INTEGRATION OF MECHANICAL CONTROL OF UNWANTED PLANTS AND SEEDING EQUIPMENT

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ABSTRACT

This paper discusses principles and practices of mechanical control of unwanted plants and seeding rangelands, and how some practices are innovatively combined. Seeding methods discussed are use of rangeland drills, press drills, grain drills, trashy seed drills, broadcasting, one-way disk plow, arid-land seeder, chaining, the land imprinter, and range interseeder.

INTRODUCTION

Man is making tremendous advances in many fields of science. We are obtaining increased productivity from all our agricultural lands, including rangelands, because of our expanding needs. Increasingly, people have been able to influence their environment. A good example of altering the environment on rangelands is the use of mechanical methods of brush management to prepare a seedbed. It is helpful to use a model to elucidate the practices used in range management (fig. 1). Sometimes, drastic manipulations of range ecosystems are needed. The encroachment and increase of unwanted plants, the past abuses of people and their improper use of grazing or fuelwood, or the desire by the operator to change botanical composition on all or part of the range unit, result in practices to control unwanted plants and to revegetate with desirable plants. These practices require great attention to detail. The risk in using plant control or revegetation is high because, even if attention is given to every detail, the weather may adversely affect the desired results. The relative costs of these practices are high and the potential benefits are high. Control of unwanted plants and revegetation may increase herbage production by 500-1,000 percent or more within 1-3 years. High management inputs are required because, if these risky, costly practices are used, the manager should attempt to maximize the outputs while maintaining the resource, and minimize the need to repeat the practice.

Few, if any, land managers use intensive practices exclusively on a unit of rangeland. Rather, some combination of both intensive and

Range Science

Extensive		Intensive
Low	Risk	High
Low	Cost	High
Low	Production	High
Low	Benefits	High
Low	Management Inputs	High

Practices

Manipulation of Grazing

Fire

Control of Unwanted Plants

Water Management — Revegetation

Fertilization

0	200	400	600	800	1000

Potential Productivity (percent increase)

Figure 1. A model of range science (from Herbel 1983).

extensive programs are utilized. After a risky and costly practice, such as revegetation, it is important to use proper management techniques to maintain or improve desirable plants. The use of practices is changing with time as dictated by economic, political, and social conditions, or as improved technology becomes available. Land managers, and others working with land managers, must be flexible and innovative in planning operations on a range unit. What will work well on one range unit may not work as well on a nearby range unit (Herbel 1983). The purpose of this paper is to discuss mechanical control of unwanted plants and revegetation.

CONTROL OF UNWANTED PLANTS

Plant control in range management involves reduction of unwanted or undesirable plants that have invaded or increased in a plant community. Migration of certain species out of their normal habitat is one of the major problems on rangelands of the arid and semiarid regions. Each species or plant association has its habitat range to which it is confined. The environmental factors in a given habitat type favor certain plant species and plant associations. This has the effect of confining the favored species and associations to the habitat type and rejecting others. This, however, is true only in an undisturbed situation.

Plant species or plant associations are released from their habitat restrictions by

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reducing the adjoining, better adapted species or plant associations. This reduction or elimination of competition can be brought about by continued disturbance. The more common disturbances are change in the frequency of fire, drought, and continual and excessive harvesting. The greatest and fastest change can be caused by a combination of two or more factors. For instance, drought in conjunction with excessive harvesting has been a leading disturbance factor in many areas of the world.

Control of unwanted plants allows a more favorable soil water regime for the growth of desirable vegetation. Plant control may be accomplished by chemical, biological, or mechanical means; by judicious use of fire; or by use of certain animal species.

Principles of Mechanical Control

The method selected for mechanical control of unwanted plants depends on a favorable cost, the availability of equipment, the size and stand of the plants to be controlled, whether the target plants have sprouting or nonsprouting characteristics, soil conditions, and the terrain. Herbel (1983) elucidated the principles of mechanical control.

1. Size and stand of the target plants. Rootplowing or disking is used when there is a sparse stand of desirable plants and revegetation is needed. Properly done, rootplowing kills most plants while disking kills nonsprouting plants. Disking is limited to small plants. Chaining is more effective in controlling even-aged, mature shrubs or small trees with stem diameters of 8 cm or more. Bulldozing is effective on sparse stands and medium-sized shrubs or small trees with a stem diameter of about 25 cm.

2. Sprouting or nonsprouting shrubs. Chaining or disking do not kill many shrubs that sprout below the surface of the ground.

3. Soil conditions. Chaining is most effective in areas with lighter-textured sandy or loamy soils. Bulldozing, rootplowing, and disking excessively disturb the soil surface, destroy most plants, and may result in soil erosion. Most mechanical methods cannot be used when the soil is excessively wet. Large rocks also hinder mechanical methods. Generally, shallow soils do not have the production capability to justify the expense associated with mechanical control.

4. Topography. Some mechanical methods leave the soil bare, unprotected, and subject to erosion. There should be a minimum of drainages so equipment can operate at a relatively high speed. Therefore, most mechanical equipment should be used on relatively level terrain.

Some Practices in Mechanical Control

From the rudimentary spike drag implements used to control sagebrush (*Artemisia* spp.) to the more advanced tree crushing equipment used to control juniper (*Juniperus* spp.), there have been many approaches to mechanical plant control because of the widespread variations in climate, topography, and woody species.

Brush Cutters

These implements resemble a stalk cutter used on cultivated crops, but they are much heavier (fig. 2). The use of two sections pulled in tandem with angular alignment between the two units allows for greater crushing and cutting effect. Brush cutters of this type have limitations for range work. Best kills of nonsprouting species are obtained on mature stands of plants of about the same age and size.

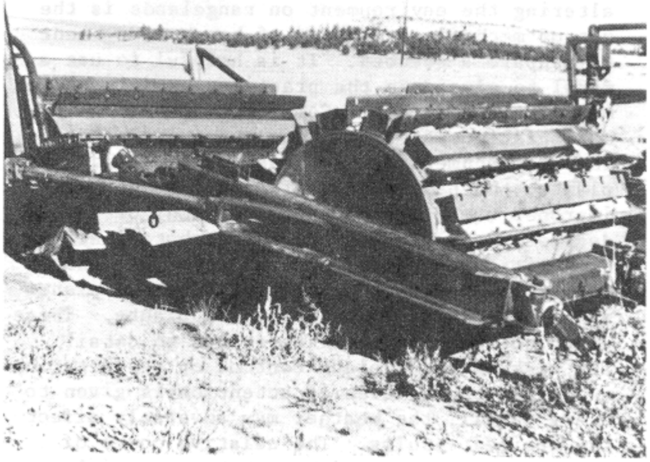

Figure 2. Brush cutter on a site infested with big sagebrush (*Artemisia tridentata* Nutt.) in northern New Mexico.

Chaining

Chaining has been used most successfully to control nonsprouting juniper and sagebush. Chains with links weighing over 30 kg are recommended (fig. 3). The advantages of this method are 1) large areas can be treated at a relatively low cost, 2) desirable herbaceous plants are not seriously damaged, and 3) debris and trash protect the soil from erosion. Limitations are 1) many small or supple shrubs and trees are not killed and 2) undesirable herbaceous plants and sprouting shrubs are only slightly damaged (McKenzie et al. 1984). An improvement on the chaining method for some sites was realized by welding disk blades to

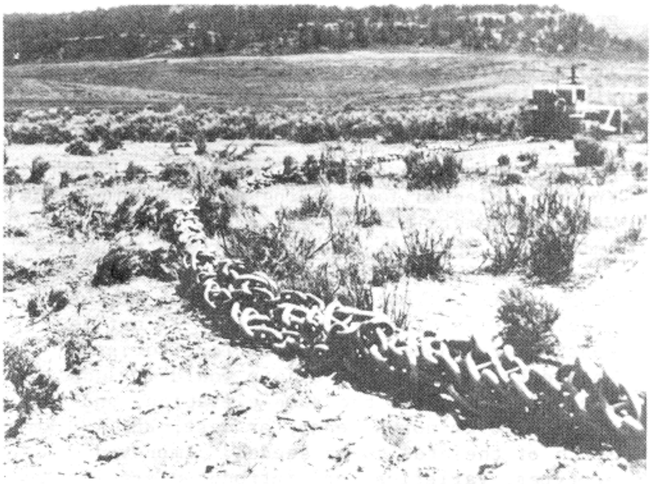

Figure 3. Chaining big sagebrush in northern New Mexico.

alternate links of a large anchor chain (Wiedemann et al. 1985). When pulled on a diagonal between two track-type tractors, the disk-chain performs like a giant one-way plow and can traverse heavy brush without difficulty. The disk-chain may cover extensive acreages and, combined with seeding, is a practical method of vegetation conversion.

Dozing

Pushing with a bulldozer is suited to light stands of trees (<500 stems/ha) (fig.4).

Figure 4. Bulldozing junipers in central New Mexico.

Rootplow

A rootplow is a horizontal V-shaped blade that a large track-type tractor pulls underground through the soil, severing plant roots in its path. Fins are attached to the blade and angled upward so plants are pushed up and out of the soil (fig. 5). It is one of the few implements capable of controlling dense stands of shrubs that regrow with vigor if only their tops are cut. It is an effective implement, often killing 80-100 percent of the vegetation and, because of this, the site must be seeded to reestablish desirable species. For lasting improvements, rootplowing is usually followed by something to prepare the seedbed: for example, fire, the land imprinter, or the arid-land seeder. A major limitation of the rootplow is that it is ineffective on rough, rocky soil.

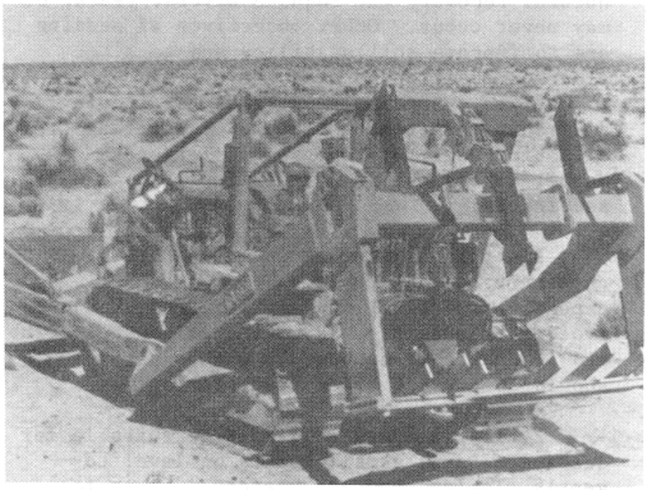

Figure 5. A rootplow with seven fins to uproot shrubs.

DIRECT SEEDING

Direct seeding can speed range rehabilitation but is expensive, can't be used in all situations, and it is risky. In deciding whether an area should be seeded, the range manager should ask the following questions:

1. Is seeding needed? Ranges can often be rehabilitated at a lower cost by improved livestock distribution, better systems of grazing, or reduced stocking rate. Sometimes, managing unwanted plants results in a dramatic increase of desirable species. Only where desirable plants are almost completely eliminated is seeding essential. Such areas will have a range condition rating of poor or low fair. Where the range condition rating is high fair or better, a range will generally improve with proper grazing management and control of unwanted plants.

2. Are proven revegetation methods available for the site? Where methods are not available, projects should not be undertaken until acceptable procedures have been developed. On many sites, the procedures are known for the general type but cannot be applied because excessive rocks, steep slopes, or other factors prevent use of the methods needed.

3. Can the area be given proper grazing management after seeding? Seeding should not begin until proper grazing management can be assured. Many seeding failures are caused by improper grazing techniques.

Principles of Seeding Rangeland

Where desirable vegetation has been severely depleted by past grazing abuses, severe droughts, or encroachment of unwanted plants, natural recovery may require several years, or may never occur. Other objectives of seeding are to improve soil stability and to alter plant composition to meet the user's objectives. Seeding rangelands is often a difficult undertaking because of limiting climatic, soil, or topographic features. Herbel (1983) outlined the principles of seeding as:

1. Change in plant cover must be necessary and desirable. Seeding is an expensive and risky undertaking, and should be avoided if possible. However, at least 1 shrub and 10 desirable herbaceous plants per 9 m^2 should be present after revegetation.

2. Terrain and soil must be suitable for seeding. Deep, fertile soils on level to gently sloping land are preferred sites for seeding. Shallow or rocky soils seldom have the potential to justify expensive reclamation measures. Excessive amounts of soluble salts in the soil often require additional attention to ensure adequate plant establishment.

3. Precipitation and water concentration must be adequate. Average annual precipitation, or equivalent from water concentration, must be adequate for germination, seedling growth, and establishment and survival of seeded species. This depends on temperatures but, in temperate climates, a minimum of 250 mm of precipitation may be needed. Where precipitation is near this minimum, only the more drought-resistant species should be used. Existing vegetation is a good indicator of the moisture situation.

4. Remove or reduce competition from unwanted plants. Most plants used for revegetation are perennials. Seedlings of these species are often slow-growing and compete poorly with existing, unwanted plants. A good seedbed will provide the best possible moisture conditions for germination and plant growth. This requires control of most existing plants before seeding. In addition, it is sometimes necessary to control unwanted plants that are competing with seedlings of desirable plants.

5. Use adapted plant materials. Plant species selected for seeding must be compatible with management objectives (e.g., palatability and growth period). It is important to use only those species and varieties well adapted to the soil, climate, and topography of the specific site being revegetated. If native species are chosen, seed from local origin should be used. Local origin would include species from about the same elevation, and within 320 km north, east, or west, and 480 km south of the area to be seeded. Improved ecotypes, varieties, and introduced species may be available for revegetation and should be used.

6. Mixtures of plant types versus single species. The danger in a monoculture seeding is that a disease or insect infestation can eliminate the one species but, in a mixture, some species are likely to survive. Where a variable terrain exists, mixtures will have some survivors on most sites. A variable ground cover will generally result in superior control of soil erosion. Also, mixtures of grasses, forbs, and shrubs will better meet the multiple needs of livestock and wildlife. However, a management problem with multispecies revegetation is that different species often have differing degrees of palatability and differing times of readiness for grazing.

7. Use seed treatments. Various microbial treatments, e.g., nitrogen-fixing bacteria or mycorrhizal fungi, may enhance seedling survival. Dormancy of most seeds can be reduced by stratification -- subjecting them to temperatures 0-4 C for 6-20 weeks in moist sand, peat moss, or newspaper. For some shrubs, treatment with thiourea, or scarification with sulfuric acid or mechanical abrasion, helps overcome dormancy.

8. Use proper seeding rates. It is important to use enough seed to get a good stand, but not more than necessary. Too much seed can produce a stand of seedlings so thick that individual plants compete with each other. Species of plants, number of pure live seeds (PLS) per kg, and potential productivity of the site are major factors determining the seeding rate. PLS is determined by multiplying the germination of a lot of seed by its purity. Seeding rates providing 125-250 PLS/m^2 should be used when the seed is placed in the soil with a drill. Broadcast seeding is not efficient and not an effective method of revegetation because seeds are left on the soil surface and establishment is tenuous. On steep slopes or sites inaccessible to ground traveling equipment, it may be necessary to broadcast. In this case, a doubled seed rate

of 500 PLS/m^2 is recommended.

9. Use the proper seeding depth. Proper seeding depth is determined by the plant species. Optimum seeding depth is roughly 4-7 times the diameter of the seed. Seeding equipment should be used that provides positive seed placement at the desired depth. More stands are lost because seeds are planted too deep, rather than too shallow.

10. Correct seeding time is important. The most desirable time to seed non-irrigated areas is immediately before the season of the most reliable rainfall, and when temperature is favorable for plant establishment.

11. Distribute the seed. Uniform distribution of seed is essential. Skips and missed strips should be avoided. Seeding equipment must be checked frequently to assure it is working properly and not plugged.

12. Alter the microenvironment. Many areas are deficient in soil water for germination and seedling establishment. In some areas, an associated treatment is needed to reduce high soil temperatures and provide more soil water by practices such as mulching, summer fallow, establishing basins, or pits. Intermediate pits, 15 cm deep, 2 m long, and 1.5 m wide were superior for plant establishment to smaller conventional pits, larger bulldozer pits, and an unpitted check in southern Arizona (Slayback and Renney 1972). Reducing soil temperatures can improve seedling establishment in a hot, arid environment (Herbel 1972a). Providing a layer of dead shrubs will reduce soil temperatures. Concentrating water with various land-forming procedures does not always ensure seedling establishment (Herbel 1972b). Surface soil dries rapidly in hot, arid and semiarid areas. This may form a heavy crust on medium- to heavy-textured soils. If the surface can be protected to reduce evaporation, seedling emergence and establishment will be greatly enhanced. Mulches should be considered for plant establishment in difficult environments. The Arid-Land Seeder (fig. 6) was developed to solve the seeding problems discussed above (Abernathy and Herbel 1973, McKenzie and Herbel 1982).

13. Seedbed preparation is essential. The major objectives for preparing seedbeds are 1) remove or substantially reduce competing vegetation, 2) prepare a favorable microenvironment for seedling establishment, 3) firm the soil below seed placement and cover the seed with loose soil, and 4) if possible, leave mulch on the soil surface to reduce erosion and to improve the microenvironment. We should not expect a comparatively weak perennial seedling to become established under conditions where a stronger annual seedling has difficulty or cannot live.

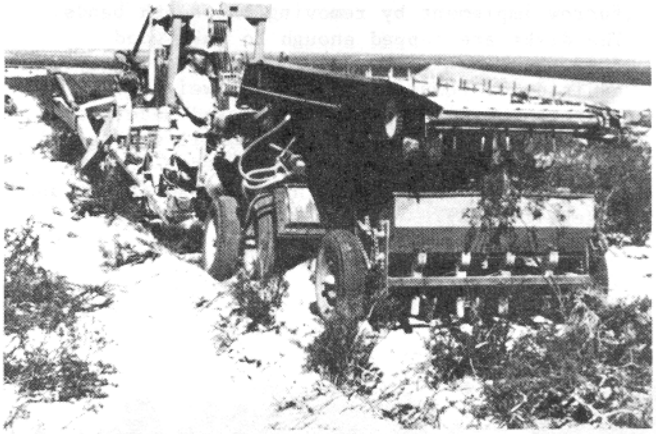

Figure 6. The Arid-Land Seeder concentrates water and seeds, and places a mulch of dead shrubs over the seeded area.

14. Fertilization. Where water is not limiting, a nitrogen-phosphorus plant fertilizer applied in bands near the seed zone may help plant establishment.

15. Revegetated areas must be properly managed. All seedings must be protected from grazing animals through the second growing season, or until the seeded species are well established. Under certain conditions, spraying to control weeds competing with the new seedlings can prevent the loss of a seeding. Rodents, rabbits, insects, and other pests should also be controlled where they are a menace to new seedings.

Methods of Direct Planting

Direct planting can be done with a rangeland drill, press seeder, grain drill, range interseeder, browse seeder, aerial broadcasting, rotary spreader, airstream, hand broadcasting, or by other methods that take into consideration range seeding principles.

Drill Seeding

Drilling is by far the superior method of planting seed where site conditions permit. The seed is covered to the proper depth by the drill control; distribution is uniform; rate of seeding is positively controlled; and compaction can be applied if needed. There are several types of drills available (Larson 1980).

Rangeland Drill. This drill is a rugged seeder with high clearance designed to work on rough sites (fig. 7). It has performed well on rough seedbeds. It can be converted to a deep furrow implement by removing the depth bands. The disks are cupped enough to make good furrows. The furrow depth is controlled by addition or removal of disk arm weights. Weights up to 30 kg have been used under some conditions. The feed on this drill will not handle trashy seed unless the feeder is especially designed for that purpose (Young and McKenzie 1982).

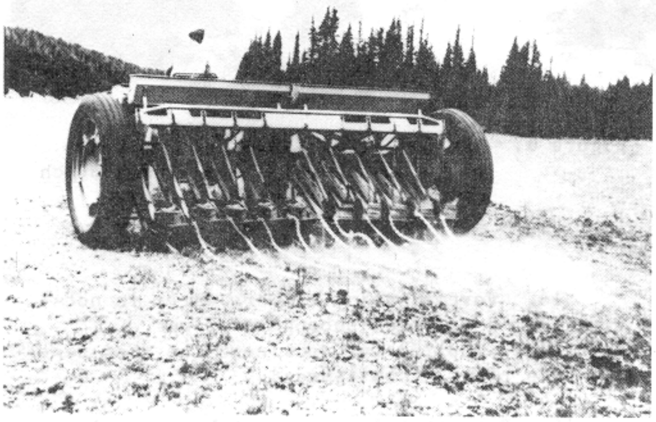

Figure 7. Rangeland drill equipped with seedboxes for small seed and for chaffy seed.

Press Drill. The press drill is designed for seeding on plowed or loose seedbeds. A heavy press wheel packs the soil. The seed is placed in the packed furrow and an adjustable drag covers the seed (fig. 8). This drill

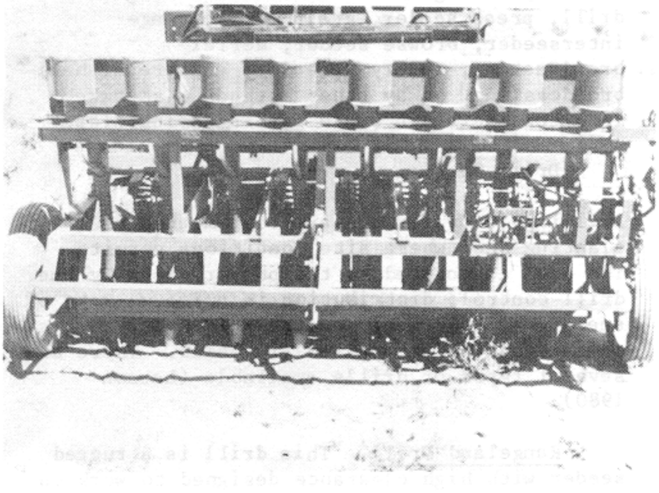

Figure 8. A press drill.

cannot be used on rocky or rough seedbeds. Trashy seed can go through the feed on this drill if it is designed for this purpose.

Ordinary Grain Drills. Grain drills are designed and built for use on cultivated fields. They are often too lightly constructed for rough rangeland seeding. Breakage is a problem and the seed may not be placed properly in the ground. For these reasons, they have limited use for critical area seedings.

Trashy Seed Drill. This drill is equipped with two types of seed boxes, one for planting trashy seed such as buffelgrass (*Cenchrus ciliaris* L.) and another for planting fine seeds, such as lovegrasses (*Eragrostis* spp). Both boxes can be used together or separately. The drill has a welded frame construction and uses rubber-tired wheels.

Broadcasting

Broadcasting is any method that scatters the seed directly on the soil without soil coverage. However it is spread, the seed must be covered in some way if it is to germinate and become established. Size of seed and condition of the seedbed are important factors influencing seed coverage with soil. A seedbed that is 5-8 cm of loose soil generally sluffs sufficiently to cover the seed. Covering the seed with a mulch is better than no coverage at all, but mulch coverage is not as good as soil coverage. If mulches are used in conjunction with seeding, best results are obtained by broadcasting the seed, covering with soil, and applying mulch. Limitations to broadcast seeding are 1) heavy seeding rate is required, 2) covering of seed is poor compared to drilling, 3) distribution of seed is often poor, 4) loss of seed to insects and rodents can be great, and 5) establishment is generally slower. This method should be avoided if possible. Some means of obtaining seed coverage include dragging a chain (chaining), raking with a hand implement, or driving a vehicle or livestock over the area after scattering seed.

Aerial Applications. Aircraft must be equipped with a positive, power-driven, seed metering device. An adjustable opening that allows the seed to drop out of the hopper by gravity is not acceptable when a mixture of various seed sizes and weights is being seeded.

Broadcasting Ground Application. Ground broadcasters are primarily of three types.

- Rotary spreaders. In this type, the seed falls from a hopper into a rotating, ribbed disk that distributes the seed by centrifugal force. The width of throw depends on size and weight of seed, speed of the rotating disk, and velocity of wind. Rotary spreaders may be carried by hand, mounted on a tractor or seedbed preparation unit, or trailed behind. They are usually powered by hand, gasoline or electric motor, or power take-off.

- Seeder boxes of the drill-like or fertilizer-spreader type. In this type, a fluted or forced gear-fed mechanism lets seed fall out of the bottom of the box onto the ground. The seedbox is mounted on equipment such as brushland plows or brush cutters. In general, the seeder box type of broadcaster distributes seed more uniformly than does the rotary type.

- Dribblers. A recent adaptation of this type of broadcaster is the seed dribbler. The dribbler was designed to be mounted on the right and left side of the deck of a track-type tractor. The seeddrop mechanism has a direct drive from a rubber-tired wheel riding on the tractor tracks and utilizes a fluted forced feed. The seed is metered onto the track pad just as it breaks over the front idler. It drops off the pad in front of the track and is embedded in the soil as the tracks pass over.

- Broadcast units using an air stream to dispense seed. The seed is metered from a hopper, either by gravity or forced gear, into an air stream. The air stream can be created either by exhaust from equipment motors or by a fan designed for this purpose. Seed distribution is poor when wind velocities are high. Swath width is unpredictable, depending on weather conditions.

- Ground application by manual equipment. This method is as old as civilization; the Bible speaks of such methods. Many small areas are still seeded by a sower throwing seed from a sack suspended at a person's side with a shoulder strap. An experienced person can maintain a good distribution of seed by this method.

An adaptation of manual seeding is the Whirlwind seeder. This hand implement consists of a canvas seed container with a controlled feed that drops seed on a disc. A crank is turned by the sower as he walks, and the crank gear turns the disc. The spinning action of the disc scatters the seed. This method is often used after bulldozing or other spot treatment that removes existing plants.

COMBINING MECHANICAL CONTROL OF WEEDS WITH SEEDING

Normally, mechanical weed control and rangeland revegetation requires consideration of the principles described above. As mentioned previously, some operations are combined to remove brush, prepare the soil, and sow the seed. The one-way disk plow with seedbox has been used on large areas to control big sagebrush (*Artemisia tridentata* Nutt.) and seed crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.] (Cornelius and Talbot 1955). The arid-land seeder combines a rootplow, a conveyor, a hydraulically-operated dozer blade, and a press-wheel seeder to control brush such as creosotebush [*Larrea tridentata* (Sesse & Mocino ex DC.) Coville] and tarbush (*Flourensia cernua* DC.), form basin pits to hold precipitation on the seeded area, seed a variety of species, and use the dead brush as a mulch on the seeded area (Abernathy and Herbel 1973).

Chaining, diskplowing, and rootplowing reduced brush competition at three sites in southeastern Arizona (Jordan 1968 as cited in Cox et al. 1982). Each treatment was pitted and sown to Lehmann lovegrass (*Eragrostis lehmanniana* Nees). Lehmann lovegrass was established with all treatments, but density and production rapidly declined unless the treatment included rootplowing.

The land imprinter is another innovative mechanism that attempts to combine some of the principles of mechanical weed control and seeding. The land imprinter is a hollow metal cylinder, 1 m in diameter and 2 m long pulled by an ordinary farm tractor (fig. 9). The cylinder surface has V-shaped ridges that leave imprints up to 10 cm deep in a furrow, making an indentation pattern that keeps rainwater where it falls. These imprints provide a small water and litter catchment capable of storing sparse rainfall. The cylinder can be filled with 2 tonnes of water to increase imprinting pressure when used on more resistant soils. A variety of imprinting patterns are available offering flexibility for working with different soils, terrains, and climatic conditions. Seeding is done by an inexpensive broadcast-type seeder mounted on the tractor, or on the towing tongue of the imprinter, which allows the imprinter being towed to press the seed

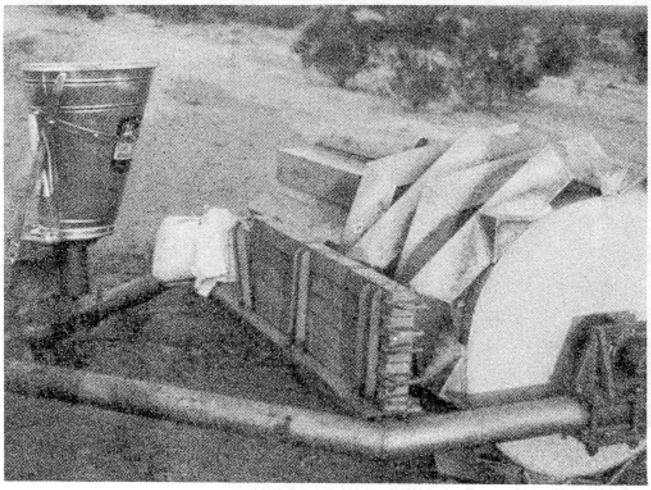

Figure 9. A land imprinter.

into the soil. The basic imprinting pattern creates a runoff groove that channels water to the seedbed groove where germination and plant growth can occur, even under less than normal rainfall. The machine rolls over and crushes brush, including individual plants with a basal diameter of up to 10 cm, although its best effectiveness is on stems less than 5 cm in diameter. Destruction of dense, old brush is not as effective as more specialized machines designed specifically for total brush removal; however, some brush is effectively killed, and the remainder is sufficiently damaged to delay regrowth until after the critical period for successful establishment of the new grass seedlings. At that time, the recuperating brush encounters strong soil water and nutrient competition from the seeded species. The land imprinter has the added benefit of mulching existing vegetation into the soil to help retain moisture, provide soil aeration, and contribute to soil structure and nutrients. When the land imprinter is operated on dry soil, crushing stems into the soil is less effective than on moist soil.

Range interseeding increased productivity and the proportion of desirable forage species on depleted ranges of the northern Great Plains (Houston and Adams 1971). The principle of range interseeding is to seed in a scalped furrow that has all vegetation removed from it. The furrows are prepared by undercutting about 5 cm below ground level and placing the sod strips to the side of the furrow. The width of the furrow, usually 25-45 cm, is important to seeding success through reduction of competition for soil water. An interseeder that prepares furrows 12-20 cm wide was developed in South Dakota (Chisholm et al. 1981). Wider furrows are desirable in arid areas.

Figure 10. A range interseeder.

CONCLUSIONS

Throughout the rangelands of the world, there are large areas where desirable forage plants have been reduced in vigor or killed by past abuses. Such lands produce few benefits and are a detriment to adjacent lands. Even with controlled livestock grazing and, in some cases, complete protection, depleted areas will require 20 or more years to develop desirable plants. Secondary succession is slow, or non-existent, in arid and semiarid rangelands when the desirable vegetation has been depleted. Mechanical control of unwanted plants may be used to manage undesirable species and prepare a seedbed. If propagules and desirable plants have been depleted, revegetation is the only means to establish plants for protection and production.

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