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Soil and Vegetation Management: Keys to Water Conservation on Rangeland

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Water is probably our least understood natural resource. The earth has virtually the same amount of water today as it did when dinosaurs roamed the planet. Water covers nearly three-fourths of the earth as rivers, lakes and oceans, but only about 3 percent of the planet's water is fresh, and two-thirds of that is ice. About 0.6 percent of the earth's water is in the earth's underground aquifers, and a small but very important amount (0.003 percent) is contained in plants, animals and the soil. Over four trillion gallons of water fall on the United States daily in the form of precipitation, but much of that disappears in evaporation or runoff. The amount that soaks into the soil determines, in part, plant life and productivity.

The hydrologic cycle (Fig. 1) is the continuous process by which water is transported from the oceans to the atmosphere to the land and back to the sea. Water evaporates from water bodies such as oceans, ponds and rivers and is moved across the earth as water vapor by wind currents. Soil, plants, people, animals, factories and vehicles also contribute to this vapor. Water vapor condenses and falls to earth as rain, sleet, snow or hail depending on the region, topography, climate and season. A large portion of the precipitation returns to the atmosphere as vapor through the evaporation process as it falls. Evaporation also occurs from plant, soil and water surfaces. Precipitation that reaches the ground either evaporates, infiltrates into the soil or runs off downstream to ponds, lakes or oceans. Part of the soil and surface water is used by plants and animals and returns to the atmosphere through transpiration and respiration. That which percolates through the soil profile seeps into underground streams or reservoirs. The amount of water on the earth is constant; it is always somewhere in the cycle.

Because the total quantity of water available to the earth is finite and indestructible, the global hydrologic cycle is a closed system with any water problem being a distribution (quantity, time, location) or pollution (quality) problem. However, the hydrologic cycle in a river basin, a state like Texas, a county, or a ranch is open. The amount of water received

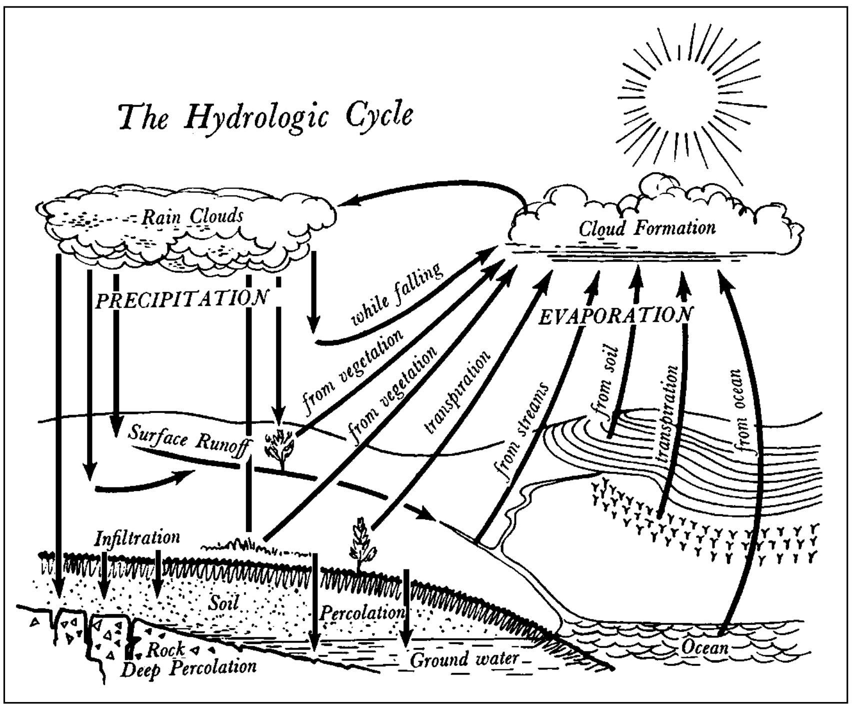

Figure 1. The hydrologic cycle.

is not a constant. Water disposition within a ranch is influenced by climate, geology and vegetation on the ranch. The water budget of a ranch depends on precipitation received and the amount of water lost over a given time. The water storage capacity of the soil and the losses through evaporation and transpiration (evapotranspiration) influence the change in storage over time. Actual water losses vary depending on the seasonal pattern of rainfall, individual storm intensity and duration, the soils, and the kind, amount and distribution of vegetation.

Evapotranspiration represents the largest water loss from arid and semiarid lands because runoff and groundwater recharge are relatively minor losses. Evapotranspiration accounts for 90 to 95 percent of water loss from Texas rangelands. Therefore, efforts to retain as much water as possible on site should theoretically concentrate on reducing evaporation and transpiration losses.

Soil and vegetation management is the key to increasing water availability on rangeland. We can do little to alter the overall water cycle so our supply of water is fixed, depending upon local climate, season and current weather patterns.

> *We can, however, manage and conserve water where and when it falls and by controlling the kind of vegetation make the fullest use of the water that falls. It is often our management of the vegetation that determines if we have both the quantity and the quality of water needed, when and where we need it.*

Effects of Vegetation on Hydrologic Processes

The fate of each drop of water falling on the land depends largely on the kind of soil and the vegetative cover. Experience and research have provided land management practices for managing soil and vegetation resources to increase water use efficiency. Adequate vegetation cover prevents erosion by breaking the impact of raindrops and slowing overland flow. Plant cover reduces soil erosion in raindrop splash by intercepting raindrops and absorbing their energy. Effectiveness of reducing soil splash is proportional to how much cover is present at the time rain occurs. Research has shown that effective control (95 percent) of raindrop splash energies requires approximately 2,000 pounds per acre of sodgrass or 3,500 pounds of bunchgrass. Soil-protective values decline rapidly as cover declines below these levels.

Plant cover also interrupts the travel of raindrop splash and overland flow thus reducing erosion. Soil movement caused by surface flow depends on the energy of the runoff, the susceptibility of the soil to detachment and transportation, and the protection afforded by vegetative cover. Plant cover protects soil from erosive action of runoff water by offering resistance to the movement of water and shielding the soil from its effects. Protection from erosion is obtained through resistance of vegetation to the energies of rainfall and runoff. Generally however, a combination of plant cover and mechanical measures designed to meet the specific combination of erosion factors operating on a particular land area is necessary for effective erosion control.

Within a particular climate, water loss through transpiration is proportional to the leaf area (transpiring surface) and the availability of water in the rooting zone. The less the transpiring surface and the shallower the root system the less water is lost through transpiration. Soil water content is generally greater under grass cover, due to lower evapotranspiration losses. It is also higher under herbaceous cover than under mixed-brush and herbaceous cover. On the other hand, vegetative cover greatly reduces the amount of runoff with grasses generally decreasing the runoff more than forbs or shrubs. Therefore, water availability should increase if vegetation conversion is from brush to grass unless some underground geologic layer disrupts normal soil water movement. An impermeable layer at a shallow depth might keep water within reach of the shortest rooting plants.

The type of vegetation, because of differences in structure, area and texture of plant surfaces, also influences how much water clings to vegetation and evaporates before passing through the canopy to the ground. Relative interception losses increase from low sodgrasses, to bunchgrasses, to shrubs and trees. For example, estimated annual interception losses are 10.8 percent from curly mesquite (sodgrass); 18.1 percent from sideoats grama (bunchgrass); and 46 percent from liveoak brush and trees. So, converting from brush or trees to grass should increase the percentage of incoming precipitation available in the soil for use by forage plants.

Conversion from brush to grass on rangeland will also theoretically yield more water downstream because infiltration is less under grass than under brush, and runoff is potentially increased if infiltration is reduced. Generally, the amount of cover (biomass), and hence the rate of infiltration, is greatest under trees and shrubs, followed in decreasing order on sites dominated by bunchgrasses, shortgrasses and bare ground (Fig. 2). In western Texas grass cover – especially bunchgrasses – provides the most desirable ground cover because it is the most water use efficient. Bunchgrasses also do an excellent job in controlling erosion by holding soil on site and yielding more water off-site than shrubs.

Effects of Vegetation Management Practices on Water Availability

Soil water increases due to vegetation management ultimately depend on whether runoff and deep drainage increase by an amount equal to the reduction in evapotranspiration. Several factors can affect this, including:

- whether shrub biomass is replaced by grass biomass (if herbaceous cover replaces shrub cover in equal amounts there will be little difference in transpiration),
- speed of percolation of water in the soil profile (restrictive layers may slow water percolation and allow more transpiration),
- high rainfall areas that get more water than replacement plants use,
- whether transpiring tissue of grasses is less than the trees or shrubs it replaces, and

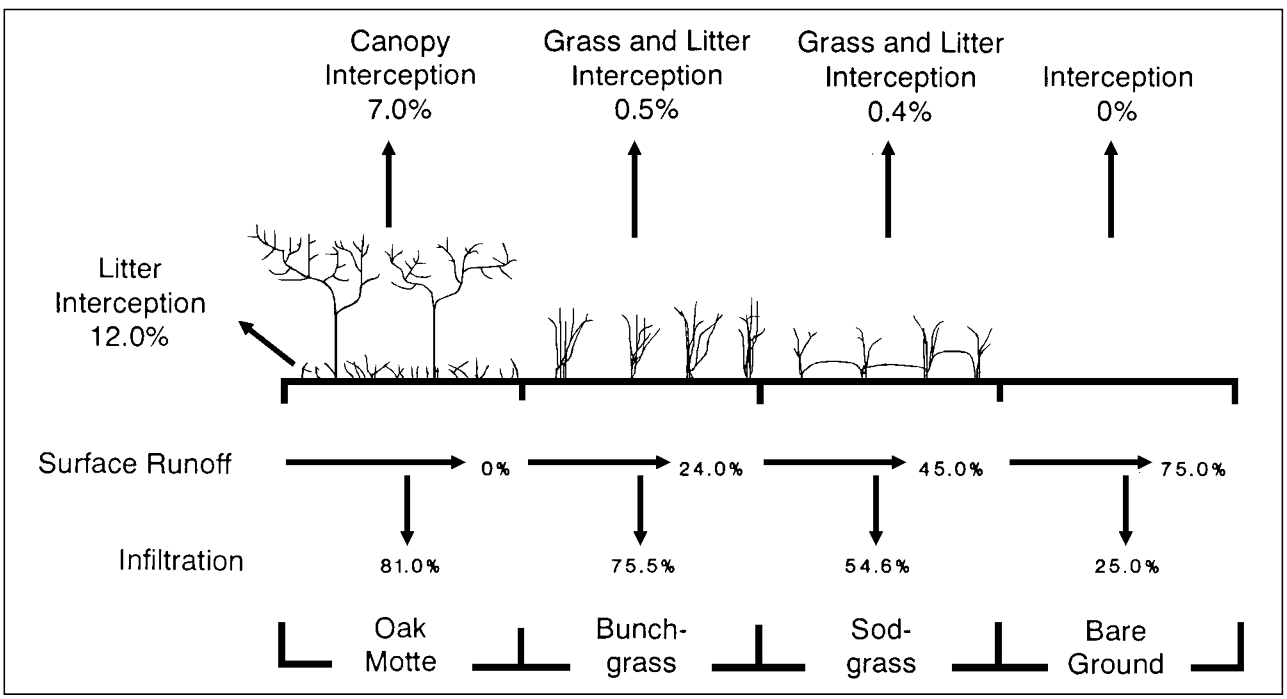

Figure 2. Vegetation type greatly influences what happens to incoming precipitation. Bunchgrass type vegetation is the most water use efficient on the Texas Agricultural Experiment Station in Edwards County, Texas. Adapted from Blackburn, et al. 1986.

- storm characteristics. Vegetative surfaces can hold only a certain amount of water at a given time. Large storms account for the major portion of runoff and deep drainage in the Southwest.

Vegetation management practices can affect both on-site and off-site water through their effects on vegetation composition and soil surface characteristics. The amount and quality of increased soil water depend on the original vegetation, soils and climate. Also it depends on the range management practice used in conversion of the vegetation and its effects on vegetative composition and soil surface characteristics. Any practice that increases standing vegetation and litter will decrease runoff and sediment production.

See "Improving Rainfall Effectiveness on Rangeland" (L-5029) for more information.

Vegetation Management Practices

Range management practices directly affecting vegetation are: (1) grazing management, (2) range revegetation and (3) brush and weed management.

Grazing Management

Ability to control kinds and numbers of animals and when they utilize the rangeland is absolutely essential in regulating the effects of grazing on vegetation. Of all the range management practices and technologies available, proper stocking or control of forage utilization is most important. Continued excessive defoliation is the major cause of range deterioration. Deteriorated range means more runoff and erosion (Fig. 3). Without control of animal numbers, the season of use, and distribution of animals, other practices are usually of limited value in maintaining desirable vegetation cover. Any grazing management strategy that enhances vegetative cover improves water use efficiency and conserves the soil resource. **Grazing management should be the first consideration in developing water management strategies.** (Fig. 4 and 5.)

Range Revegetation

Artificial revegetation utilizes agronomic practices to restore native plant communities or to introduce desired species. It is an expensive and ecologically disruptive process, particularly risky in arid and semi-arid areas. Artifical revegetation should not be attempted unless natural revegetation through grazing management will not restore the range to

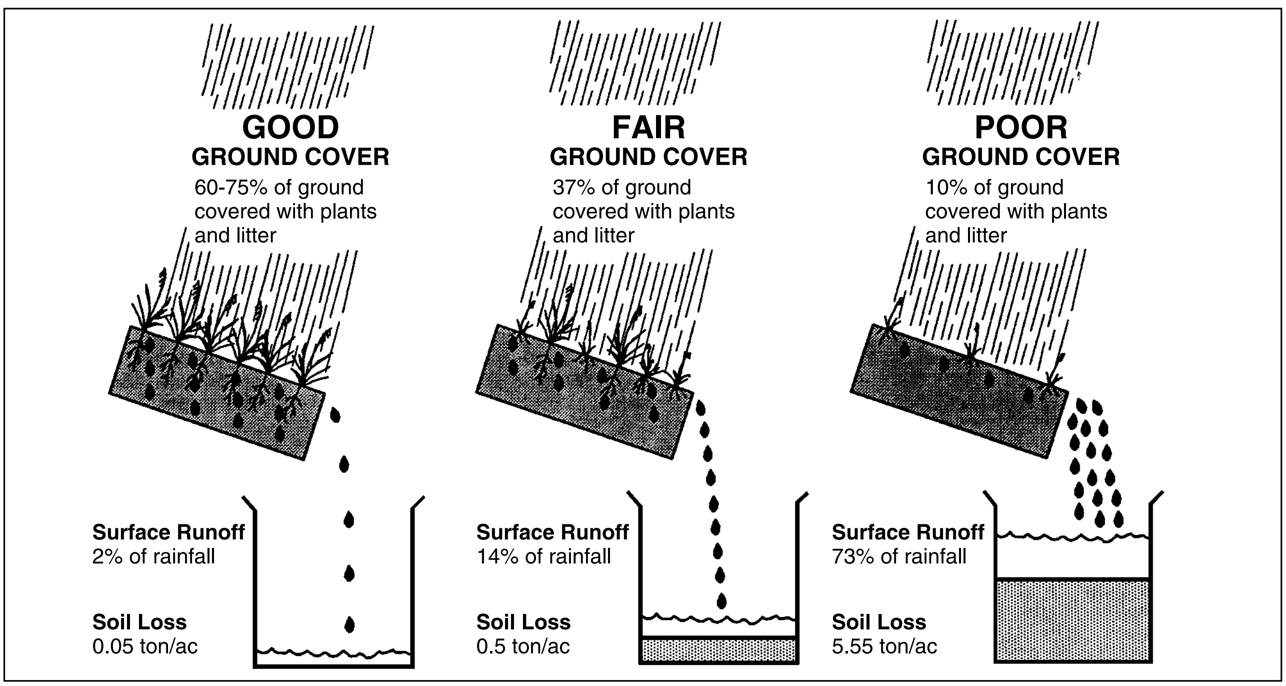

Figure 3. Good ground cover means less runoff and erosion and better water use efficiency. (Adapted from R. W. Bailey and O. L. Copeland, Jr. 1961. Low flow discharges and plant cover relations on two mountain watersheds in Utah. International Association of Science Hydrology Publication 51:267-278.)

the desired condition within an acceptable period. In general, artificial revegetation is not recommended if 10 percent or more of the vegetative cover is made up of desirable species. Revegetation may also not be feasible because of poor soil conditions, erosion hazard or economic considerations. Seeding in conjunction with land surface modification techniques such as water spreading, water harvesting, contour furrowing, pitting and diking will enhance the probability of success for reseeding and managing water use.

Seeding should be considered on severely depleted ranges and where vegetation modification practices call for a change in species. It is a valuable practice in replacing one plant cover with another to provide the desired forage or water management (Fig. 6).

Brush and Weed Management

Development of ecologically sound land management practices requires a clear understanding of how the practices affect the hydrology of the site. Reducing the density of undesirable species increases the availability of moisture and nutrients for more desirable forage species. Also, water yields should increase if brush removal reduces transpiration losses. Control methods include burning, mechanical control, herbicidal control and biological control. The hydrological impact of all the methods has not been studied specifically, but many studies allude to increased on-site moisture availability. Others report increased downstream flow. Each method affects the water regime differently.

Herbicidal Control

Defoliation of plants with herbicides immediately affects evapotranspiration losses. When plants defoliate, transpiration is reduced and litter is added to the soil increasing soil aggregation and water infiltration. Dead stems and roots decay and leave organic matter on the surface and in holes created by decomposing roots. The total impact is that both the on-site and off-site water regime is enhanced without risk of erosion or increase in sediment loads due to physical disturbance. Replacement of brush species with herbaceous species, especially grasses, provides water conservation plus forage. As much as a 500 percent increase in forage production has been recorded after herbicidal control of brush (Fig. 7).

Herbicidal control of undesirable vegetation is applicable where:

1. vegetational change to more desirable species is needed,
2. the undesirables are susceptible to the herbicides, and
3. the terrain does not lend itself to mechanical methods.

Mechanical Control

Mechanical methods such as axing, shredding or roller chopping add litter to the soil with relatively little soil disturbance. These methods are applicable on nonsprouting species or where retreatments can be applied (Fig. 8). Dozing, root-plowing, grubbing or chaining remove plants from the soil and create considerable soil disturbance. Bulldozing and grubbing create pits where trees and roots are extracted (Fig. 9). These pits act as water catchments which concentrate water nutrients and enhance moisture infiltration. Evapotranspiration is reduced making more water available for replacement plant use or deep percolation. However, the reduction will not be maintained unless another vegetative cover is established. Erosion is a hazard until herbaceous vegetation is re-established.

These methods are applicable on most non-rocky soils and where vegetative cover can be replaced.

Chaining, cabling or dragging usually does not increase runoff and erosion if debris and litter are left in place to protect the soil and the herbaceous vegetation is re-established. Generally, soil moisture and runoff are much higher on chained areas than unchained areas throughout the year. These differences are due to changes in the microclimate, mulching effect of the litter and differences in water accumulation.

Innovations that make chaining even more effective include the disk chain and disk-chain-diker (Fig. 10).

Chaining and dragging are applicable on large acreages and work best with moist soil conditions and single stem non-sprouting species. Chaining, dragging and cabling should be considered temporary and followed in due time with repeat applications or other follow-up methods of control.

Figure 4. Overstocking results in deteriorated rangeland and poor water use efficiency.

Figure 5. Proper stocking benefits livestock production, wildlife, aesthetics and the water regime.

Figure 6. Seeding into pits created by grubbing noxious brush and burning periodically changed woodland back to grassland at the Texas Agricultural Experiment Station near Sonora.

Figure 7. Control of noxious brush provides more water and nutrients for forage species.

igure 8. Roller chopping reduces noxious brush and increases forge production through its influence on the water availability.

Figure 9. Power grubbing removes water-using brush and creates basins which concentrate water and nutrients for forage plants.

Figure 10. The disk-chain diker designed by Harold Wiedemann, Texas Agricultural Experiment Station, Vernon, Texas, reduces brush and creates pits which concentrate water and nutrients for forage species.

Figure 11. Contour furrows reduce runoff and increase soil water storage.

Figure 12. Creating pits in the soil, either by roller chopping, aerating or with a specially designed pitter increases water availability and forage yields on deteriorated range.

The relative impact of any plant control technique on the water regime depends on several factors:

- severity of the soil disturbance;
- the response of the herbaceous vegetative;
- effectiveness of the control method in removing brush;
- the impact of the practice on litter and ground cover; and
- time since implementation of the practice.

Soil Modification Practices

Soil modification practices used for range improvement generally bring about improvements in range productivity through increased conservation of water and water use efficiency. Many farming techniques and implements have been adapted for range use, and some have been developed specifically for range use.

Contour Furrowing

Contour furrows are grooves or ditches made in the soil by various implements (plows, chisels, furrowers, etc.). The furrows should be placed on the contour to collect runoff water and increase soil water storage. Furrow dimensions vary considerably from grooves 4 to 6 inches wide and 3 to 4 inches deep to as much as 2 feet wide and a foot deep. Interrupting the furrows with dams at intervals increases their effectiveness in ponding water and increasing infiltration.

Contour furrows have been used successfully in semi-arid regions to reduce runoff and improve infiltration for increased forage production (Fig. 11). Contour furrowing of poor condition range has been shown to reduce runoff and conserve more than one inch of water annually in the Great Plains. Increased herbage production follows improved water retention and storage and the transport of nutrients from surface layers to lower depths.

Contour furrowing is applicable on productive soils of restricted permeability on long uniform slopes with simple contour patterns. They are most effective when rainfall intensities do not greatly exceed the hydraulic properties of the furrows.

Terracing

Terraces differ from furrows in that they are larger and applied on the grade to allow controlled runoff. They are designed primarily for flood control and reduction of runoff and sedimentation on moderately steep slopes. Although terraces have been widely used in restoring critical watersheds in the West, their use is generally impractical except as a watershed treatment practice on rangeland.

Pitting

The creation of small basins or pits to catch and hold precipitation on the site has been used since the dust bowl days of the 1930s. Known as pitting, it is often used in conjunction with reseeding to enhance seedling establishment by concentrating nutrients and water.

Tools used for pitting vary widely. Almost any equipment capable of gouging, digging or in some way creating pits in the soil surface can be used. The most commonly used implements are: (1) modifications of disk-plows, and (2) spike-toothed pitters. Modified disk-plows gouge out long shallow pits while the spike type pitter creates small basins. Modifications of spike-tooth pitters are called aerators. Aerators use spikes or cleats to create pits and aerate the soil increasing water and air movement (Fig. 12).

Pitting has been effective in increasing forage production by as much as 100 percent, primarily due to enhanced water relations. The disturbance and better water relations increase productivity of the remaining vegetation and, through plant succession, make better plant communities. The value of pits in water retention depends on their density, size, depth and soil permeability. The pit effectively serves as a basin to collect water and allow soil penetration.

Pitting is best suited to medium textured soils with less than 8 percent slope. Its value is limited on sandy, rocky or brush covered soils.

Ripping

Ripping on rangeland is synonymous with chiseling or subsoiling on farmland. It is done to fracture compacted soil layers to allow water and root penetration. Implements used include chisel-type plows capable of penetrating to depths below soil hardpans to 36-inch depths. However, 12 inches or less is the most common depth of ripping on rangeland. Because of the soil disturbance and furrowing effect, ripping increases soil water penetration and can dramatically increase forage production.

Ripping can reduce surface runoff dramatically. **It is applicable on medium to fine textured soils with compacted soil layers.** Ripping should be done on the contour, and under dry soil conditions. Forage yield increases of 100 to 300 percent have been obtained from chiseling or aerating coastal bermudagrass, kleingrass and buffelgrass in south Texas (Fig. 13).

See "Renovation Practices to Improve Rainfall Effectiveness on Rangeland and Pastures" (L-5077) for more information.

Water Harvesting Practices

Microcatchments

Collecting runoff water by creating small basins or microcatchments is practiced in arid and semi-arid regions throughout the world.

Figure 13. Chiseling or aerating coastal bermudagrass, kleingrass and buffelgrass may increase forage yield by 100 to 300 percent.

The goal of microcatchments is to catch water and allow its storage in the soil rather than runoff. The water stored can be used for plant growth or ground water recharge. The basins concentrate water in a small area and provide extra water for plant establishment. Once plants are established, the catchment continues to collect water and nutrients for plant growth. The water that can be stored depends upon the size of the microcatchment and ultimately the effective depth of the soil profile (Fig. 14).

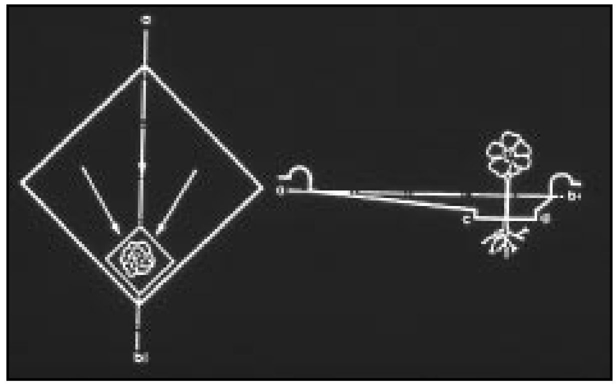

Figure 14. Schematic of a microcatchment. Microcatchments consist of a catchment area and an infiltration basin.

Microcatchments have been used successfully to establish saltbush and enhance establishment of herbaceous vegetation in the Trans Pecos region of Texas.

They are applicable in semi-arid regions on medium to fine textbook soils and on slopes of less than 5 percent.

Water Spreading

Water spreading was developed in arid regions receiving limited rainfall that falls during short, intense storms resulting in runoff. Water spreading is a simple irrigation method whereby flood waters are diverted from their natural course and spread over adjacent flood plains. Ditches, dikes, small dams, rock, brush and wire fences are used to divert flood flows and spread the water over the flood plain to allow infiltration (Fig. 15a and 15b). The water that penetrates is then available for plant growth or deep percolation.

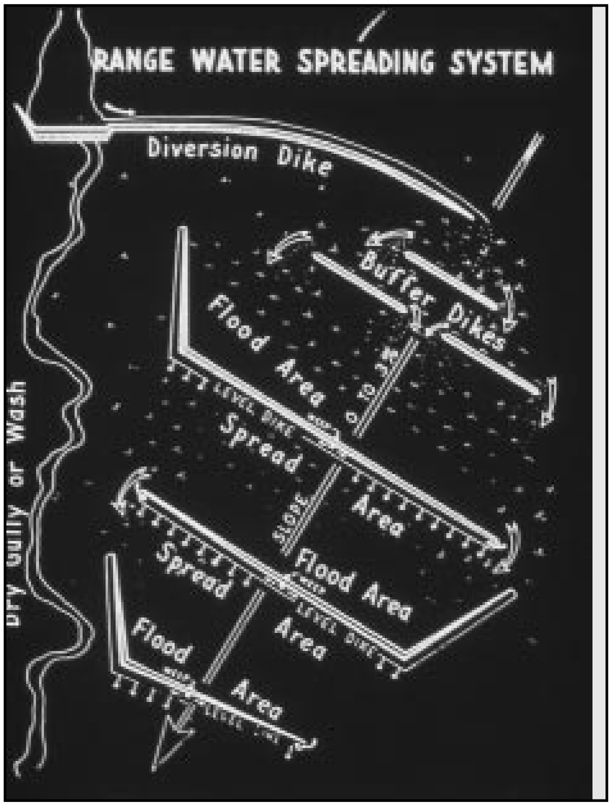

Figure 15a. Water spreading should be considered in arid regions with thunderstorm type rainfall. Flood waters are diverted from the stream channel and spread across the flood plain.

Figure 15b. A low wire fence across a wash in the Trans Pecos spreads water for better infiltration.

Water spreading is applicable where ephemeral streams are dry most of the time but flooding occurs during the growing season following heavy rains or snow melt. It has been applied effectively in semi-arid regions such as the Trans Pecos region of Texas.

Summary

The earth's water cycle is a closed system with a finite but indestructible quantity. The water budget of a particular ranch, however, is open and depends upon how much precipitation is received and how much water leaves the ranch.

The kind, amount and distribution of vegetation are the major variables affecting water use and loss from a range site. Within a particular climate, water loss through transpiration is proportional to the leaf area and the availability of water in the rooting zone. Grasses, especially bunchgrasses, provide the most desirable ground cover because they are the most water efficient, control erosion very well, and yield more runoff water off-site than shrubs.

Soil water content is greater under herbaceous cover, especially grasses, than under mixed-brush and herbaceous cover. Water yield increases resulting from vegetation management ultimately depend upon whether runoff and deep drainage water losses exceed transpiration losses.

Range management practices can affect both on-site and off-site water through their effects on vegetation composition and soil characteristics. The amount and quality of increased water availability depend on the original vegetation, soils and climate. Range improvement practices such as grazing management, revegetation, brush and weed management, and soil modification techniques directly affect the water regime.

Proper stocking should be the first consideration in range water management. Any grazing management strategy that enhances vegetative cover improves the water regime both in the pasture and down stream. Range seeding should be considered on severely depleted range and where vegetation modification practices call for a change in species. Seeding in conjunction with land surface modification techniques will enhance the probability of success.

Brush control with herbicides reduces transpiration losses, adds litter to the soil surface and increases water infiltration. Mechanical brush control methods enhance the water regime by creating soil disturbance, reducing transpiration and increasing infiltration. Both the on-site and off-site water regimes are enhanced.

Soil modification practices generally bring about increases in range productivity through increased conservation of water and improved water use efficiency. Practices applicable to Texas rangelands include contour furrowing, pitting, ripping, microcatchments and water spreading. Water harvesting practices such as microcatchment and water spreading systems collect runoff water that would otherwise be lost.

Additional Readings

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