Water Management

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A superior water management program seeks to provide an optimal balance of water and air in the soil, which allows full expression of genetic potential in plants. The differences among poor, average, and record crop yields generally can be attributed to the amount and timing of the soil's water supply. Indeed, a large part of getting agriculture "right" involves getting the water "right." When there is not enough water, one irrigates and when there is too much water, one can improve land drainage.

Improving water management is an important way to increase crop yields. By minimizing crop-water stress—both too much and too little water—the producer obtains more benefits from improved cultural practices and realizes the full yield of the cultivars now available. Crops are particularly sensitive to water stress when they are undergoing reproductive growth.

To produce maximum yields, the soil must be able to provide water as it is needed by the crop. But the soil seldom has just the right amount of water for maximum crop production; a deficiency or a surplus usually exists. A good water-management program seeks to avoid both extremes through a variety of measures. These measures include draining waterlogged soils, making more effective use of the water-holding capacity of soils so that crops will grow during periods of insufficient rainfall, increasing the soil's ability to absorb moisture and conduct it down through the soil profile, reducing water loss from the soil surface, and irrigating soils with low water-holding capacity. This chapter is organized around those two themes: improving the drainage and irrigation.

Too much water: Improving drainage

In Illinois, the most frequent water management need is improved drainage. Close to 10 million acres of land have subsurface (tile) drainage, and another several million acres have some form of surface drainage system. Initial efforts in the 1800s to artificially drain Illinois farmland made our soils among the most productive in the world. Excessive water in the soil limits the amount of oxygen available to plants and thus retards growth. This problem occurs where the water table is high or where water ponds on the soil surface. Removing excess water from the root zone is an important first step toward a good water management program. A drainage system should be able to remove water from the soil surface and lower the water table to about 12 inches beneath the soil surface in 24 hours and to 21 inches in 48 hours. In most Illinois soils, this is equivalent to removing 3/8 inch of water from the soil profile in 24 hours.

Benefits of Improved Drainage

A well-planned drainage system provides a number of benefits: better soil aeration, more timely field operations, less flooding in low areas, less surface runoff, better soil structure, better incorporation of herbicides, better root development, higher yields, and improved crop quality.

Soil aeration. Good drainage ensures that roots receive enough oxygen to develop properly. When the soil becomes waterlogged, aeration is impeded and the amount of oxygen available is decreased. Oxygen deficiency reduces root respiration and often the total volume of roots developed. It also impedes the transport of water and nutrients through the roots. The roots of most nonaquatic plants are injured by oxygen deficiency, and prolonged deficiency may result in the death of some cells, entire roots, or, in extreme cases, the whole plant. Proper soil aeration also will prevent rapid losses of nitrogen to the atmosphere through denitrification.

Timeliness. Because a good drainage system increases the number of days available for planting and harvesting, it can enable more timely field operations. Drainage can reduce planting delays and the risk that good crops will be drowned or left standing in fields that are too wet for harvest. Good drainage may also reduce the need for additional equipment that is sometimes necessary to speed up planting when fields stay wet for long periods.

Surface runoff. By enabling the soil to absorb and store rainfall more effectively, drainage reduces runoff from the soil surface and thus reduces soil erosion.

Soil structure. Good drainage is essential in maintaining the structure of the soil. Without adequate drainage the soil remains saturated, precluding the normal wetting and drying cycle and the corresponding shrinking and swelling of the soil. The structure of saturated soil will suffer additional damage if tillage or harvesting operations are performed on it.

Herbicide incorporation. Good drainage can help avoid costly delays in applying herbicide, particularly postemergence herbicide. Because some herbicides must be applied during the short time that weeds are still relatively small, an adequate drainage system may be necessary for timely application. Drainage may also help relieve the cool, wet-stress conditions that increase crop injury by some herbicides.

Root development. Good drainage enables plants to send roots deeper into the soil so that they can extract moisture and nutrients from a larger volume of soil. Plants with deep roots are better able to withstand drought.

Crop yield and quality. All of the benefits previously mentioned contribute to greater yields of higher-quality crops. The exact amounts of the yield and quality increases depend on the type of soil, the amount and timing of rainfall, the fertility of the soil, crop-management practices, and the level of drainage before and after improvements are made.

Drainage Methods

A drainage system may consist of surface drainage, subsurface drainage, or some combination of both. The kind of system needed depends in part on the ability of the soil to transmit water. The selection of a drainage system ultimately should be based on economics. Surface drainage, for example, would be most appropriate where soils are impermeable and would require too many subsurface drains to be economically feasible. Soils of this type are common in southern Illinois.

Surface Drainage

A surface drainage system is most appropriate on flat land with slow infiltration and low permeability and on soils with restrictive layers close to the surface. This type of system removes excess water from the soil surface through improved natural channels, human-made ditches, and shaping of the land surface. A properly planned system eliminates ponding, prevents prolonged saturation, and accelerates the flow of water to an outlet without permitting siltation or soil erosion.

A surface drainage system consists of a farm main, field laterals, and field drains. The farm main is the outlet serving the entire farm. Where soil erosion is a problem, a surface drain or waterway covered with vegetation may serve as the farm main. Field laterals are the principal ditches that drain adjacent fields or areas on the farm. The laterals receive water from field drains, or sometimes from the surface of the field, and carry it to the farm main. Field drains are shallow, graded channels (with relatively flat side slopes) that collect water within a field.

A surface drainage system sometimes includes diversions and interceptor drains. Diversions, usually located at the bases of hills, are channels constructed across the slope of the land to intercept surface runoff and prevent it from overflowing bottomlands. These channels simplify and reduce the cost of drainage for bottomlands.

Interceptor drains collect subsurface flow before it resurfaces. These channels may also collect and remove surface water. They are used on long slopes that have grades of 1% or more and on shallow, permeable soils overlying relatively impermeable subsoils. The locations and depths of these drains are determined from soil borings and the topography of the land.

The principal types of surface drainage configurations are the random and parallel systems (Figure 11.1). The random system consists of meandering field drains that connect the low spots in a field and provide an outlet for excess water. This system is adapted to slowly permeable soils with depressions too large to be eliminated by smoothing or shaping the land.

The parallel system is suitable for flat, poorly drained soils with many shallow depressions. In a field that is cultivated

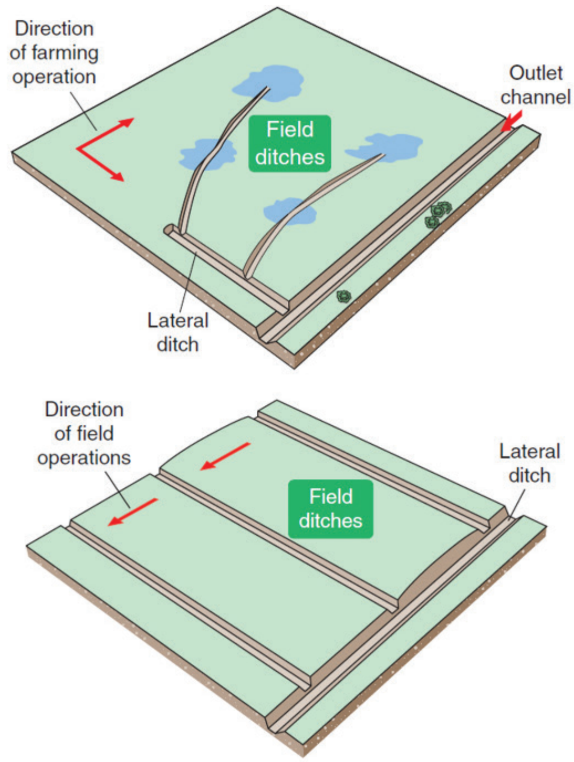

Fig. 11.1. Types of surface drainage systems: random ditches (top); parallel ditches (bottom).

up and down a slope, parallel ditches can be arranged to break the field into shorter lengths. The excess water thus erodes less soil because it flows over a smaller part of the field before reaching a ditch. The side slopes of the parallel ditches should be flat enough to permit farm equipment to cross them. The spacing of the parallel ditches will vary according to the slope of the land.

For either the random or parallel systems to be fully effective, minor depressions and irregularities in the soil surface must be eliminated through land grading or smoothing.

Subsurface Drainage

Many of the deep, poorly drained soils of central and northern Illinois respond favorably to the improvement of subsurface drainage. Historically these systems have been called “tile drainage” systems due to the clay tile cylinders used for many decades. Today, high-density polyethylene (HDPE) plastic pipe is most commonly installed, but many old tile drainage systems that today may be a mix of materials are still operating and the colloquial term, “tile drainage” is still most commonly used.

A subsurface drainage system is used in soils permeable enough that the drains do not have to be placed too closely together. If the spacing is too narrow, the system will not be economical. By the same token, the soil must be productive enough to justify the investment. Because a subsurface drainage system functions only as well as the outlet, a suitable one must be available or constructed. The topography of the fields also must be considered because the installation equipment has depth limitations, and a minimum amount of soil cover is required over the drains.

Subsurface systems are made up of an outlet or main, sometimes a submain, and field laterals. The drainpipes are placed underground, although the outlet is often a surface drainage ditch. Subsurface drainage conduits are constructed of clay, concrete, or HDPE plastic, as noted above.

There are four types of subsurface systems: random, herringbone, parallel, and double-main (Figure 11.2). A

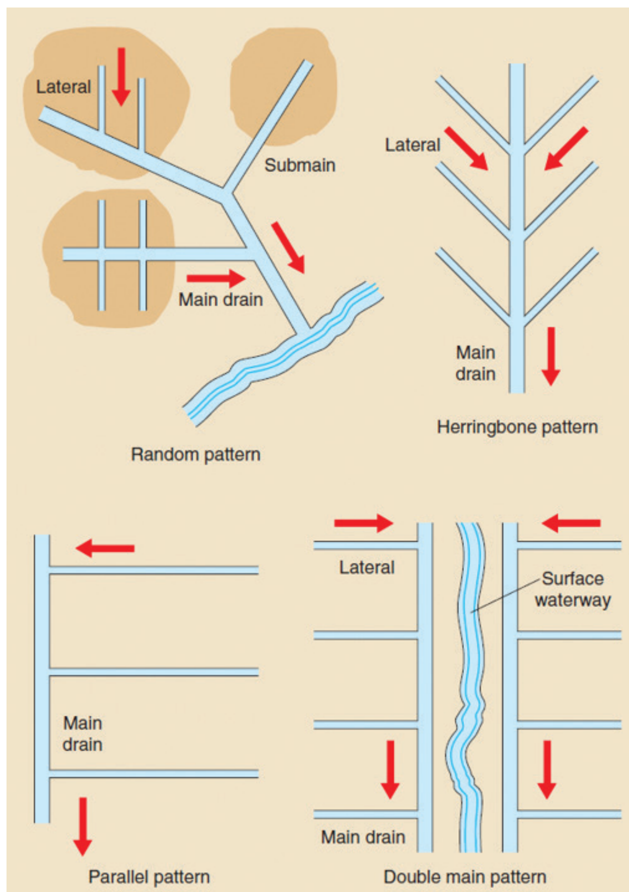

Fig. 11.2. Types of subsurface drainage systems. The arrows indicate the direction of water flow.

single system or some combination of systems may be chosen according to the topography of the land.

For rolling land, a random system is recommended. The main drain is usually placed in a depression. If the wet areas are large, the submains and lateral drains for each area may be placed in a gridiron or herringbone pattern to achieve the required drainage.

With the herringbone system, the main or submain is often placed in a narrow depression or on the major slope of the land. The lateral drains are angled upstream on either side of the main. This system sometimes is combined with others to drain small or irregular areas. Because two laterals intersect the main at the same point, however, more drainage than necessary may occur at that intersection. The herringbone system may also cost more because it requires more junctions. Nevertheless, it can provide the extra drainage needed for the heavier soils found in narrow depressions.

The parallel system is like the herringbone system, except that the laterals enter the main from only one side. This system is used on flat, regularly shaped fields and on uniform soil. Variations are often used with other patterns.

The double-main system is a modification of the parallel and herringbone systems. It is used where a depression, frequently a natural watercourse, divides the field in which drains are to be installed. Sometimes the depression may be wet due to seepage from higher ground. A main placed on either side of the depression intercepts the seepage water and provides an outlet for the laterals. If only one main were placed in the center of a deep and unusually wide depression, the grade of each lateral would have to be changed at some point before it reaches the main. A double-main system avoids this situation and keeps the grade lines of the laterals uniform.

The advantage of a subsurface drainage system is that it usually drains soil to a greater depth than surface drainage. Subsurface drains placed 36 to 48 inches deep and 80 to 100 feet apart are suitable for crop production on many medium-textured soils in Illinois. When properly installed, these drains require little maintenance, and because they are underground, they do not obstruct field operations.

More specific information about surface and subsurface drainage systems can be obtained from the Illinois Drainage Guide (Online) at http://www.wq.illinois.edu/DG/. This website addresses the planning, design, installation, and maintenance of drainage systems for a wide variety of soil, topographic, and climatic conditions.

Deciding to Drain

For the producer, the decision to install or improve a drainage system is a practical one, based on principles of good economics and good crop husbandry. If the benefits outweigh the associated costs, then drainage makes good sense. However, the cost–benefit analysis is not always clear-cut. The associated expenses include material costs, installation costs, and maintenance costs. There may also be other expenses, such as increased hauling costs associated with the increased yield that comes from drainage. Even more difficult to grasp and to quantify are the hidden costs associated with water quality degradation.

Many tools have been developed to help determine the practicability of drainage. The Illinois Drainage Guide (Online), for example, includes an economic analysis calculator (click the link at left for "Economic Considerations," then "Economic Analysis") that can be used to determine the profitability of a drainage system. It provides many measures of profitability, but they are all consistent with each other and are but a reflection of user preference. The measures of profitability used in the guide are listed here:

- The **net present value (NPV)** is the present value of the expected future cash flows minus the initial cost. A positive NPV value indicates a profitable system.
- The **profitability index (PI)**, also known as the benefit–cost ratio, is the ratio of the net present value to the initial capital investment. If the NPV is positive, then the PI is greater than 1.0, indicating that the benefits of a system outweigh the costs.
- The **internal rate of return (IRR)** is the rate at which the future cash flow, discounted back to the present, equals its price. It can be viewed as the interest rate that results in an NPV of 0 or a PI of 1. If the IRR exceeds the interest rate at which capital can be obtained, then the system is profitable.

- The **discounted payback time (DPT)** is the length of time it takes to recover the cost of an initial investment, considering the time value of money. For this measure, the value of future income is discounted by the cost of obtaining capital, that is, the interest rate charged on a loan.
- The **undiscounted payback time (UPT)** is the length of time it takes to recover the cost of an initial investment, without regard to the time value of money. In effect, the UPT is the same as evaluating the DPT under the assumption that the cost of capital, the interest rate, is 0.

Drainpipe spacing plays an important role in determining the cost of a subsurface drainage system. A typical drainage system in the Midwest is designed with a drainage coefficient of 3/8 inch, meaning it is designed to remove 3/8 inch of water in 24 hours, when the water table is initially at the soil surface. This drainage coefficient can be achieved with different combinations of depth and spacing. In Drummer Silty clay loam, for example, a 3/8 inch drainage coefficient can be achieved by installing drains 60 feet apart at a depth of 2.5 feet, or by installing drains 100 feet apart at a depth of 5 feet. The system with the more closely spaced laterals would be more expensive. In general, for a given depth, crop yield will increase with decreased drain spacing up to a point, beyond which yield is insensitive to decreases in spacing. In fact, computer simulations indicate that in some soils in some locations, it is possible to place drains so close together that yield is adversely affected. The objective is to determine the spacing that maximizes profitability.

Drainage Strategy

Once the decision has been made to incorporate drainage into a farm management plan, a good strategy is to start with fields or sections of fields that will benefit most from drainage. The proceeds from this exercise can then be applied to areas with lesser benefit until the desired coverage is achieved. It is important to remember that there may be situations in which the yield increase does not justify drainage, and the best option is not to install a drainage system in that field or section of a field. Under most conditions, drainage makes economic sense on most hydric soils. However, if the mains are too costly, if the outlets are distant and inaccessible, or if the soil is such that iron ochre or sedimentation would reduce the life of a drainage system to an uneconomic level, it is best not to install a drainage system.

Drainage Installation

The price of drain installation is dependent on many factors, including the equipment used in installation, the size of the job, the time of year when the system will be installed, the contractor's pricing structure, and the level of competition in the county or region. These factors make it worthwhile to obtain quotes from two or more drainage contractors. Different contractors have different pricing structures and business strategies.

The choice of a drainage contractor can significantly affect the profitability of a drainage system. Improper backfilling or grade reversals during installation can dramatically reduce the system's life, though problems may not show up in the first few years. It is best to select a contractor with a good reputation who will provide a performance guarantee. Take care to select someone who emphasizes quality rather than speed of installation. While it is possible to move through the field relatively quickly with modern drainage equipment, problems such as excessive tile stretch, and grade reversals, can be minimized by reducing the speed of travel to recommended levels.

Some producers choose to install their own drainage systems. In such instances, getting training on installation techniques is recommended. Such training is often offered by state extension services, trade associations, and equipment manufacturers. It is also strongly recommended that laser leveling or real time kinematic (RTK) GPS equipment be used in all drain installations. Because of the small slopes at which drains are typically installed, there is not much room for error, so using a properly calibrated laser level or an RTK GPS system is essential.

Light Detection And Ranging-based (LiDAR-based) digital elevation data is available for all counties in Illinois and can be accessed from the Illinois Height Modernization Program's website (https://clearinghouse.isgs.illinois.edu/). These data can be used for preliminary design and layout of drainage systems. The data are available in

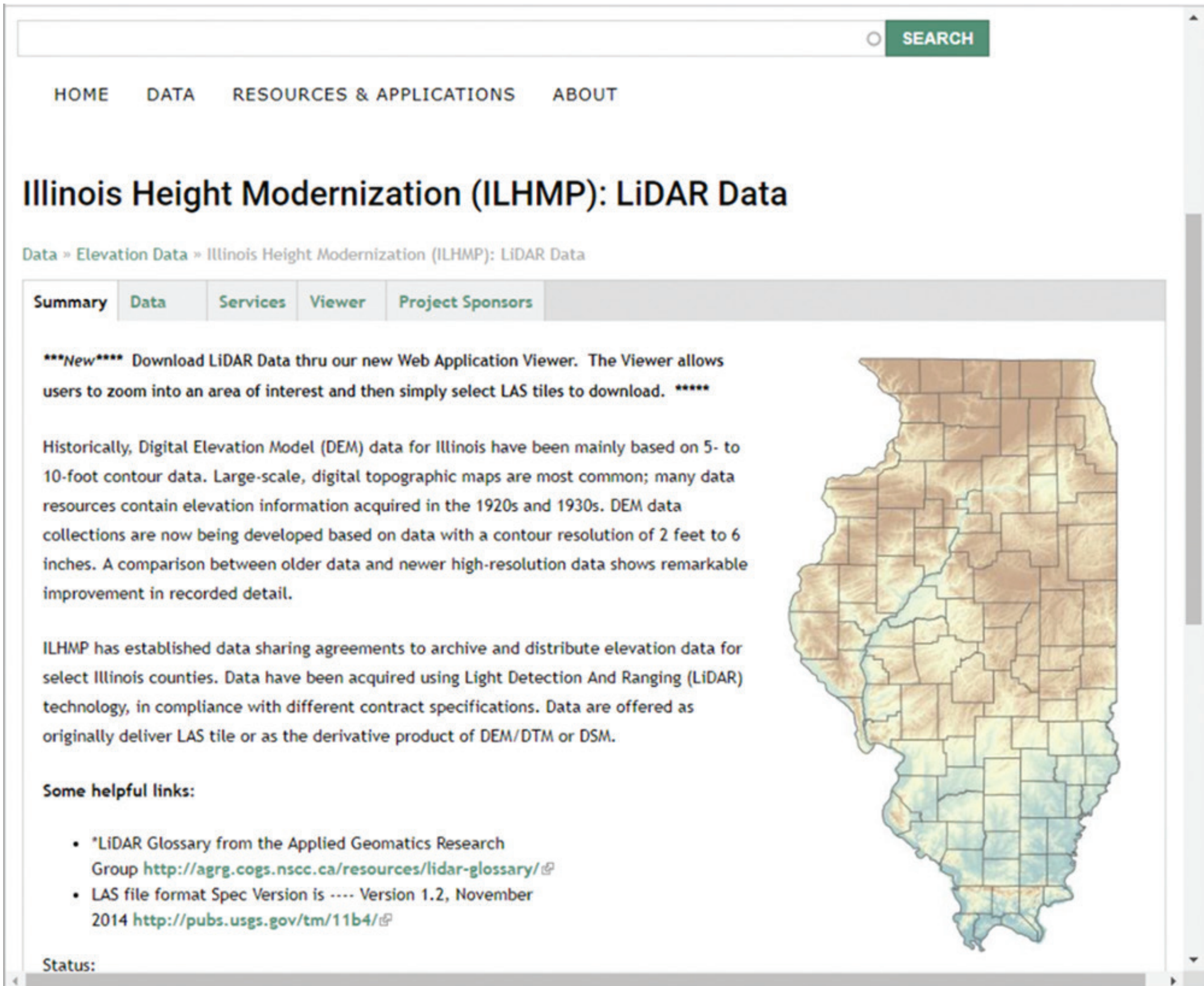

Fig. 11.3. Accessing Light Detection And Ranging-based (LiDAR-based) digital elevation data from the Illinois Height Modernization Program for preliminary design and layout of drainage systems.

many formats with the most easily accessible being LAS files under the VIEWER tab at the website (Figure 11.3). However, the LAS files are not suitable for drainage design as they include the elevation data for trees, buildings, or crops on the ground. The most suitable datasets for drainage purposes are the derivatives under the DATA tab. These derivatives include either a Digital Terrain Model (DTM) or a Digital Elevation Model (DEM), mostly with 4 feet x 4 feet cells, with ground elevation data. The recommended procedure for using LiDAR files for drainage applications is to download and expand the derivatives file for the relevant county and clip the DTM or DEM file using the boundaries of the required area.

Conservation Drainage

Across the Midwest, research is being conducted on management practices that improve drain outflow water quality without adversely affecting crop yield. Conservation drainage, as these practices are collectively termed, is the optimization of drainage systems for production, environmental, and water supply benefits. This concept includes the practices of: drainage water management (controlled drainage); denitrifying woodchip bioreactors; saturated buffers; constructed wetlands; blind inlets to replace tile risers; and drainage water recycling. The first three are discussed below.

Drainage water management, which is often referred to as the practice of controlled drainage, uses a control

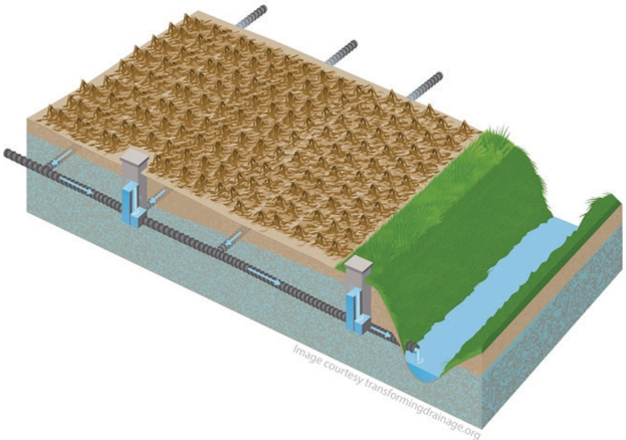

Fig. 11.4. The practice of drainage water management (AKA, controlled drainage) uses a series of control structures placed along the main to control the outlet elevation.

structure placed at the outlet, or a series of structures placed along the main of a tile system, to control the outlet level (Figure 11.4). The elevation of the outlet is controlled with these structures by adding or removing “stop logs” (AKA, plates, drop chutes, check dam boards) inside the structures. This practice can be used to raise the water level after harvest, thereby reducing nitrate loading from tile effluent, or to retain water in the soil during the growing season. The normal mode of operation in Illinois is to set the water table control height to within 6 inches of the soil surface on November 1 and to lower the control height to the level of the tile on March 15. Thus, water is held back in the field during the fallow period. Regionally this practice is considered to provide nitrogen loss reductions of approximately 30-45%. Research on the yield benefit of this practice has confirmed a benefit is possible but does not happen every year. Any such benefit may vary by soil and climate. The practice can also be used to benefit wildlife by creating ponded conditions in some fields during the fallow period, providing temporary aquatic habitats for migrating birds.

A **denitrifying woodchip bioreactor** is an edge-of-field conservation drainage option consisting of a trench filled with woodchips through which drainage water is routed (Figure 11.5). These trenches are most commonly between 30-100 feet long and 7-25 feet wide; their depth is set by the depth of the tile drainage system. The organic carbon in the woodchips fuels the natural process of denitrification where nitrate in the water is converted into nitrogen gas. Denitrification is a biological process performed by native denitrifying bacteria, hence the name *bio*-reactor. Woodchips are the most common media used, but other carbonaceous materials like corn cobs and wheat straw have also been tried in bioreactors. Using woodchips as bioreactor fill is generally thought to reduce maintenance because current evidence shows the woodchips last approximately 7-12 years before needing to be replaced. This practice is a recommended practice in the Illinois Nutrient Loss Reduction Strategy with a nitrogen loss reduction of 25%.

A **saturated buffer** is the newest of these three conservation drainage practices. This edge-of-field practice consists of a vegetated buffer area between a cropped field and the stream or ditch where the field’s tile drainage system outlets (Figure 11.6). A control structure intersects the main tile pipe and diverts the drainage water to flow underground through a tile pipe that runs parallel to the ditch. As the drainage water seeps through the buffer’s soil, natural processes convert the nitrogen in the water into harmless nitrogen gas and the plant’s roots uptake the water and nitrogen. Both processes reduce the amount of nitrogen sent downstream. The practice hydrologically reconnects the drainage water to the stream by converting the water back into shallow groundwater before it gets to the stream. This practice has recently been added to the list of recommended practices in the Illinois Nutrient Loss Reduction Strategy with a 40% nitrogen loss reduction.

Fig. 11.5. Construction of a denitrifying woodchip bioreactor at the University of Illinois Department of Crop Sciences Northwest Research and Education Center near Monmouth, Illinois (image: J. Chandrasoma/UIUC).

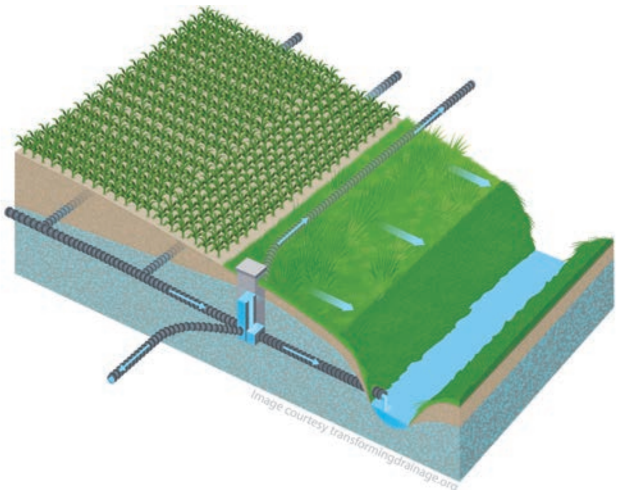

Fig. 11.6. A saturated buffer is an edge-of-field modification of the drainage system designed to meet both agronomic and water quality goals.

More information on conservation drainage can be found in the Illinois Drainage Guide (Online) at http://www.wq.illinois.edu/DG/. The Conservation Drainage Network also has many useful resources: https://conservationdrainage.net/.

Too little water: Irrigation

Benefits of Irrigation

During an average year, most regions of Illinois receive ample rainfall for growing crops, but as shown in Figure 11.7, rain does not occur when crops need it the most. From May to early September, growing crops demand more water than is provided by precipitation. For adequate plant growth to continue during this period, the required water must be supplied by stores in the soil or by irrigation. During the growing season, crops on deep, fine-textured soils may draw upon moisture stored in the soil if the normal amount of rainfall is received throughout the year. But if rainfall is seriously deficient or if the soil has little capacity for holding water, crop yield may be reduced. Yield reductions are likely to be most severe on sandy soils or soils with claypans. Claypan soils restrict root growth, and both types of soils often cannot provide adequate water during the growing season.

Water stress delays the emergence of corn silks and shortens the period of pollen shedding, thus reducing the time of overlap between the two processes. The result is

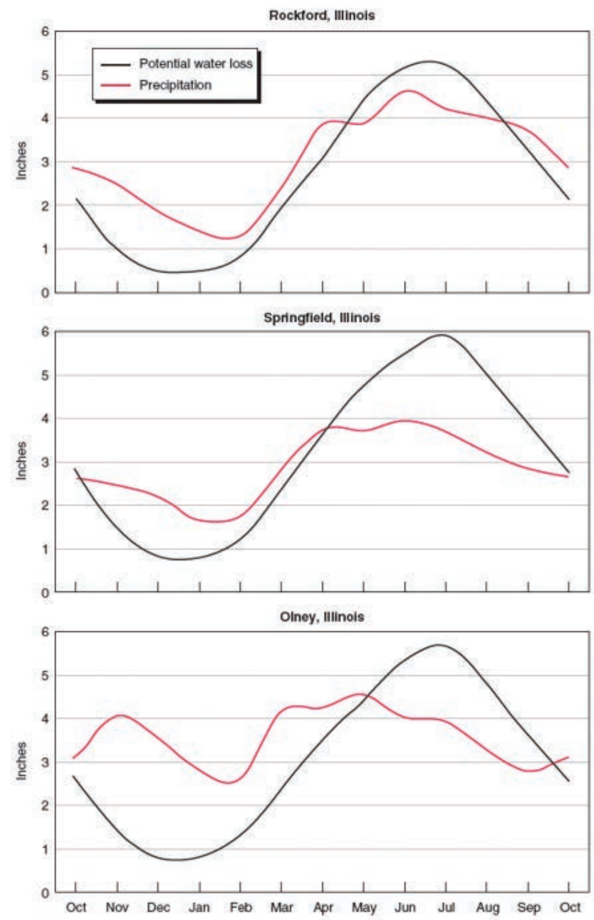

Fig. 11.7. Average monthly precipitation and potential moisture loss from a growing crop in three regions of Illinois.

incomplete kernel formation, which can have disastrous effects on corn yields. Corn yields may be reduced by as much as 40% when visible wilting occurs on four consecutive days at the time of silk emergence. Studies have also shown that severe drought during the pod-filling stage causes similar yield reductions in soybeans.

To prevent crop-water stress during the growing season, increasing numbers of producers are using irrigation. It may be appropriate where water stress can substantially reduce crop yields and where a supply of usable water is available at reasonable cost. Irrigation is still most widely used in the arid and semiarid parts of the United States, but it can be beneficial in more humid states, including Illinois. Almost yearly, Illinois corn and soybean yields are limited by drought to some degree, even though the total annual precipitation exceeds the water lost through evaporation and transpiration.

With current cultural practices, a good crop of corn or soybeans in Illinois needs at least 20 inches of water. All sections of the state average at least 15 inches of rain from May through August. Satisfactory yields thus require at least 5 inches of stored subsoil water in a normal year.

Crops growing on deep soil with high water-holding capacity, that is, fine-textured soil with high organic matter content, may do quite well if precipitation is not appreciably below normal and if the soil is filled with water at the beginning of the season.

Sandy soils and soils with subsoil layers that restrict water movement and root growth cannot store as much as 5 inches of available water. Crops planted on these soils suffer from inadequate water every year. Most of the other soils in the state can hold more than 5 inches of available water in the crop-rooting zone. Crops on these soils may suffer from water deficiency when subsoil water is not fully recharged by about May 1 or when summer precipitation is appreciably below normal or poorly distributed throughout the season.

Irrigation Methods

Irrigation methods include surface, sprinkler, subsurface, and micro-irrigation options. Surface methods include flood irrigation and furrow irrigation which are inexpensive and common globally, but most irrigation in Illinois uses sprinkler methods. Types of sprinkler irrigation systems include solid set systems, hand move and side roll systems, center pivots, and stationary or traveling guns. Micro-irrigation is the use of low pressure, low volume discharge devices (for example, drip emitters) supplied by small diameter surface or buried pipelines. Subsurface irrigation and fertigation are described below.

Subsurface Irrigation

Subirrigation can offer the advantages of good drainage and irrigation using the same system. During wet periods, the system provides drainage to remove excess water. For irrigation, water is forced back into the drains and then into the soil.

This method is most suitable for land where the slope is less than 2%, with either a relatively high water table or an impermeable layer at 3 to 10 feet below the surface. The impermeable layer ensures that applied water will remain where needed and that a minimum quantity of water will be sufficient to raise the water table.

The free water table should be maintained at 20 to 30 inches below the surface. This level is controlled and maintained at the system’s control structures, and water is pumped accordingly. In the event of a heavy rainfall, pumps must be turned off quickly and the drains opened. As a general rule, to irrigate during the growing season requires a minimum of 5 gallons per minute per acre.

The soil should be permeable enough to allow rapid water movement so that plants are well supplied in peak consumption periods. Tile spacing is a major factor in the cost of the total system and is perhaps the most important single variable in its design and effectiveness. Where sub-irrigation is suitable, the optimal system will have closer drain spacings than a traditional drainage system.

Fertigation

The method of irrigation most common in Illinois, the overhead sprinkler, is the one best adapted to applying fertilizer along with water. Fertigation permits nutrients to be applied to the crop as they are needed. Several applications can be made during the growing season with little or no additional application cost. Nitrogen can be applied in periods when the crop has a heavy demand for both nitrogen and water. Corn uses nitrogen and water most rapidly during the 3 weeks before tasseling. About 60% of the nitrogen needs of corn must be met by silking time. Generally, nearly all the nitrogen for the crop should be applied by the time it is pollinating, even though some up-take occurs after this time. Fertilization through irrigation can be a convenient and timely method of supplying part of the plant’s nutrient needs.

In Illinois, fertigation appears to be best adapted to sandy areas where irrigation is likely to be needed even in the wettest years. On finer-textured soils with high water-holding capacity, nitrogen might be needed even though water is adequate. Neither irrigating just to supply nitrogen nor allowing the crop to suffer for lack of nitrogen is an attractive alternative. Even on sandy soils, only part of the nitrogen should be applied with irrigation water; preplant and sidedress applications should provide the rest of it.

Other problems associated solely with fertigation include possible lack of uniformity in application, loss of ammonium nitrogen by volatilization in sprinkling, loss of nitrogen and resultant groundwater contamination by leaching if overirrigation occurs, corrosion of equipment, and incompatibility and low solubility of some fertilizer materials.

Deciding to Irrigate

The need for an adequate water source cannot be overemphasized when one is considering irrigation. If a producer is convinced that an irrigation system will be profitable, an adequate source of water is necessary. In many parts of Illinois, such sources do not currently exist. Fortunately, underground water resources are generally good in the sandy areas where irrigation is most likely to be needed. A relatively shallow well in some of these areas may provide enough water to irrigate a quarter section of land. In some areas of the state, particularly the northern third, deeper wells may provide a relatively adequate source of irrigation water.

Some farmers pump their irrigation water from streams, a relatively good and economical source if the stream does not dry up in a droughty year. Impounding surface water on an individual farm is also possible in some areas of the state, but this water source is practical only for small acreages. However, an appreciable loss may occur both from evaporation and from seepage into the substrata. Generally, 2 acre-inches of water should be stored for each acre-inch actually applied to the land.

A 1-inch application on 1 acre (1 acre-inch) requires 27,000 gallons of water. A flow of 450 gallons per minute provides 1 acre-inch per hour. So a 130-acre center-pivot system with a flow of 900 gallons per minute can apply 1 inch of water over the entire field in 65 hours of operation. Because some of the water is lost to evaporation and some may be lost from deep percolation or runoff, the net amount added is less than 1 inch.

The Illinois State Water Survey provides the most up-to-date information for irrigators interested in using a high capacity well or surface water intake. A high-capacity groundwater well or surface water intake is defined as a single point of withdrawal or a series of points that together pump more than 70 gallons per minute (which is equivalent to just over 100,000 gallons per day). All high-capacity wells or intakes in Illinois, including for irrigation, must be reported according to a 2010 amendment to the Illinois Water Use Act. See the Illinois State Water Survey for more information: https://bit.ly/3zAiZGE.

Irrigation Scheduling

Experienced irrigators have developed their own procedures for scheduling applications, whereas beginners may have to determine timing and rates of application before feeling prepared to do so. Irrigators often measure soil water and plant stress by taking soil samples at various depths with a soil probe, auger, or shovel and then measuring or estimating the amount of water available to the plant roots; inserting instruments such as tensiometers or electrical resistance blocks into the soil to desired depths and then taking readings at intervals; or measuring or observing some plant characteristics and then relating them to water stress.

Considering the moisture of the soil as a continuum, Figure 11.8 illustrates a very dry soil on the left to a saturated soil on the right. In a well-drained or artificially drained field, drainage occurs when the

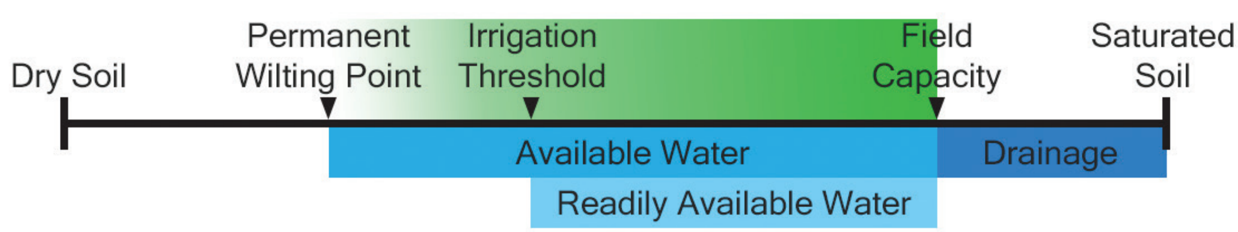

Fig. 11.8. The continuum of soil moisture status.

soil moisture status is between field capacity and saturation. **Field capacity** is defined as the water content of a soil when downward movement of gravitational water has ceased. The **permanent wilting point** is the water content of a soil when the water is held so tightly that roots cannot absorb this water and a plant will not recover from wilting. **Available water** is the water content in soil at field capacity minus the water content at the wilting point (Equation 1). However, there is an additional concept of "readily available water" relevant for irrigators.

Equation 1.

Available Water in inches =
(Field Capacity - Permanent Wilting Point) x
Root zone depth in inches

Readily available water is the amount of "easily" available water that can be depleted between irrigations without serious plant moisture stress occurring. Although, in theory, the crop can utilize 100% of the water that is available, the last portion of that water is not actually as available as the first portion that the crop takes from the soil. Much like with a sponge that is half wrung-out, the water remaining in the soil following 50% depletion is more difficult to remove than the first half. For irrigators, once readily available water in the soil profile has been used, an **irrigation threshold** is met such that the farmer determines an irrigation event would provide benefit. Readily available water is calculated as the available water multiplied by a management factor call the **management allowable depletion** (Equation 2). This depletion factor can vary by crop and growth stage; for corn, the factor is around 50% meaning that an irrigator would be comfortable using up to 50% of the available water before the irrigation threshold was met and an irrigation to the corn would be provided. The management allowable depletion and associated irrigation threshold are management decisions where benefit, risk, cost, personal objectives, and other factors are weighted by the irrigator.

Equation 2.

Readily Available Water in inches =
Available Water in inches x
(Management Allowable Depletion in %/100)

Management Requirements

Irrigation will provide maximum benefit only when it is integrated into a high-level management program. Good seed of proper genetic origin planted at the proper time and at an appropriate population, accompanied by optimal fertilization, good pest control, and other recommended cultural practices, are necessary to ensure the highest benefit from irrigation.

Farmers who invest in irrigation may be disappointed if they do not manage to irrigate properly. Systems are so often overextended that they cannot maintain adequate soil moisture when the crop requires it. For example, a system may be designed to apply 2 inches of water to 100 acres once a week. In two or more successive weeks, soil moisture may be limited, with potential evapotranspiration equaling 2 inches per week. If the system is used on one 100-acre field one week and another field the next week, neither field may receive much benefit. This is especially true if water stress comes at a critical time, such as during pollination of corn or soybean seed development. Inadequate production of marketable products may result.