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Principles of Intensive Range Improvements

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Abstract

Our expanding population is demanding more productivity and other contributions from our rangelands. Range science is concerned with the plants, animals, soils, and waters on rangelands, particularly the interaction of these factors. Native plant communities should only be used as guides to determine site potential. Extensive practices on rangelands include manipulation of animals and burning. Intensive practices include control of unwanted plants, revegetation, and fertilization. When properly conducted, intensive manipulation practices often result in much higher production than before treatment. Each land manager determines the desired level of productivity based on economic, cultural, political, and social factors, and the availability of technology. The most effective method for control of unwanted plants varies with the sites, the species, and the degree of infestation. Revegetation may be required where desirable vegetation has been depleted by past grazing abuses, droughts, and encroachment of unwanted plants. Water is generally the primary factor limiting plant growth but when that need has been satisfied, additional plant nutrients such as nitrogen and phosphorus may be useful. The more costly practices are riskier and require higher management inputs, but the potential benefits are great. With changing technology or favorable economic conditions, the range manager may decide to intensify his range improvement efforts.

Man is making tremendous advances in many fields of science. Our expanding population is demanding increasing productivity from all of our agricultural lands, including rangelands. The rise of our present civilization has been made possible by the advances in agricultural production. The development occurred because people were able to influence their environment. A primary principle of range science has been that the natural plant communities provide a guide to potential herbage cover and production. We must remember that the native plant communities are only guides to site potential. Some plant species may be introduced to an area with some of the manipulative treatments that may be superior in some, if not all, aspects of rangeland management (Love 1961). An example of this is the introduction of crested wheatgrass *(Agropyron desertorum)* in the western areas of Canada and the United States. These manipulative treatments require the application of a number of principles. This paper is an attempt to establish a concept of range science and discuss some of the major principles that the resource manager should consider when conducting manipulative treatments on rangelands.

It is useful to conceptualize the practices used in range science in a diagram (Fig. 1). Each land manager determines the desired level of productivity based on economic, political, cultural, and social factors, and the availability of technology. Examples of extensive practices for rangelands are manipulation of grazing, as in various systems, and the use of fire. These practices may require some fencing, water developments, and/or fire lines, but they generally do not risk the loss of the present vegetation cover as do some of the more intensive manipulative practices. These extensive practices are less costly but the opportunities to dramatically increase production are low. The potential benefits are low and these extensive practices do not require a high level of management. Water management often requires a higher level of input than manipulation of the animal or fire, and is intermediate between extensive and intensive practices used in range science.

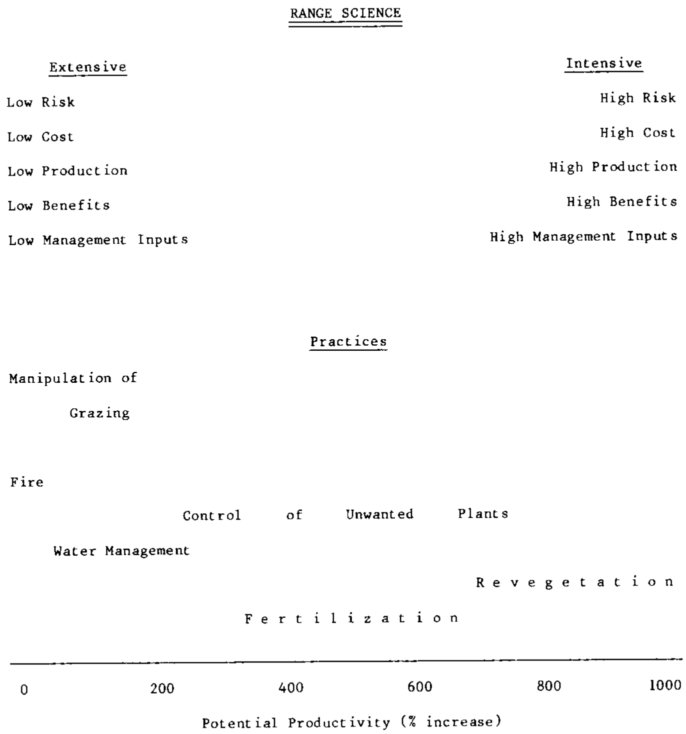

Figure 1. Concept of range science.

On the other hand, drastic manipulations of range ecosystems are sometimes required or desired. The invasion of unwanted plants, severe droughts, past abuses by grazing animals, or the desire by the operator to change botanical composition, or productivity, on all or part of the range unit, result in practices to control the unwanted plants and to revegetate with desirable plants. The latter practices require great attention to every detail, as will be discussed later. The risk of using plant control or revegetation is high because if attention is not given to every detail, or even sometimes when everything is done properly, the practice(s) may not give the desired effects. The relative costs of these practices are high. The potential benefits are high. Control of unwanted plants, revegetation, and/or fertilization may result in increasing production of that land 100 to 1,000% within 1-3 years (e.g., Herbel et al. 1977). High management inputs are required because if these risky, costly practices are used, the land manager should attempt to maximize the outputs while maintaining the basic resource and minimizing the need to repeat the practice. To implement revegetation one may ask the question, what is the potential for this site? Are there plant species, even on the other side of the world, that may be more productive or better able to meet a particular requirement than the plants growing there now? Generally, control of unwanted plants, revegetation, and fertilization are intensive practices for rangelands.

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Few, if any, land managers use intensive practices exclusively on a unit of rangeland. Rather, some combination of beneficial practices is used whereby both intensive and extensive principles are utilized. For increased plant production and soil protection, each unit of rangelands must be managed to maximize economic, political, and social factors while maintaining or improving the basic resource. In the Northern Great Plains of Canada and the United States, this may mean seeding part of the range unit with Russian wildrye *(Elymus junceus)* and crested wheatgrass, and using nitrogen fertilizer on both native and introduced species (e.g., Smoliak 1968). In portions of the Northern Great Plains, the best practices may include judicious burning practices on parts of the native rangeland and plowing up the native sod on some of the better sites and seeding wheat for forage, or for forage and grain. On the semiarid Southern Great Plains of the United States and associated grasslands of Mexico and the United States, a useful strategy may include seeding weeping lovegrass *(Eragrostis curvula)*, sideoats grama *(Bouteloua curtipendula)*, wheat, and sudangrass (McIlvain 1976). In the arid portions of the southwestern United States and northern Mexico, range productivity could be greatly increased by control of mesquite *(Prosopis juliflora)* and tarbush *(Flourensia cernua)* and seeding with Lehmann and Boer lovegrass *(Eragrostis lehmanniana* and *E. chloromelas)* and fourwing saltbush *(Atriplex canescens)* (Herbel et al. 1977). On rangelands infested with big sagebrush *(Artemisia tridentata)*, control of the sagebrush and seeding with crested wheatgrass often results in much greater productivity and soil stability than would be obtained without sagebrush control and seeding. In some instances, composition of plant species may be manipulated to improve wildlife habitat, while at the same time maintaining or improving livestock production. The use of various practices is changing with time as dictated by economic, political, and/or social conditions, or as improved technology becomes available. Range science utilizes various principles for use on rangelands. However, we should not be bound by semantics. It is only important that the range resource be maintained or improved as it is managed to meet various objectives. My plea is for land managers, and others working with land managers, to 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 the range unit next to it, or on the range unit 250 km distant. Differences in opinion over management objectives can, and do, lead to serious conflicts. The manipulations discussed in this paper include: control of unwanted plants, revegetation, and fertilization. These are relatively intensive practices that require much attention to detail.

Control of Unwanted Plants

Many millions of hectares of rangeland around the world are dominated by, or being invaded by, unwanted plants. In North America, most brush cover is native vegetation that has invaded large areas of former grasslands and savannahs, converting them into brushlands and woodlands. Originally, woody plants were present as a lesser component of the climax vegetation of grazing lands. In semiarid and subhumid rangelands having sufficient fuel, repeated fires kept grasslands relatively free of woody plants. During those times, less intensive utilization of forage by animals permitted enough litter to accumulate to serve as fuel for the occasional fires that killed young trees and shrubs. After colonization, intensive livestock grazing steadily reduced the amount of fuel available for fires, and man largely excluded fires from rangelands (National Academy of Sciences 1968). There has been an accelerated invasion of rangelands by undesirable shrubs. For example, mesquite dominated only 5% of a southern New Mexico range in 1858 before colonization, but dominated about 50% of the range in 1963; creosotebush *(Larrea tridentata)* occupied less than 1% of the area in 1858 and more than 14% in 1963; and tarbush dominated less than 1% of the area in 1858 and about 9% in 1963 (Buffington and Herbel 1965).

Once established, woody plants such as mesquite, juniper *(Juniperus* sp.), creosotebush, tarbush, and sagebrush cannot be eliminated by proper grazing practices alone. The unwanted plants must be controlled before rangelands can benefit from other practices such as grazing systems, revegetation, fertilization, or water management. Each method of suppressing unwanted plants has advantages and disadvantages, but the objective in all cases is to substitute desirable plants for those not wanted. The most effective method for control of unwanted plants depends on the site, the species, and the degree of infestation. Any control of unwanted plants requires considerable attention to detail to maximize results. Control is generally less costly when infestation is low and the plants are small. In this situation, a method is selected that will not destroy the residual forage plants. On sandy soils heavily infested with brush, a broadcast chemical method will control the undesirable plants and result in an increase of forage plants. Mechanical control methods are generally avoided on sandy soils because of the wind erosion hazard if a good plant cover is not maintained. A mechanical method of control accompanied by seeding may be required on soils with medium to heavy textures, heavy infestations of brush, and poor stands of desirable plants (Herbel 1979).

It is important to consider the plant species growing in association with target plants. Some desirable plants may be present that should not be killed. On the other hand, two or more undesirable plant species may be present, so the control method must meet the requirements of the land manager (Gould and Herbel 1970).

The management of animals on an area before and after treatment may influence the ultimate results. It may be desirable to defer grazing of animals during the growing season prior to treatment to improve the vigor and seed production of desirable plants. After control of the unwanted plants, it is extremely important to defer grazing until the desirable plants have become established. The number of growing seasons needing deferment will depend on the stand of desirable plants present when treated, the precipitation after treatment, and the degree of plant improvement desired by the land manager.

Principles of Chemical Control

Satisfactory control of unwanted plants and considerable improvement in the grazing capacity of rangelands may often be obtained by applications of herbicides. Specific approaches to this problem have been developed for numerous plant species, but information is still needed on some plants (National Academy of Sciences 1968).

Herbicides may be classified as contact, translocated, selective, nonselective, and soil sterilant (Vallentine 1971). A contact herbicide kills only those plant parts that are directly exposed to the chemical, e.g., diquat (6, 7-dihydrodipyridol[1,2-*a*:2′,1′*c*]pyrazinediium ion) and paraquat (1,1′-dimethyl-4,4′-bipyridinium ion). A translocated herbicide is applied to one part of a plant but is carried to other parts of the plant by plant tissues, e.g., 2,4-D ([2,4-dichlorophenoxy]acetic acid), 2,4,5-T ([2,4,5-trichlorophenoxy]acetic acid), silvex (2-[2,4,5-trichlorophenoxy]propionic acid), picloram (4-amino-3,5,6-trichloropicolinic acid), and dicamba (3,6-dichloro-*o*-anisic acid). A selective herbicide kills or damages a particular species or groups of species with little or no injury to other plants, e.g., the herbicides listed as translocated herbicides. A nonselective herbicide kills or damages all plant species, e.g., amitrole (3-amino- *s*-triazole) and paraquat. A soil sterilant is a herbicide that kills or damages plants when it is present in the soil, e.g., bromacil (5-bromo-3-*sec*- butyl-6-methyluracil), dicamba, monuron (3-[*p*-chlorophenyl]-1,1-dimethylurea), picloram, or tebuthiuron (*N*-[5-(1,1-dimethylethyl)-1,3,4-thiadizol-2-yl]-*N,N*′-dimethylurea). Most of these latter herbicides are selective at low rates and nonselective at high rates.

Broadcast spraying is the method of herbicide application most commonly used on rangelands. Since the herbicide is applied to all plants, desirable as well as undesirable, selective herbicides are generally required. Broadcast sprays can be applied either by ground rigs or by aircraft. Applying granulated or pelleted herbicide is also used to control unwanted plants. The latter method is less dependent on stage of growth than foliar sprays but does require precipitation to dissolve the granules or pellets so the herbicide may penetrate into the soil. In some areas, excessive herbicide losses may result from leaching beyond the root zone of the target plants, adsorption on soil colloids, or decomposition by light or high temperatures. Fundamentals to consider follow:

1. Proper herbicide. Herbicides such as 2,4-D, 2,4,5-T, silvex, picloram, and dicamba control a wide variety of plants. Spraying with ground or aerial equipment may be used to control most plants.

2. Proper rate of herbicide. The amounts of herbicide required to provide adequate control vary among plant species. Higher rates than those needed for adequate plant kill cause damage or death to leaves and branches so that herbicides are not translocated to the proper site and death of the plant does not result. As an example, effective rates are 0.3 to 0.6 kg/ha acid equivalent (a.e.) of 2,4,5-T for mesquite, and 2.2 to 3.3 kg/ha (a.e.) of 2,4-D for big sagebrush. Higher rates than those required for adequate plant control are rarely more effective.

3. Proper volume. The volume is dictated by the target species. It is important to obtain adequate coverage but not excessive amounts that will seriously contaminate the adjacent environment. On mesquite, aerial applications of a total volume of 9.3 liters/ha gave as much or slightly better plant kill as a total volume of 46.5 liters/ha. This total volume is composed of 1/8 herbicide, 1/8 diesel oil, and 6/8 water.

4. Proper time. The phenologic development of the target species, or associated plants, is a reliable index to seasonal susceptibility. Plants are most sensitive to foliar sprays when they are growing vigorously and the leaves are fully expanded. In New Mexico, there was an increased control of mesquite when precipitation for the November to May before treatment was average or above average (Valentine and Norris 1960). Dry herbicides, applied to individual plants or broadcast, should be applied just before or in the early part of a period of expected precipitation.

5. Proper method. Fixed wing or helicopter aircraft are commonly used to apply herbicidal sprays to large areas. Foliar sprays may also be applied with ground equipment, but the size of the job, the terrain, or the size and density of plants often prevent such operations. Aerial spraying is a specialized job. Gould and Herbel (1970) listed factors that must be considered.

a. Application equipment,
b. Weather conditions,
c. Swath width
d. Flight height,
e. Mixing-loading equipment,
f. Spray material,
g. Proximity to non-target plants,
h. Removal of livestock.
i. Directions on the herbicide container.

Principles of Mechanical Control

The choice of whether to use manual methods, such as grubbing, or mechanical equipment to remove unwanted plants depends on the cost, on the availability of the equipment, the size and stand of the plants to be eliminated, whether the target plants have sprouting or nonsprouting characteristics, soil conditions, and the type of terrain (National Academy of Sciences 1968).

1. Size and stand of the target plants. The best time to employ hand-grubbing is during early invasion of unwanted plants, before the stand of desirable species becomes greatly reduced. Hand-grubbing of small shrubs (up to 90 cm in canopy diameter) is an economical control method when the stand is relatively thin, usually less than 80 plants/ha. With sprouting species, the root must be severed below the budding zone (Herbel et al. 1958). Cabling or chaining is most 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 trees. Disking is limited to small plants. Rootplowing or disking is used when there is a sparse stand of desirable plants and revegetation is needed.

2. Sprouting or nonsprouting shrubs. This characteristic must be considered in choosing a method. Cabling, chaining, and disking do not give a high degree of kill on shrubs that sprout below the surface of the ground.

3. Soil conditions. Cabling or chaining is most effective in areas with lighter-textured sandy or loamy soils. Bulldozing, rootplowing, and disking excessively disturb soil, destroy desirable plants, and may result in soil erosion. Most mechanical methods cannot be used when the soil is excessively wet.

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

Revegetation

Where desirable vegetation has been severely depleted by past grazing abuses, droughts, and encroachment of unwanted plants, natural recovery may take several years, or it may never oocur. Under such conditions, seeding may be the only hope of re-establishing desirable plants. Other objectives of seeding are to improve soil stability and to alter plant composition to meet the user's objectives. Seeding rangelands is generally a difficult undertaking because of limiting climatic, soil, and/or topographic features. Merkel and Herbel (1973) outlined the principles of seeding as:

1. Remove or reduce competition from unwanted plants. Most plants used for revegetation are perennials. Seedlings of these species are often slow-growing and cannot compete with existing, unwanted plants. A good seedbed will provide the best possible moisture conditions for germination and plant growth. This requires the control of most existing plants before seeding. In addition, it is sometimes necessary to control unwanted plants that are competing with the seedlings of the desirable plants.

2. Use of adapted plant materials. The plant species selected for seeding must be compatible with management objectives (e.g., palatability and growth period). They should be selected to obtain the management objectives. It is important to use only those species and varieties that are well adapted to the soil, climate, and topography of the specific site being revegetated. If native plants are revegetated, species from local origin are 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.

3. Seeding rates. It is important to use enough seed to get a good stand, but not more than necessary. Too much seed may produce a stand of seedlings so thick that individual plants may compete with each other. Species of plants, number of pure live seeds (PLS) per kg, and potential productivity of the site are the major factors determining the rate of seeding. 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 an inefficient and less effective method of revegetation, and should be avoided. Many seeds are left on the soil surface where germination and seedling establishment are tenuous. Where broadcast seeding must be used, a rate of 500 PLS/m^2 is recommended.

4. Depth. Proper depth of seeding is determined by the plant species. For optimum emergence, small-seeded species such as the lovegrasses (*Eragrostis* sp.) should not be seeded deeper than 0.6 cm, whereas species such as crested wheatgrass should be seeded at a depth of 1.2–1.8 cm. Optimum depth of seeding is roughly 4–7 times the diameter of the seed. Seeding equipment should be used that provides for positive seed placement at the desired depth. More stands are lost because seeds are planted too deeply rather than too shallowly.

5. Seeding dates. The most desirable time to seed rangeland is immediately prior to the season of the most reliable rainfall, and

when the temperature is favorable for plant establishment.

6. Seed distribution. Uniform distribution of seed is essential. Seeding equipment must be checked frequently to assure that it is working properly.

7. Alteration of the microenvironment. Most range areas are deficient in soil water for germination and seedling establishment of the desirable plants. In many areas, associated rangeland treatment is needed to reduce the high soil temperatures and provide more soil water (e.g., mulching), or just provide more soil water (e.g., summer fallow or establishing basins or pits).

8. Seedbed preparation. The major objectives of preparing seedbeds for range seeding are to: (a) remove or substantially reduce competing vegetation, (b) prepare a favorable microenvironment for seedling establishment, (c) firm the soil below seed placement and cover the seed with loose soil, and (d) if possible, leave mulch on the soil surface to reduce erosion and to improve the microenvironment.

All range seedings must be protected from grazing by animals through the second growing season, or until the seeded species are well established. Spraying to control weeds that are competing with the new seedlings may prevent the loss of seeding. Rodents, rabbits, insects, and other pests should also be controlled where they are a menance to new seedings.

Fertilization

The variety encountered in the world's rangelands, with the diversity of climate, topography, soil types, and vegetation, complicates any attempt to generalize on a range management practice such as fertilization. Seasonal variations in local weather conditions add further complications. In addition, the complex mixture of plants on rangelands requires more diligent management than does a seeded pastures with one or two species. Fertilization affects each species differently, and even plants within a species may respond differentially to additional nutrients.

In some areas, low amounts of available nitrogen (N), phosphorus (P), and other soil nutrients limit plant growth. Water is generally the most important factor limiting plant growth but when that need is satisfied, additional plant nutrients may benefit plant growth. N was the major growth-limiting plant nutrient on the rangelands of the Northern Great Plains, with measurable responses to P occurring as N became non-limiting (Wight and Black 1979). Fertilizing with the deficient nutrients is economical only where there is adequate moisture and plants respond to the added nutrients. The root systems of range plants often act as nutrient-deficient sinks that have a high potential to immobilize relatively large quantities of applied N and P (Black and Wight 1979). Wight (1976) gave some points on range fertilization to consider:

1. Soil water. Response to fertilization is directly related to availability of soil water. Range fertilization should not be used in areas with a low average precipitation. Seasonal distribution of precipitation and evaporative demand may be confounding factors. Range fertilization has been effective in the Northern Great Plains in areas where annual precipitation is as low as 280 mm. Annual precipitation of 380 mm or more is required before range fertilization is feasible in warmer regions and where precipitation is more evenly distributed during the year. Areas that have overland flow or subirrigated may have less precipitation but they have sufficient water so the plants can use the added nutrients.

2. Economics. Applications of 30 to 50 kg/ha of N annually or in annual rate equivalents are most efficient in the Northern Great Plains. This rate will produce up to 20 kg of additional forage per kg N applied, or, under a grazing situation, about 1 kg beef/kg N. Thus, when the price of beef exceeds the cost of applying N, fertilization becomes an economical management practice. The total cost of fertilization must be weighed against the benefits.

3. Ecology and fertilizer timing. Usually, cool-season species respond most to N fertilization. However, the effect of fertilization on species composition can be somewhat offset by timing fertilizer applications. Late spring or summer applications tend to benefit warm-season species, whereas late fall or early spring applications tend to benefit cool-season plants. If application rates are high enough to cause a significant carryover of N fertilizer from one year to the next, cool-season species may use the fertilizer to the detriment of warm-season plants. Nitrifying soil bacteria are less active in cool weather than in warm weather (Lorenz and Rogler 1973). Thus, plants growing earliest in the season will use the residual N.

4. Toxicity. At N rates above 200 kg/ha, nitrates accumulate in some plants, especially annual forbs. Caution is required if applying high N rates on rangelands with nitrate-accumulating plants. Ground water contamination with nitrates may also result where high N levels are used and where the ground water is close to the surface.

5. Water use efficiency. Range fertilization increases the efficiency of the limited water supply in plant growth processes. When nutrients are not limiting, plant growth is at least doubled per unit of water used. Fertilized range plants extract more water from the soil profile than do unfertilized plants because of deeper root penetration. Thus, if precipitation is adequate to fully recharge the soil profile, fertilized range will use the precipitation more effectively than unfertilized range.

6. Drought. There has been concern that fertilization will compound the effects of drought, resulting in additional damage to the range vegetation. In some situations, there is a greater loss of desirable plants during drought (Donart et al. 1978, Kay and Evans 1965). However, fertilizer not used during drought years is available for plant use following the drought. Therefore, recovery from drought is generally more rapid on fertilized ranges.

7. Fertilizer materials. There have been very little response differences to the inorganic forms of N and P. Under some conditions, urea, an organic formulation, will undergo high volatization losses when broadcast on the soil surface.

8. Management. It is generally necessary to fertilize the entire range unit or the animals will concentrate on the fertilized portion and neglect the unfertilized area. Plants that have been fertilized generally are green earlier in the spring and later in the fall if soil water is available. Increased palatability of fertilized plants may be useful as a management tool to improve animal distribution and forage utilization. However, plants toxic to animals on fertilized areas may also become more palatable and create toxicity problems among the animals using rangeland. Plants growing on fertilized range generally have a high nutrient content and this will also affect management decisions.

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