Rainfed Farming

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INTRODUCTION

As farmers grow plants in a wide range of environments, rainfed-farming systems are highly diverse, ranging from intense production systems with high capital, equipment, and management investments to systems that consist of reseeding forage species with grazing animals harvesting the crop. Regardless of the size of the enterprise or the crop grown, a key to the success of rainfed-farming systems is soil water management. Crop plant productivity in rainfed systems is greatly determined by the amount and/or seasonal distribution of soil water and by the physiological capability of the plants to use that water. Systems that have been developed to increase crop yields include soil management techniques that optimize root zone water content and crop management techniques that best utilize the stored soil water plus seasonal precipitation. Continued increases in productivity of rainfed-farming systems will require a combination of improved soil and crop management practices. For a more in-depth treatment of the subject of rainfed-farming characteristics than space allows here, the reader is referred to Loomis and Conner[1] and Gimenez et al.[2]

SOIL MANAGEMENT

Under rainfed conditions, there are two water-related problems that farmers have to contend with; either not enough or too much water. For some farmers, particularly in humid areas, both of these problems can occur during the same growing season. Optimizing soil water content and using methods that minimize the effects of excess or ill-timed rain are important for timely application of agronomic practices, plant health, and, in many cases, crop quality.

SOIL MANAGEMENT UNDER CONDITIONS OF EXCESS WATER

A significant amount of land used for farming in humid regions is prone to excess water, at least during some part of the growing season. For most crops, a long period of excess water causes root damage or death because of lack of soil oxygen. Many common crops cannot survive flooded conditions for more than a few days. In addition, saturated soil conditions can increase severity of plant disease.

Agricultural soils prone to prolonged periods of excess water are generally relegated to grazing land or actively drained with subsurface drain lines. More recently, subsurface drainage has been replaced by controlled drainage, or water table management, to allow for better water management of the crops. With this, the same drain-line systems are used, but ditch outlets are controlled to keep ditches partially filled much of the time keeping the soil saturated deep in the profile. Controlled drainage conserves water for periods of low rain and reduces nitrate contamination of surface and ground water.

Excess precipitation often creates the most problems by affecting farming operations. Wet soils or long periods of rain can delay tillage, planting, farm chemical applications, and harvesting. Operating equipment on wet fields can severely damage soils by compaction and rutting. To help overcome crop losses because of too much rain, technological advances have been made in field equipment such as large tires and high horsepower tractors and harvesters that allow for field operations under wetter soil conditions. In addition, the post-harvest technologies of grain drying or ensiling forage and grain crops when animals are a part of the farm enterprise allow for earlier harvesting (which reduces the amount of time the crop is at risk from too much rain).

Encyclopedia of Water Science
DOI: 10.1081/E-EWS 120010095

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SOIL MANAGEMENT PRACTICES TO INCREASE PLANT AVAILABLE WATER

Water that falls on an agricultural field can become unavailable to crops in three ways, previously illustrated using the hydrologic balance.[3] It can run off the field before it enters the soil, it can enter the soil and drain below the rooting zone, or it can evaporate from the soil surface. In water-deficit conditions, management techniques to reduce these losses can have profound effects on crop productivity.

Reducing Runoff/Increasing Rainfall Infiltration

Techniques that farmers use to reduce water loss via runoff were originally designed to control soil erosion. By protecting the soil surface, those farming practices that increase the long-term sustainability of land for crop production and enhance environmental quality also increase the amount of rainwater that enters the soil.

Farming practices that have long been used to reduce runoff losses include terracing, strip cropping with alternating bands of sod and row crops, and contour plowing. These practices keep water from moving quickly down slopes, allowing it time to seep into the soil. A more recent practice, rapidly growing in use among farmers, is conservation tillage or any cropping system that keeps 30% of the soil surface covered with plant residues. Residues increase rainfall infiltration by acting as small barriers that slow water movement down slopes. Residues on the surface also absorb the force of raindrops that fall to the soil, reducing the packing effect of raindrop impact on the soil surface. If the surface layer of soil becomes packed, infiltration slows and more water is susceptible to runoff.

Increasing the Soil's Capacity to Provide Water

On many soils throughout the world, crop plants often become water-stressed because soil physical properties reduce the volume of soil that roots can grow into. Compaction is common throughout the world and can be caused by animal or machinery traffic, or be a natural characteristic of the soil. Current management systems to loosen compacted soils generally consist of some form of tillage. This can range from lightweight surface tillage implements designed to loosen and crumble compacted surface soils to large, energy-intensive tillage tools designed to loosen compacted subsoil layers. Relieving compaction stress generally results in increased crop yields, especially in rainfall-limited seasons and environments. Similarly, eliminating chemical restrictions to root growth, such as liming acid subsoils, increases the volume of soil for roots to extract water.

The capacity of the soil to provide water to plants can also be increased by enhancing soil water holding capacity with soil organic matter. Adding large amounts of organic material has resulted in crop yield increases in soil inherently low in organic matter. In conservation tillage, and especially no-tillage, improvements in yield can occur because the slowly decomposing residues that are left on the surface build soil organic matter near the surface and thereby increase water-holding capacity of the soil.

Reducing Soil Water Evaporation

A common method used to reduce soil water evaporation, especially in semiarid areas, is conservation tillage. Stirring and mixing the soil with tillage implements aerates the soil and exposes moist soil to the atmosphere where the soil water can quickly evaporate. Keeping the ground covered with plant residues also reduces evaporation rates by keeping soils cooler so there is less energy at the soil surface for evaporation. In addition, plant residues that are left on the soil surface act as a physical barrier to water vapor movement from the soil to the air.

CROP MANAGEMENT

In most rainfed-farming situations, variability in rainfall from year to year is more detrimental to the cropping system than is the lack of rainfall. Since farmers cannot plan for a specific amount of water for their crop each year, they tend to be cautious and limit inputs to levels that optimize a historically normal rainfall year. This management, quite different from irrigated farming where yield can be more accurately predicted, does not allow for the most efficient use of water in most years.

Water use efficiency (WUE) is calculated as the product of aboveground biomass of the crop and its harvest index divided by the sum of evaporation and transpiration (ET) ($\mathrm{WUE} = \mathrm{biomass} \times \mathrm{harvest\ index}/\mathrm{ET}$). Harvest index is the ratio of harvested product to the aboveground biomass. Production practices differ between forage and grain crops partially because of the differences in the contribution of harvest index to WUE and yield.

Biomass production of plants is closely related to the amount of water transpired; so forage production practices generally attempt to maximize early-season vegetative growth. To accomplish this, forages are usually solid seeded at high populations. This planting practice maximizes early season vegetative growth, minimizes E, and results in many roots across the entire surface layer so that more of the stored soil water is used. Grain crop

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species planted for forage are generally seeded at higher populations than when grown for grain; an example would be corn (*Zea mays* L.).

For grain crops, rainfed-farming practices must be designed so that the water needs of the crop are met during both the vegetative and the reproductive growth stages. Maximizing early-season vegetative growth, as is done with forages, can have a detrimental effect on yield in some environments if stored soil water is exhausted during that growth stage and rainfall during reproductive growth is not enough to prevent water stress of the crop. To reduce early-season water use, summer-seeded grain crops are generally planted at lower plant densities and often in wide rows. This increases the amount of water available per plant, and stores water in the soil for the reproductive stage. Some grain crops are solid-seeded such as wheat (*Triticum aestivum* L.), but they avoid excessive early-season water use by being grown in cooler climates or are planted so that vegetative growth occurs during the time of year when air temperatures are cool.

Farmers often grow a mix of crop species and cultivars under rainfed conditions. Growing crops with a range of maturities spreads the risk of water-deficit stress during the growing season. This practice is especially valuable for crops that have extremely sensitive periods to water-deficit stress, like silking in corn. Planting genotypes with a range in maturity ensures that not all of the crop will be in the sensitive period should short droughts occur. In addition, a wide range of maturities allows for more timely management at critical times during the growing season and at harvest. Similarly, planting dates of crops can be spread out to ensure a range of crop growth stages throughout the season.

Farmers generally apply less fertilizer to rainfed than to irrigated crops. Lower amounts of relatively immobile nutrients like phosphorous and potassium are applied because crop productivity is generally less under rainfed conditions than under irrigated, so lower amounts of these nutrients are removed from the fields with the harvest. Nitrogen fertilization schemes for grain crops under rainfed conditions generally include lower amounts early in the season, especially in semiarid and arid areas, because fast vegetative growth may deplete all of the soil water and result in drought stress during reproductive growth. In more humid areas, N amounts are generally recommended based on yield potential for average rainfall years.

Pests can reduce crop transpiration by competing for water resources (weeds), by reducing root numbers (insects and diseases), and by damaging leaves (diseases and insects). Insects and diseases that attack seeds and fruits can also reduce water-use efficiency by lowering harvest index. Pests are generally managed through crop rotations, mechanical means, and with pesticides, often using the principles of integrated pest management (IPM). With IPM, multiple methods of pest management are employed and applications of pesticides are based on in-field determinations of pest populations and economic thresholds. Where grown, new crop genotypes with insect and/or broad-spectrum herbicide resistance simplify pest management decisions.

CONCLUSION

New rainfed-farming practices will likely be combinations of soil and crop management practices. For example, farmers in the southeast United States traditionally grew soybean [*Glycine max* (L.) Merr.] in 76-cm wide rows (or wider) with conventional tillage practices and in-row subsoiling. Many hectares of soybean in the area are now being produced with conservation tillage in narrow rows (25-cm wide or less) and with deep tillage implements that loosen the entire surface horizon of soil. Yield increases with this conservation tillage system were realized in research[4] and by early farmer adopters of the technology, but the system gained rapid popularity with growers when new soybean genotypes became available that tolerated broad-spectrum herbicides. Integrating soil and crop management practices into systems that reduce water losses and increase the ability of crop plants to use soil water will continue to be a high priority of research to improve rainfed farming.

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