends from the center of the rosette upwards two to four feet) and producing reproductive structures can eventually deplete root reserves and weaken the infestation. If regrowth bolts again and produces flowers, an additional mowing will be necessary (Sheley et al. 2001).

When the dominant vegetation is a noxious weed, mow two inches high when the weed is between the early bud and early flowering stages. However, in some cases, noxious weeds will reach the appropriate stage for mowing before the grasses have reached dormancy. If so, mow the weeds at a height above the desired plants. Mowing above the height of actively growing grasses allows continued vigor, and defoliating the weeds reduces seed production and vigor, increasing resources available for neighboring grasses (Sheley et al. 2001).

Carefully timed roadside mowing may reduce the seed ban of noxious weeds (Tyser et al. 1998). In a Montana State University study, mowing as the only management tool decreased spotted knapweed density by 85 percent (Rinella et al. 2001). A further reduction in density could be anticipated if mowing were integrated with a herbicide treatment applied to the rapidly developing regrowth one month after mowing.

Consider mowing and applying a herbicide in a single entr with a wet-blade mower. This mower's blade cuts the plants while applying a herbicide. Cavitation pulls the herbicide into the stem; the herbicide then moves into the plant's vascular sy tem. Because the blade precisely places the herbicide only on t stems of the cut plants, advantages of wet-blade mowing inclu reduced herbicide rates and runoff and drift. Excellent wet-blade mowing results have been documented for many noxiou weeds, including Canada thistle (*Cirsium arvense*), Dalmatian toadflax (*Linaria genistifolia* ssp. *dalmatica*), leafy spurge (*Euphorbia esula*), Russian knapweed (*Centaurea repens*, and saltcedar (*Tamarix* spp.).

Appendix C
Understanding succession to direct successful revegetation

Revegetation can be most successful when it works with successional processes to direct communities toward a desired plant community. Three components can influence the direction of succession and can be modified to direct predictable successional transitions. These are:

1. ***Site availability (disturbance)*** This plays a central role in initiating and altering successional pathways. Site availability can be a designed disturbance such as seedbed preparation to produce seed safe sites or herbicide applications for weed removal to open niches for occupation by desired species. Although site availability is important for the persistence of many native species, it can also facilitate noxious weed invasion (Kotanen 1997).

2. ***Species availability (colonization)*** This is the intentional alteration of seed availability by influencing seed banks and propagule pools of desired plants and weeds and the regulation of safe sites for desired plant germination and establishment. Weed seed banks can be depleted through attrition if seed production is prevented or significantly reduced each growing season. For example, Olson et al. (1997) found that the number of spotted knapweed seeds in the soil was reduced after three years of intensive sheep grazing directed at buds and flower heads, resulting in decreased weed density.

3. ***Species performance*** This is the manipulation of the relative growth and reproduction of plants in an attempt to shift the plant community in the desired direction. Domestic sheep can shift a plant community toward desired grasses by selectively grazing forbs. By contrast, cattle can shift a plant community toward forbs (e.g., weeds) by selectively grazing grasses. Herbicide applications can alter resource availability and increase desired species performance through competitive weed removal. In other words, soil resources become available for neighboring desired plants through careful herbicide treatment.

Pioneer species (e.g. annual forbs or early-seral species) are usually the first plant types to begin to grow on a disturbed site. These pioneer species are eventually replaced by later-seral species such as grasses that are in turn replaced over time by shrubs and trees. This is plant succession. Noxious weeds act as pioneer species but can then interfere with or arrest succession before it reaches the mid- or late-seral stage most landowners hope to attain (Munshower 1994). In response, developing a plant community that is more mature than the classic pioneer stage can help ensure that noxious weeds do not become established at the disturbed site. This requires careful weed management.

The first manipulation to a site to make it capable of supporting later-seral species is topsoiling—if this layer is absent. Since topsoil is generally "mature" enough to support mid-seral stage plants, providing or replacing salvaged topsoil upon the subsoil strata can move the successional process from the primary level to the secondary. Seeding later-successional species can further accelerate plant succession.

However, in some cases, the topsoil may lack the maturity needed to support late successional or climax communities. Such plant communities require mature soils with intact and complex nutrient cycles, essential mycorrhizal associations and proper surface litter distribution—soil microtopographies that can be easily damaged by and following disturbance (Munshower 1994). The introduction of early successional species can direct changes in soil properties that facilitate later successional species. Care in selecting species that complement site soil maturity is recommended.

Although the soil may be mature enough to support some mid- to late-seral species, seeding early-seral species can provide environmental protection—and immediate soil stability is necessary for the germination and establishment of later-seral species. Pioneer species grow very rapidly and need no protection from wind, sun or high temperatures. By contrast, perennial grasses, forbs and shrubs are slow-growing and do need protection—especially during the first growing season (Munshower 1994).

Referer

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