Lessons from Historical Rangeland Revegetation for Today's Restoration

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Abstract—Rangeland revegetation in the Western United States historically was applied at a large scale for soil conservation and forage production purposes. Principles of revegetation that have developed over years of research include matching site potential and plant materials adaption, use of appropriate seedbed preparation and sowing techniques, and development of large supplies of seed of adapted plants. Although many of these large-scale projects were extremely successful in terms of their original objectives, they often lacked native plant diversity. Increased use of native species for revegetation of these lands, in the face of exotic weed spread, will require a more detailed knowledge of disturbance effects relative to site potential and of native plant requirements for establishment and persistence in mixed communities.

The purpose of this paper is to briefly review rangeland history for the Western United States, discuss some of the lessons learned as large-scale revegetation was developed, and raise some of the challenges and opportunities for using native species for restoration in the semiarid West.

Ecologists are appreciating much better these days the importance of disturbance in plant succession (Mooney and Gordon 1983). A number of factors combined to change the disturbance regime of Western rangeland plant communities. Except for parts of the Southwest and California that had been settled by the Spanish in the 1700's, most of the Western United States was colonized after the mid 1800's. The Donner party crossed the Great Basin on their ill-fated journey to California in 1846, the Mormons settled in the Salt Lake Valley in 1847, and the discovery of gold at Sutter's Mill and subsequent expansion of mining after 1849 all were the beginnings of a great Western migration. The end of the Civil War and the completion of the railroad in 1869 brought many more to the West.

West of the plains grasslands, plant communities were distributed across elevational gradients associated with high mountains and plateaus and relatively high valleys. Variations in temperature, precipitation, and soil conditions were associated with geological and elevational differences. Natural and Native American-ignited fire was an important regular disturbance, occurring every 10 to 30 or more years and providing for diversity of many communities that would otherwise have been dominated by woody species such as sagebrush (*Artemisia* spp.), juniper (*Juniperus* spp.), and mesquite (*Prosopis* spp.) (West in press; Wright and Bailey 1982).

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As the Native Americans were controlled by the Army, and mining and the railroads created a market and transportation for meat, stock raising went from the subsistence economy of the early pioneers to a market economy with wealth-generating incentives. Post Civil War soldiers, like John Sparks in Nevada, drove cattle from Texas to stock the Western ranges (Young and Sparks 1985).

Many viewed the free grass of the West as a great economic opportunity for grazing. Initially, a Spanish style form of stock raising was used with stock left on the range year-round and rounded up mainly for shipping to market (Young and Sparks 1985). By the end of the 19th century, excessive grazing associated with open range had depleted the grasses and palatable shrubs and forbs near water, and major droughts in the Southwest and winters in the North had temporarily devastated livestock herds. Reports to Congress from ranchers and from Bureau of Plant Industry officials, like David Griffiths, on the condition of the Western range, eventually led to grazing management legislation and practice (Roundy and Call 1988).

What came out of all of this?

1. Overuse, especially of grasses, as well as the need to put up hay for winter or drought, led to the development of guidelines for carrying capacity and proper stocking.

2. Grazing-sensitive bunchgrasses on many ranges were replaced by unpalatable woody shrubs and trees. Overgrazing reduced fine fuels and fire frequency, allowing woody plants to invade or dominate sites where herbaceous plants had been dominant.

3. Heavy summer rainstorms on mountain slopes that had been excessively grazed resulted in debris flows to the towns below. This prompted research by Arthur Sampson and others on the effects of grazing on watershed response, as well as on methods to rehabilitate damaged watersheds (Keck 1972).

4. Exotic weeds brought in with grain, and otherwise transported from the Old World, began spreading onto depleted rangelands (Mack 1986; Monsen and Kitchen 1994).

5. All of these factors led to the development of range management as a profession with a focus on learning to manage grazing for production and sustainability. In addition, methods of undesirable plant control and re-establishment of grasses for soil conservation and forage production were developed (Vallentine 1989).

As well as the Western United States, the best-reported example of large-scale and long-term rangeland revegetation research is from the deserts of Central Asia (Nechaeva 1985). Revegetation goals there were to establish mainly adapted shrubs to meet the year-round dietary requirements of sheep and to control wind erosion. Success of the work involved years of research to understand the biology of the candidate species, the potential and constraints of different sites, and appropriate seedbed preparation and sowing methods. The revegetation research in the Western United States and in former Soviet Central Asia are generally parallel in approach, although grasses were the focus in the United States, while shrubs were the focus in Central Asia. The point is that conducting large-scale revegetation in semiarid and arid areas required a major commitment in long-term research to be successful.

A major break-through in revegetation success in the Western United States occurred when it was found that certain introduced grasses were successful in establishing and persisting under extreme environmental conditions. For example, crested wheatgrass (*Agropyron desertorum*) was highly adapted to big sagebrush (*Artemisia tridentata*) rangelands and was seeded extensively as an early growing, grazing-tolerant forage on thousands of acres (Johnson 1986), while smooth brome (*Bromus inermis*) was seeded extensively to rehabilitate mountain watersheds (Monsen and McArthur 1995). An exception to this emphasis on exotic grasses was the work of A. Perry Plummer who pioneered in the use of native grasses, shrubs, and forbs for revegetating mule deer winter ranges in Utah (Plummer and others 1968). Much later in the 1960's, mineland reclamation in the West borrowed many of its approaches and methods from range revegetation technology. The approach was more agronomic than ecological, emphasizing the use of large machines to prepare the land and seed easily sown, widely adapted, vigorous grass species (Jackson 1992).

With our current emphasis on diversity rather than production, some have looked critically at these past efforts to revegetate rangelands. But remember, the goals are different today—we are the Supermarket Generation. In 1995, there were 1.4 million farm operators and managers and 3.5 million total individuals (less than 2 percent of the total population) employed in agriculture and related occupations in the United States (U.S. Bureau of the Census 1996). Past goals of the land reflected a much larger percentage of the population that lived directly from production agriculture, as well as reflecting the demands for shortages of agricultural products through two world wars.

Lessons from Rangeland Revegetation

There are some lessons—good and bad—that can be learned from Western rangeland revegetation development. These efforts resulted in some of the largest scale revegetation projects on semiarid lands in the world.

The Lesson of Scale

It is one thing to create small-scale ecological gardens as a restoration goal. It is quite another to revegetate or restore thousands of acres of rangeland in poor ecological and hydrological condition. The United States Park Service has been able to establish shrubs in the dry Mojave Desert by bypassing the vulnerable seedling stage. They grow deep-rooted shrubs in plastic tubes before transplanting and deep-watering them through a smaller tube. This allows them to restore roads to native shrubland. However, if large areas need to be restored, direct seeding is usually necessary.

The need to revegetate large areas affected much of the historical approach to rangeland revegetation and still affects large-scale fire rehabilitation on Western rangelands today. Big machines (such as the brushland plow and the rangeland drill) were developed to control competing plants and to seed large acreages of topographically diverse rangelands. The anchor chain was employed to control large areas dominated by trees, such as pinyon (*Pinus* spp.) and juniper, and to cover seeds broadcast from the air. Widely adapted, easily established species were selected that had high germination and that were easily seeded through a drill.

The lesson for today—don't expect small-scale methods to fix large areas. Large-scale methods and machines can be used, however, to create more floristic and structural diversity across the landscape than was done in the past. For example, anchor chaining and other mechanical methods can be used to create diverse patterns of woodland for cover and shrublands for forage to support wildlife (Fulbright and Guthery 1996; Roundy 1996). Special trashy seed drills and other machines are being developed to allow sowing of native seeds across large areas.

The Lesson of Site Potential

Historical rangeland revegetation was generally successful at and above the big sagebrush (*Artemisia tridentata*) zone in the Intermountain West. In the lower elevational, drier, and more saline shadscale (*Atriplex confertifolia*) zone, seedings failed (Bleak and others 1965). Vegetation restoration must be site-specific and requires an understanding of soils, climate, and species adaptation. Rangeland revegetation guidebooks have categorized site potential and adapted species (Roundy and Call 1988); however, the emphasis has been on forage species, predominately grasses. Many perennial species do not establish every year on semiarid areas; their establishment may be episodic on unusually wet years. Some species may establish on a wet year, but do not persist under the long-term climate of the site (Roundy 1995).

The Natural Resource Conservation Service has developed a system of Major Land Resource Areas, Subareas, and specific range sites that characterizes site potential (Shiflet and McLauchlan 1986). Range site descriptions list the species that are considered to have been present in the natural plant community. A Plant Materials Handbook (OSMRE 1988) lists recommended species for revegetating disturbed range sites. The best recommendations for matching species to sites have come from years of field plot research. Because abiotic and biotic changes such as soil erosion and weed invasion have occurred on many sites, historical potential may no longer exist. On those sites, current potential should be realistically assessed, based on existing plant community and soil conditions.

The Lesson of Plant Materials Selection

Historically, range revegetation practitioners selected a few, high-performing and widely adapted species. These were often introduced grasses with exceptional establishment ability and vigor. Plummer and others (1968) found out early on that if you are going to use native species, you need to understand the range of adaptability of specific ecotypes. Meyer and others (1995), Meyer and Monsen (1990), and Meyer and Pendleton (1990) found that many native ecotypes have germination characteristics that are tied to the environments of the collection population. Past and continuing research has shown the ecotypic nature and wide genetic diversity of many wildland plants (McArthur and Tausch 1995).

Some concerns about plant materials selection are that high genetic diversity may be necessary to maintain adaptation in dynamic environments, that nonlocal seed sources will not necessarily have adapted genomes, or that nonlocal sources may result in genetic pollution and loss of local genomes (Linhart 1995; Rhymer and Simberloff 1996). These concerns led to changes in plant source identification, selection, and improvement approaches for wildlands (Meyer and others 1995; Pyke 1996; Young and others 1995). An understanding of the genetics and reproductive biology and ecology of many wildland species appears to be lacking, and is necessary to speak intelligently about these issues in particular situations. Using highly specific ecotypes requires a more intensive and longer term research effort than planting widely adapted species.

The agronomic approach to plant improvement has been to select or breed for plants with specific desirable characteristics. In so doing, genetic diversity is often reduced. The Natural Resources Conservation Service, Plant Materials Centers, and other plant materials researchers in the past have taken this agronomic approach of collecting from many populations, evaluating the segregated collections in common environments, and increasing and releasing the best performers for similar environments (Englert and White 1997; Shiflet and McLauchlan 1986). Developing improved plants based on ecological principles involves discovery and characterization of plant materials from native populations followed by possible selection or genetic manipulation for specific management needs (McArthur 1988). Some Plant Materials Centers are now developing nonsegregating methods such as convergent-divergent schemes to increase, rather than narrow, the genetic diversity of plant materials (Munda and Smith 1995). Researchers are continuing to try to determine the ecophysiological and morphological basis of adaptation to more easily evaluate plant materials as an alternative to lengthy field trials (Criddle and others 1994; Johnson and Asay 1993; Monaco and others 1996; Smith and others 1996).

An appreciation for the ecotypic nature of wildland plants has led to the concept and certification of source-identified plant materials (Currans and others, in press; Vankus 1996; Young 1995; Young and others 1995). The Forest Service has implemented the approach of seed collection zones for commercial tree species, but not for grasses, shrubs, and noncommercial trees. However, the Pacific Northwest Region of the Forest Service is developing techniques for increasing use of native species as evidenced by a native seed collection guide for the Wallowa-Whitman National Forest (Huber and Brooks 1993), a native plant project summary for the Mt. Hood National Forest (Cray and others 1995), and a native plant notebook for the Mt. Baker-Snoqualmie National Forest (Potash and others 1994).

The Sowing Lesson

The need to match the seedbed preparation and sowing method to the site and seeded species is well illustrated by two stories from rangeland revegetation history (Roundy and Biedenbender 1995). Pelleted seeding studies, conducted from the 1940's to the 1960's, sought an easy and inexpensive way to reseed degraded Western rangelands. The idea of broadcasting pelleted seeds was conceived by Lytle Adams, a retired dentist, who first thought of the idea in southern California when he noticed small cactus plants emerging from rabbit droppings. In 1945 he interested Congress in the idea of aerially distributing pelleted seed. The idea was that seed could be compressed into earthen pellets with fertilizers, fungicides, and insect and rodent repellents. The weight of the pellets would promote their even distribution and penetration into the soil. This idea was inexpensive and appealing, especially when compared with the alternative methods of broadcasting seeds alone, in which success was usually limited by lack of soil coverage, and mechanical seedbed preparation and sowing on the ground, which was slow and expensive over a large area. Dr. and Mrs. Adams actively promoted the pelleted seeding program at the local and national levels. Mrs. Adams made hats from Lehmann lovegrass (*Eragrostis lehmanniana*) and devil's claw (*Proboscidea* spp.) and presented them to such prominent ladies as Mrs. Morris Udall and Jacqueline Kennedy.

Jordan's (1967) findings on a Chihuahuan desertscrub site were similar to the results of other studies: pelleted seeds established to a similar or lesser extent than aerially broadcast nonpelleted seed. Mechanical seedbed preparation and sowing on the ground produced successful stands of grass when pelleted seeding did not, even in years with favorable precipitation. Pelleted seeding failed primarily because of inadequate soil coverage but also partly because the pelleting process reduced germination (Jordan 1967). When Adams's advocate in Congress, Representative Ben F. Jensen of Iowa, learned that pelleted seed research money had been used to make comparisons with other methods, he accused the University of Arizona of sabotaging the program. This story illustrates the need to do careful comparative research to test apparently easy solutions.

The land imprinter developed by R. M. Dixon (1978) is a heavy water-filled cylinder with metal ridges that modifies seedbeds by imprinting rain-catching furrows in the soil (Dixon and Simanton 1980). Theoretically, imprinting enhances soil surface roughness and promotes infiltration by allowing water to replace air in macropores that are open to the soil surface (Dixon 1978). The imprinter has been highly promoted as a tool to greatly improve revegetation of semiarid rangelands in the Southwest and throughout the world. Imprinting helps bury seeds (Winkel and others 1991), firms seedbeds, reduces wind erosion, increases seed contact with the soil, and increases seedling emergence on some soils (Clary 1989; Haferkamp and others 1987), but it is not effective for controlling sprouting brush (Cox and others 1986; Larson 1980). Imprinted furrows on sandy soils may slough and bury broadcast seeds too deep for emergence.

In comparative studies conducted in southern Arizona on a sandy loam soil, imprinting and other methods of soil disturbance increased seedling emergence of broadcast-seeded grasses in a moderately wet summer, but did not make a difference on a wet year or prevent failure on a dry year (Winkel and Roundy 1991). Seedbed preparation and sowing methods should be evaluated for different sites and species over a number of years in relation to where the seeds end up in the seedbed. The location of seeds and seedling roots should be determined in relation to the location of needed resources in time and space, such as available soil water and adequate temperatures for germination and growth (Roundy 1994; Roundy and others 1997).

The lesson from all this is that a knowledge of species establishment requirements and effects of seedbed preparation and sowing methods is needed to maximize success. For example, small seeded sagebrush and rabbitbrush (*Chrysothamnus*) have been successfully established by broadcasting them between successive pinyon and juniper chainings (McArthur and others 1995). Aerial seeding of species requiring very shallow burial has been successful when chaining or when some other mechanical treatment just barely covers them—the soil disturbance and burial depends on the method, as well as the soil water content and soil texture. Many larger seeded species, such as bitterbrush (*Purshia tridentata*), are most successful when seeded by a drill or from a seed dribbler off the tracks of a bulldozer to help bury them.

Seeding failures with native species can result from a lack of understanding establishment requirements. Scientists are working on developing seedling establishment models driven by soil moisture and temperature to better predict both weed and desirable species establishment (Christensen and others 1996). These efforts will increase our ability to use native species.

The Seed Availability Lesson

A major reason that some exotic species have been used preferentially over natives in the past is that these exotics were chosen not only for their wide adaptability, but also because their seeds are easily grown, harvested, cleaned, and sown. They are, therefore, less expensive than native seeds. The resulting lack of demand for native seeds historically restrained development of a native seed production industry, which in turn limits seed availability (Roundy and others 1997). Quality standards for produced and collected wildland seeds are being developed as the demand for native seeds increases.

The Surface Mining Control and Reclamation Act of 1977 greatly helped to promote the demand for native seeds by requiring the preferential use of native species for coal mine land reclamation. The way out of the seed availability bottleneck is to create a demand for native seeds and the resulting industry by developing seed warehouses. Existing warehouses have been essential for providing native seeds for fire rehabilitation projects in the West, but they are inadequate for current demands. Invasion of Western rangelands by cheatgrass (*Bromus tectorum*) and other annual weeds has caused a fire feedback loop that favors continual weed dominance. Fire rehabilitation is the major effort in revegetation on Western rangelands today (Roundy and others 1997).

To illustrate the magnitude of the problem, consider the 2 million acres of Western rangelands under Bureau of Land Management stewardship that burned after an unusually wet spring produced abnormally high fine fuels in 1995. Failure to seed these lands with perennial species would result in a return to weed dominance. In Utah alone, over 65 tons of seed were ordered for revegetation. Because of the relatively limited supply and high cost of native seeds, mainly introduced grasses were used.

The Lesson or Dilemma of Resource Protection Versus Diversity

In the past, as well as now, aggressively establishing introduced grasses have been used after fire for mountain slope watershed protection and also for site recapture from weeds. The fear has been that native species do not establish dependably or vigorously enough to protect the resource. Some of the vigorous exotic grasses then dominate the site and limit subsequent diversity (Pyke 1996). Land managers are still reluctant to seed expensive native species when it looks like the site could be lost to weeds or erosion.

The Maple Mountain burn of 1994 illustrates this dilemma. After an August fire burned the steep slopes of Maple Mountain above Mapleton, Utah, residents feared that thundershowers would produce damaging debris flows in town, just as happened 100 years earlier when Wasatch Mountain slopes were heavily grazed (Ellison 1960). The Forest Service was under pressure to seed immediately to establish plant cover and control runoff. The hydrologist was reluctant to trust native species alone, so smooth brome, intermediate wheatgrass (*Agropyron intermedium*), and orchardgrass (*Dactylis glomerata*) were the dominant species seeded. The Utah Division of Wildlife was able to contribute native species seed from their warehouse, but soil stabilization was considered to be dependent primarily on the exotic grasses.

Some managers have learned to increase diversity by reducing the rate of introduced species in the seed mix and by encouraging native species success with specific seeding techniques. For example, in Idaho the Bureau of Land Management has had success aerial seeding sagebrush into snow; the seed germinates just as the snow melts in the spring. They still seed crested wheatgrass on these areas, but at the rate of 1 kg pure live seed per ha rather than the usual 6 kg per ha. This allows sagebrush and the native bluebunch wheatgrass a much better chance of establishing.

The solution to this dilemma for some sites is difficult—possibly requiring initial resource protection of some sites with exotics, followed by retreatment to control the exotics and establish natives. Native plant material developed for greater vigor might help, but may also limit diversity.

In the past, we have learned that only partial control of some highly competitive species results in their rapid return to dominance. Yet other species are compatible with each other. For example, the two-layered root system of big sagebrush makes it much more competitive with associated bunchgrasses than does the tap root system of rubber rabbitbrush (*Chrysothamnus nauseosus*) (Frischknecht 1963). We need to better understand competitive and facilitory relationships among different species in our wildland plant communities (Pyke and Archer 1991) and which species can be most compatible by partitioning of resources in time and space.

The Lesson of Management

Rangeland managers in the Western United States learned fairly quickly that revegetation does not necessarily solve grazing management problems. If overstocking or heavy seasonal use resulted in deterioration of the plant community in the first place, appropriate grazing management had to be implemented to maintain the subsequent revegetation community. Management and control of both domestic and wild graziers is necessary. Normally, grazing is deferred for 2 years after revegetation of semiarid rangelands. Although this length of deferment may not be necessary for introduced grasses that evolved under herbivory, it is well recommended for many native plants, especially shrubs. Wild ungulates are harder to restrict from a revegetated area than are domestic livestock, and require special fences (Carson and Edgerton 1989). Management of revegetated grass and shrublands may also require the use of fire to control tree invasion. Restoration of a site to "near historic" conditions must also involve restoration of the historic disturbance regime.

Conclusions

The relatively new goal of restoring native, diverse plant communities is a challenging one, especially on a large scale. It requires us to understand much better the vegetation dynamics and disturbance ecology of our sites, the characteristics of native plant ecotypes and populations, and the ecology of species relationships. Hopefully the lessons from the past can guide us rather than limit our thinking in the future.

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