# Cropping Systems Module

# Certified Crop Advisor

# State Performance Objectives

***General New Mexico Cropping Systems Competency Areas:***

1. Crop systems and rotation considerations
2. Factors that are part of production systems
3. Efficiencies in water use and tillage systems
4. Cover, green manure, trap and rotational crop management
5. Sustaining crop systems

***The objectives for the New Mexico Cropping Systems Module are:***

· Learn how crops are adapted for rotational systems
· Consider how water use and tillage systems affect crops
· Review cover, trap and rotational system selection in crops
· Consider crop aspects that make a system sustainable

***Pre-Study Questions for Review***

1. Tillage that inverts, cuts or shatters the soil below six inches and usually leaves the soil rough is know as _____ ?
   a. secondary tillage
   b. primary tillage
   c. disk plow operation
   d. coulter cut
2. The primary and secondary tillage operations performed to prepare seedbeds within a region are known as _____ tillage.
   a. minimum
   b. clean
   c. conservational
   d. conventional
3. This type of tillage system reduces loss of soil and possibly water compared to unridged or even clean tillage.
   a. minimum
   b. clean
   c. conservational
   d. conventional
4. This type of tillage system promotes the soil for seed germination and plant establishment without excess tillage operations.
   a. minimum
   b. clean
   c. conservational
   d. conventional
5. This type of tillage uses plant residues or other materials to cover the ground surface to effectively block excessive soil moisture evaporation and limit wind and water erosion.
   a. minimum
   b. clean
   c. conservational
   d. mulch

Check your answers before proceeding into the unit to find out how much you already know about the basic concepts on cropping systems. Each correct answer is worth 20 points, based on a total of 100 points for the five questions. Answers: 1. b.; 2. d.; 3. c.; 4. a.; 5. d.

***Crop Systems and Rotation Considerations***

Cropping systems are usually designed to improve soil tilth while maintaining a sustainable series of crops for the landowner. In specific instances, cropping systems may be used to leave some or all of the soil surface covered during part or all of the year in order to limit erosion from wind and water. Lessening damage from erosion will help improve the soil productivity and increase fertility availability to rotational crops. Appropriate cropping systems can protect both present and future crop productivity by controlling erosion and helping the overall crop system to build up soil and moisture resources.

Crop selection to include in a rotation is important as it affects the many of the production input factors such as seedbed type and preparation, seed variety and quality, seed treatment, seeding methodology and timing, fertilizer application, pest management, and even harvesting methods. It can also influence the movement of nitrogen through soil profiles and the transport of phosphorus to surface waters. Indeed, including legumes within the rotation sequence will allow crops that do not require supplemental nitrogen to effectively scavenge nitrogen remaining in the soil from previous crops. Crops will low nitrogen requirements used in sequence with crops that require high nitrogen inputs or even crops that inefficiently recover nitrogen can utilize the mineral more efficiently over a number of years. On soils naturally high in phosphorus, high phosphorus-demanding crops such as alfalfa in the rotation can help draw down or efficiently make use of this nutrient while also reducing soil and runoff losses to nearby surface waters.

Inclusion of a legume is commonly recommended within a long-term rotation sequence as legumes fix atmospheric nitrogen and also serve as an organic source of nitrogen. And, although legumes may also utilize inorganic nitrogen in the soil in preference to fixing nitrogen, deeply rooted legumes such as alfalfa can actually utilize soil nitrogen below the rooting depths of other crops such as corn. With the potential to extend its roots more than 18 feet into the soil, alfalfa can pull up nitrogen normally lost to other crops. This is especially true in medium to heavy textured soils more than in sandy soils.

These examples are just some of the considerations that should be made before deciding on cropping systems and rotations. Other factors to consider include: plant cover (crop and/or companion selections) that is adapted climatically and can easily be grown under the location conditions; amount of plant cover needed to protect soil and be sustainable; what type of crop can be grown based on the farmer’s experience and location; plant population needs and row spacing requirements; soil fertility and fertilizers; seasonal changes in plant cover; any crop residue utilization; if multiple cropping is possible; maintaining soil productive potential as well as soil structure; and, the cost analysis of each crop, each system (monoculture versus multiple cropping), and the additive requirements to plant, cultivate, maintain, control pests and harvest the crops.

Rotating crops usually means fewer problems with insects, parasitic nematodes, weeds and diseases caused by bacteria, viruses and fungi. Rotations are effective in controlling insects like the corn rootworm, nematodes like the root knot nematode in cotton and the soybean cyst nematode as well as diseases such as root rot of cotton and alfalfa. When you alternate just two crops, such as winter wheat and cotton, you have a very simple rotation. More complex rotations require three or more crops and a five- to ten-year (or more) cycle to complete. Rotations are important in any sustainable agricultural system, particularly in the south where multiple cropping can influence yields. Yields of crops grown in rotations can be ten percent higher than monoculture systems. For example, growing corn following grass hay or cotton following corn, you can get higher yields than when corn or cotton are grown year after year. This yield benefit is often called a rotational effect. Rotations also often provide another benefit. They may spread out labor needs and reduce risk caused by climate or market conditions.

Within rotations, the types of crops grown, their yields, the amount of roots produced, the portion of the crop that is harvested, and even how you treat crop residues all affect soil organic matter. Crops with extension root systems stimulate high levels of soil biological activity, thus roots of a healthy grass or legume-grass sod can return more organic matter to the soil than many other crops. The more residues crops leave in the field, the greater the populations of microorganisms and we are interested in not only soil organic matter but also a variety of organisms living in the soil in order to promote soil tilth and productivity. Tillage may also affect both the soil organic matter and the populations of soil organisms as well as earthworms. Having a variety of type of residues on a field is also important. A goal of a minimum of at least three different crop species within a rotation will encourage soil tilth. Farm labor and finances are also affected by the use of rotations. Varying crops by rotation allow farmers to spread labor over the growing season, often making it easier to utilize family labor alone and with more diversified crops, you are less affected by price fluctuations felt with only one or two crops giving more year-to-year financial stability.

***Factors that are Part of Production Systems***

With all the benefits, there are some costs and complicating factors to rotations. Labor and management capacity must be clearly defined before diversifying on a large scale. Equipment needs and conflicts in time, labor and money for growing different crops such as needs in cultivation and sidedressing that might occur at the same time hay harvest occurs must be considered. The more diversified the farm, the more organized and the less time available to relax.

Some of the general principles to consider before incorporating in another crop into your rotation include: follow legumes with high nitrogen-demanding crops, such as corn to take advantage of the nitrogen supply; grow less nitrogen-demanding crops such as small grains in the second of third year after a legume sod; grow the same annual crop for only one year, if possible, to decrease the likelihood of insects, diseases and nematodes becoming a problem; don’t follow one crop with a very similar species, again to limit pest problems from developing; use crop sequences that promote healthy crops such as cabbage following onions or potatoes following corn; use crop sequences that will help in controlling weeds; use longer periods of perennial crops, such as alfalfa, on sloping land or highly erosive soils; try to grow a deep-rooted crop within your rotation such as alfalfa to scavenge for nutrients and water as well as promote soil tilth; grow some crops that will leave a significant amount of residue like sorghum or corn to maintain soil organic matter levels; and when growing a wide mix of crops, group the crops into blocks so that you can manage the timing of crop operations as well as cultural practices such as irrigation or other needs such as plastic mulch on specialty vegetables. One common example of a rotation in areas where vegetables as well as agronomic crops are grown is a two- to three-year alfalfa sod program within a larger six- to eight-year cropping cycle. In this example, the crops following the alfalfa are high-demanding crops such as corn or squash, followed by cabbage or cotton, and in the last two years crops that need a fine seedbed may be used such as lettuce, onions or carrots may be grown. Annual weeds are controlled in this rotation, especially due to the alfalfa harvesting as well as the change of crops and perennial weeds are decreased by cultivation during row-crop phases of the rotation. This rotation can also prevent or lessen compaction of soils and can cover the soil well during the time alfalfa is grown. Appropriate rotations can limit residue problems in following crops and thus reduce tillage needs. And, a nutrient management program is introduced to the system by the use of a legume before crops that are higher nitrogen users.

Within a single crop (monoculture) system, some of the requirements include:

1. additional pesticide and fertilizer inputs
2. less machinery and equipment
3. increased pest problems

4. increased opportunities for government program participation (as currently operated)
5. increased soil erosion potential.

On the other hand, crop rotations allow:

1. reduced fertilizer and pesticides
2. reduced soil erosion potential
3. a break in the pest cycles
4. additional machinery and equipment
5. potential improvements in yields by five to twelve percent
6. potential increases in soil fertility levels and tilth

***Efficiencies in Water Use and Tillage Systems***

Choice of crop may also demand that you look at water use efficiencies and tillage demands. Many crops will work under different tillage systems, however, optimizing the system is important. Ease of system management to the farmer, equipment needs available and avoidance of excessive pest problems all play a part in optimizing the cropping system. Likewise, using a system that can maintain a moisture supply to the crop over time, particularly during peak crop development times, is important. Even if irrigation is available, crops that are efficient in water use will cut water bills toward a more sustainable crop.

Different crops use different amounts of water and some are more efficient at using water supplies than others. Crops also vary in rooting depth and length and thus vary in scavenging ability for moisture in the soil profile. The evaporation-transpiration rates on crops also vary, thus in dry climates like the semi-arid to arid climates in New Mexico, crops more efficient at retaining moisture during the heat of the day, such as grain sorghum, that are grown in areas where irrigation is not used are important. However, grain sorghum can also use quite a bit of water from the soil supplies and thus may not be as efficient a water use plant as alfalfa. Crop economics for cost of production and ultimate value of the crop must also be considered before deciding which crops to include in your cropping system.

One way to determine crop water use efficiency is to determine how much water from the soil profile (replenish by irrigation) is used to complete the life cycle of the crop. Many studies have defined allowable soil water depletions as applied to specific crop-soil-climate combinations with the use of many types of irrigation systems. However, the table of the Taylor (1965) and the Hagan and Stewart (1972) summaries for their research may provide a quick look at water use by crop by showing the water depletion that can occur with some crops.

***Root Zone Water Depletion between Irrigations for Near Maximum Crop Yields***
(using irrigation scheduling on set type sprinkler and non-automated gravity systems)

| Crop | Depletion of Available Water (percent) | Root Zone Depth (deep soil irrigation) (inches) |
|---|---|---|
| Alfalfa | 30-50 | 47-70 |
| Beans, dry | 50-70 | 23-35 |
| Corn | 40-60 | 29-47 |
| Cotton | 50-65 | 35-47 |
| Deciduous fruit | 50-70 | 47-70 |
| Potatoes | 25-50 | 23-35 |
| Sugarbeet | 30-60 | 35-47 |
| Grain sorghum | 50-70 | 35-47 |
| Soybean | 50-60 | 23-35 |
| Wheat | 50-70 | 35-47 |
| Vegetable crops | 25-50 | 23-47 |

Source: Hagan, R.M. and I.J. Stewart. 1972. Water deficits-irrigation design and programming. Proc. Of ASCE, Irrig. and Drain. Div. 98 (IR2):215-237. Taylor, S.A. 1965. Managing irrigation water on the farm. Trans. ASAE 8(3):433-435. As seen in Jensen. 1980. Design and operation of farm irrigation systems. ASAE monograph, no. 3, St. Joseph, MI.

For these same crops, there are growth stages that should not be deficit in moisture availability. In most crops, the key stage when moisture is needed for yield is during flowering. Listed below are the critical stages and the growth intervals when irrigation provides the greatest boost.

***Growing Periods that Benefit Most from Adequate Water Supplies toward Yield***

| Crop | Key Growth Period | Time when Irrigation Most Benefits |
|---|---|---|
| Sorghum | boot-heading | boot-soft dough |
| Wheat | boot-flowering | jointing-soft dough |
| Corn | tassel-pollination | 12 leaf-blister kernel |
| Cotton | first bloom-peak bloom | first bloom-bolls well formed |
| Beans, dry | flowering-early pod fill | axillary bud-pod fill |
| Potatoes | tuberization | tuberization-maturity |
| Soybean | flowering-early pod fill | axillary bud-pod fill |
| Sugarbeets | no critical stages | when water depletion is limited to 50% available Water |
| Alfalfa | no critical | maximized for full growth potential from start of spring growth until water supply is depleted |

Source: Jensen. 1980. Design and operation of farm irrigation systems. ASAE monograph, no. 3, St. Joseph, MI.

Many of the properties of crops and their crop canopies affect water use. The plant species, in some cases even the plant variety, affects the phenological development, rooting depth, leaf density and orientation, plant height and even plant morphology. The plant architecture (spacing and orientation) will also influence water use efficiency, as will the cultural practices around the plant such as row direction, plant population and even pruning on some plants such as grapes or fruit trees to influence water use. These factors affect reflection, absorption and transmittance in the radiation regime of the plant canopy that in turn affect water use efficiency. Plant leaf diffusion resistance and canopy resistance also depend on leaf morphology, light intensity, water deficits and other factors that control leaf stomata opening and closing and resistance to transpiration to ultimately affect water use efficiency. Even preconditioning with water stress events can affect water use efficiency on plants. Soil type, holding capacity and retention of moisture, and evaporation rates can also affect a crop's water use efficiency on a field. Plant rooting depth and root proliferation that is genetic as well as affected by preconditioning and soil texture and compaction also affect water use efficiency. Even crop plant leaf rolling or folding can reduce transpiration, thereby, affecting water use efficiency. Water can be lost to the environment through atmospheric demand (solar radiation effects, temperature effects, relative humidity effects, wind effects) which make semi-arid or arid environments more demanding on plants, testing plant water use efficiency. All of these factors mentioned above come together to determine the total amount of water lost from a field by both soil evaporation and plant transpiration and are known as losses from evapotranspiration (ET). The lower the range of seasonal ET for a crop plant, the less moisture that is required to maintain the crop.

Crop water requirements under drip irrigation or even in a dryland situation may be different from crop water requirements under surface and sprinkler irrigation primarily because the land area wetted is reduced, resulting in less evaporation from the soil surface. Also, the actual ET values will be affected by climate, soil, plant and cultural factors. Some of the average ET rates in inches over a cropping season are listed below.

***Approximate Range of Seasonal ET for Crops***

| Crop | Low Use Rate | High Use Rate |
|---|---|---|
| | Low (in) | High (in) |
| Alfalfa | 23.6 | 59.1 |
| Beans | 9.8 | 19.7 |
| Cotton | 21.7 | 37.4 |
| Deciduous trees | 27.6 | 41.3 |
| Small Grains | 11.8 | 17.7 |
| Corn | 15.7 | 29.5 |
| Onions | 13.8 | 23.6 |
| Potatoes | 13.8 | 24.6 |
| Sorghum | 11.8 | 25.6 |
| Soybeans | 17.7 | 32.5 |
| Sugarbeets | 17.7 | 33.5 |
| Vegetables | 9.8 | 19.7 |
| Vineyards | 17.7 | 35.4 |

Source: Doorenbos, J. and W.O. Pruitt. 1977. Crop water requirements. FAO Irrigation and Drain. Paper no. 24, FAO, Rome, p. 144.

ET gives an estimate of moisture needed to carry a plant through the season, however, the actual water use efficiency of a crop plant is expressed as a relation of dry matter production (DM) and the ET rate. The water use efficiency (WUE) is defined as:

$$\text{WUE} = \frac{\text{Dry matter production (DM)}}{\text{Evapotranspiration}}$$

Where DM is expressed as a unit weight per weight of plant water (such as pounds DM per acre/inch of water for ET or grams DM per hectare/centimeter water for ET). Differences in efficiencies exist between plant types. In general, most of the grass crops are $C_4$ plants (plants that respire and utilize energy within the plant more efficiently—in other words, a categorization of the plants based on their $CO_2$ fixation pathways) than broadleaf crops, $C_3$ plants. Use of WUE measurements can be made on plants in containers, on individual plants in the field or even on crop communities. These measurements can also be used with economic yield as well as total dry matter in the equation. WUE is not the same as drought resistance, but rather, refers to yield in relation to the water used to produce the yield. Water use efficiency research on crop plants usually works on attaining high WUE while maintaining high productivity. Increased crop yields in the past years have been obtained without much increase in seasonal ET, thus WUE has increased along with these increases in yields. In fact, management factors that reduce growth limitations of crop plants without significantly increasing ET will indeed increase the WUE. Fertilizer application, control of weeds and other crop pests, water conservation, improved tillage techniques, timely planting and even improved crop varieties all can substantially increase both yield and WUE.

A related term, water requirement, for crop plants is the reciprocal of WUE. Water requirement is expressed in terms such as pounds of water (ET) per pounds of dry matter (DM) or grams of water per grams of dry matter and is expressed by the following equation:

$$\text{Water requirement} = \frac{\text{evapotranspiration}}{\phantom{x}}$$

Dry matter production

In many cropping situations, the field ET is influenced more by the atmospheric demand, amount of ground cover and water availability than by the specific crop species. Listed below is some summary information showing the type of crop, average growth period, seasonal and daily average ET, seasonal and daily average DM, water requirement and the water use efficiency.

***Water Use and Dry Matter Productivity of Seven Crop Species under Well-Watered Conditions***

| Crop | CO2 Pathway | Growth Period (days) | Season (in.) | Daily (in.) | Season (#/A) | Daily (#/A) | Water Req. (#water/#DM) | Water Use Effic. (#DM/(A/in.)) |
|---|---|---|---|---|---|---|---|---|
| Corn | C4 | 135 | 26 | 0.19 | 15181 | 113 | 388 | 579.8 |
| Sorghum | C4 | 110 | 23 | 0.21 | 12949 | 118 | 402 | 559.6 |
| Potato | C3 | 128 | 21 | 0.17 | 8930 | 70 | 532 | 422.5 |
| Sugarbeet | C3 | 190 | 35 | 0.18 | 12949 | 68 | 606 | 370.8 |
| Wheat | C3 | 112 | 19 | 0.17 | 6876 | 62 | 613 | 366.3 |
| Soybean | C3 | 113 | 24 | 0.21 | 7591 | 67 | 704 | 319.1 |
| Alfalfa | C3 | 195 | 44 | 0.22 | 10002 | 51 | 993 | 227.0 |

Source: Jensen, M.E. 1973. Consumptive use of water and irrigation water requirements. New York, ASCE.

Tillage system as well as the plant canopy can affect evaporation from the soil surface. Tillage systems are often classified by the amount of surface residue remaining on the soil. Conservation tillage are those systems that leave more than 30 percent of the soil surface covered with crop residue, a level at which erosion can be significantly reduced. This does, however, depend on the amount of residue left after a crop is harvested and may vary greatly such as corn harvested for grain versus silage. Tillage systems are also classified by whether they are full-field systems (ex. moldboard plowing) or restricted tillage systems (ex. ridge-till).

Full-field systems manage the soil uniformly across the entire field surface and usually includes a primary pass to loosen soil and incorporate materials at the surface (such as fertilizers, amendments, weeds) and is followed by one or more secondary tillage passes in order to create a suitable seedbed. Some of the primary tillage tools used in this system may include: moldboard plows, chisels, and disks. The secondary tillage tools may include: finishing disks, tine or tooth harrows, rollers, packers, drags or other to create the uniform and often finely aggregated seedbed over the field. Moldboard plowing is less desirable as it is energy intensive, leaves very little residue on the surface and often requires multiple secondary tillage passes as well as can create plow pans. Chisels are less energy intensive and leave more residue on the soil surface and allow more flexibility in depth of tillage. Disks also usually perform shallow tillage and leave some residue and can be used both as primary and secondary tillage tools. Full-field tillage is used, even with the mentioned disadvantages, to overcome certain field problems such as compaction and high weed pressure.

***Generalized Tillage System Benefits and Limitations***

| System | Benefits | Limitations |
|---|---|---|
| Full-Field Tillage | | |
| Moldboard plow | easily incorporates | leaves soil bare |
| | buries surface weed seeds | destroys soil aggregation/organic matter |
| | dries out soils | surface crusting/erosion |
| | reduces compaction | can cause plow pans |
| | | high energy requirement |

| | | |
|---|---|---|
| Chisel plow | same as above, but more surface residues | same as above, but less soil destruction and erosion, crusting, plow pans as well as less energy use |
| Disk harrow | same | same |
| Restricted Tillage | | |
| No-till | little soil disturbed<br>few trips over the field<br>low energy use<br>erosion protection | incorporation of fertilizers/amendments difficult<br>wet soils slow to dry or warm up<br>can't alleviate compaction |
| Zone-till | same | same but less problem with compaction |
| Ridge-till | easy incorporation except phosphorus placement<br>weed control around ridges<br>seed zone dries/warms well | difficult to work with narrow-row crops<br>equipment must be adjusted to not disturb the ridges |

Source: Magdoff, F. and H. van Es. 2000. Building soils for better crops. CSREES, USDA.

Restricted tillage systems are centered around the idea that tillage can be limited so compaction and residue removal is limited. No-till does not involve any soil loosening except for a very narrow and shallow area of the seed zone using a fluted, ripple coulter on a planter. No-till is well adapted for coarse-textured soils (sands and gravels) as they compact less. However, it usually takes several years for the system to improve soils as microbial populations and management techniques take time to build up to optimize this system. Zone till, or conservation tillage, allows some soil disturbance around the plant row without disturbing the whole field. Multiple fluted coulters in front of the planter are often used to develop a narrow, finely aggregated seedbed and sometimes trash wheels are used to move residue away from the row. This system may also use a "zone building" pass during the off season to inject fertilizers, remove trash or hill disk (to overcome compaction problems). Besides also being called conservation tillage, it may also be referred to as limited tillage or strip tillage. Ridge tillage establishes a set row pattern (or ridge) using limited tillage. Used more in wet, cold soils, additive operations are done by banding fertilizers or pesticides and is more frequent on fine and medium-textured soils with wet, cold springs.

***Crop Residue Remaining after a Single Operation with Tillage Equipment***

| Implement | Proportion of Residue Remaining (%) |
|---|---|
| Sweeps (wide swath) | 90 |
| Sweeps (narrow swath) | 85 |
| Duckfoot cultivator | 75 |
| Rod-weeder | 90 |
| Rod-weeder with shovels/sweeps | 85 |
| Chisel | 75 |
| One-way disk plow | 50 |
| Tandem disk | 50 |
| Moldboard plow | 0 |

Source: Woodruff, N.P., C.R. Fenster, W.S. Chepil and F.H. Siddoway. 1965. Performance of tillage implements in a stubble mulch system. I. Residue conservation. Agron. J. 57:45-51.

Tillage practices and crop residue management also play a role in the way that irrigation systems perform and are managed. The practices affect the way water moves into and off of the soil (infiltration and runoff) and the way that water moves from the soil into the atmosphere (ET). Physical conditions such as soil texture, soil structure, field slope, field length, furrow shape as well as the amount of crop residue cover all affect irrigation performance. The way the irrigation is managed including furrow flow rate, length of application time and irrigation frequency also affect performance. Irrigation efficiency is often measured as the percentage of water applied that remains in the root zone after the irrigation event. Any deep percolation or runoff should be minimized. Tillage can affect furrow irrigation systems by altering the infiltration characteristics of the soil and the crop residue in the furrow. A change in tillage practice may cause changes in infiltration rates that are too severe to overcome with management factors alone and thus physical changes to the system may have to be made such as field slope or length of run, furrow packing or surged flow to overcome these problems.

In center pivot irrigation, the key problems encountered are runoff and erosion, especially if the application rate exceeds the infiltration rate of the soil. To lower pumping costs, some farmers may retrofit center pivots with low to medium pressure sprinkler packages and unless wisely done can cause sprinkler rates to be improperly matched with soil infiltration rates and lead to runoff and erosion problems. Simply reducing the application depth per irrigation may not solve the problem as this then increases the soil evaporation losses over the season. Crop residues under sprinkler irrigation will help reduce surface crusting and erosion from water droplets while increasing infiltration rates. Under center pivots, crop residues also act like small dams, allowing temporary soil surface storage of excess water that then may have time to infiltrate into the soil. Under irrigated conditions, improving water application uniformity across similar soils can result in more consistent infiltration rates, less runoff and reduced soil evaporation losses.

In a dryland situation, careful selection of tillage system may be even more important—especially in semi-arid to arid conditions. In low rainfall areas, crop residues may provide both a way to prevent excessive soil evaporation losses and a way to encourage moisture infiltration into the soil profile. Access to irrigation eliminates some risk in low rainfall areas and allows moisture to be available during peak plant use times. Dryland cropping requires that consideration of moisture management techniques be employed in areas where climate does not always cooperate with cropping cycles.

Selection of crops on higher residue fields is also a major management task. Personal preference, price outlook, fertility levels, potential pest problems (weeds, diseases, insects, small mammals) and the amount of vegetative cover must all be considered. For instance, corn may be a good crop under a low-till system as seed placement and depth are not quite as critical as in other smaller seeded crops. The wide diversity of herbicides available also open up alternatives to growing corn in low- or no-till systems. Limited weed control options in grain sorghum make no-till systems more difficult to work with but as this crop is often one of the better alternative in drier climates, crop residues can help in retaining moisture as long as seed is planted later when soil is warmer and drier so optimum germination and stand establishment can be achieved. Winter wheat can be no- or low-tilled but potential insect and weed problems as well as disease must be closely monitored. The same is true with cotton. Special insect and potential disease problems that can erupt in low-tilled cotton as well as strict requirements for residue plow-down (of at least cotton residue) may make farmers hesitant to try low-till systems even with crop rotations. In the South, the temperatures help in breaking down crop residue that otherwise might accumulate to levels that would be difficult to manage and although limited rainfall slows this process a bit in the Southwest, residue rarely creates a quantity or equipment use problem here. Consideration of low-tilling larger seeded crops that have a wider temperature range under which they may successfully germinate, should be considered if seasonal pest problems can be controlled economically.

Choice of tillage system will depend on soil texture and management strategy as well as equipment available, residue and soil characteristics, soil temperature, allelopathy, soil moisture and drainage, soil density, organic matter, soil aggregation, climate, crop rotation, traffic pattern/control needs, and in general tillage adaptability to the specific location. Cost comparisons on the different tillage systems have been done based on the factors above and crop models can compare systems. Some generalizations from these comparisons do suggest that as tillage is reduced, the number of operations are decreased and the size and number of machines required are decreased. Also, costs for machinery and labor decrease. Changing tillage practices does require careful consideration, especially if the change requires major machinery purchases. The major costs affected are generally the machinery needs and the herbicide needs.

***Cover, Green Manure, Trap and Rotational Crop Management***

Concerns with using cover and trap crops as well as the basic rotation crops run very similar to those when using crop residues. Cover crops can be effective in many cropping systems but for maximum benefit, they require management. Seeding methods must ensure good seed distribution, timely planting and good seed-soil contact. Good quality seed should be planted to ensure reasonable germination resulting in good stands. With many cover crops, they may have to be killed about 10 to 14 days before planting in order to eliminate any potential of allelopathy or crop interference, especially as shown in research on cotton following a cover crop system. In cover crops that remain in the field during and after the main crop is planted, management strategies and careful selection of the cover crop becomes even more important. Crops grown in tangent with one another must be compatible and not cause undo competition that might limit both. Often in either system (cover crop before the main crop or both grown in tangent or intercropped), adjustments to fertilization has to be carefully managed, especially for nitrogen. With grass covers, the nitrogen fertilizer may have to be increased or split applied. With legume covers, the nitrogen may have to be reduced by as much as 70 to 100 pounds, depending on the situation. With cover crops, planters will also have to be carefully adjusted to properly cut through residue, place seed at the proper depth and effectively close the planting slot to insure good seed-soil contact. Soil temperatures may also take longer to warm up with cover crops as with crop residues and in some cases either may need row-cleaners to improve stands for the main crop. The main disadvantages of using cover crops are the time and costs of establishment, negative impacts on crop nitrogen use efficiency (remember, C:N ratios may also be affected in this system), lower soil temperatures, and even soil water depletion by the cover crop. The benefits may include soil erosion protection, productivity improvement under well-planned systems and water quality enhancement in situations where poorer quality water is used. Cover crops may also improve soil physical properties such as increase soil organic matter, enhance microbial activity, promote soil aggregation and even lead to less soil compaction. Before growing cover crops consider these questions:

1. What type of cover crop should you plant?
2. When and how should the cover crop be planted?
3. When should the crop be killed or incorporated into the soil?

Also, you must consider what you want to accomplish with the cover crop in regard to the soil conditions and the climate. So further consider these questions:

1. Will the main use of the cover crop be to add available nitrogen to the soil or to provide large amounts of organic residue?
2. Is erosion control, especially in the late fall or early spring, a primary objective?
3. Is the soil very acidic and infertile with low availability of nutrients thus it may benefit from the use of cover crops?
4. Does the soil have a compaction problem that some cover crops could alleviate?

More information may be found with on-farm demonstration examples in the Sustainable Agriculture Network’s handbook number 3 on “Managing Cover Crops Profitably” which was produced in 1998 or in their handbook number 4 on “Building Soils for Better Crops” produced in 2000.

Green manure crops or forages that are plowed or disked in can benefit soil organic matter content, structure and permeability. The more growth on the forage, the better except that young succulent growth is best as it contains a higher concentration of plant nutrients and decomposes faster than older material (with less C:N tie-up). Thus, legumes that can also add some fixed nitrogen with incorporation have further benefits. Management of green manure crops is important so that the benefits outweigh any potential detriments due to residue breakdown and potential nutrient tie-up as with cover crops that are eventually turned under as green manure.

Trap crops are used to physically protect the plant against intrusions from pests or other materials or to eliminate the pest entirely. Trap crops are used to lure pests, such as insects, to a set area rather than into the main crop in other portions of the field. It may also serve as a simple barrier to disease or insect movement into another crop. It may be a different crop than the rest of the field such as a more susceptible crop or simply a more appealing crop to the pest it is being used to attract. Or, the trap crop may be the same type of crop but it serves as a narrow barrier to further entry of the pest into the rest of the field. Trap crops may also serve other purposes such as being used as an erosion barrier on one side of a field or through an arroyo area or as a filtration buffer to clean brackish water or to slow water movement into the main crop. Crop height, rooting system, quick establishment, ease of germination, thickness of crop cover, or susceptibility to the intrusive pest that the trap crop is being used to prevent are factors that may play into choosing a helpful trap crop. If the trap crop is effective in doing the job it was planted for without invading or disrupting harvest of the main crop, the program may be a success. However, if trap crops are not carefully chosen, the use of the barrier may be ineffective and the field space used for the trap crop wasted. Also, if pest numbers grow beyond the size of the trap crop, the trap crop may serve as an unwanted breeding ground for pests that may slowly gain ground into the main crop due to growing pest numbers. A careful evaluation of the true benefits of a proposed trap crop must be done along with a projected plan on pest numbers, location where the trap crop will be planted and alternative plans if pest numbers rise beyond expected populations as well as timing of the planting of both the trap crop and the main crop so that the trap crop is effective.

There are advantages as well as disadvantages to growing cover, green manure, trap or even companion crops within a cropping system. To recap, some of the advantages include:

1. these crops can protect the soil from erosion
2. with legumes, these crops may add plant nutrients to the soil
3. they can improve soil tilth for the major crop
4. managed correctly, they will allow the crops to be established during optimum growing conditions

Some of the disadvantages may include:

1. the potential for increasing pests
2. an increased water use requirement across the field
3. will probably add the expense of seeding of the companion crop

Rotational crop planning, as discussed earlier, requires preplanning so that the farmer can optimize the cropping systems to dovetail from one crop to the next without tillage, nutrient, pesticide or pest problems from one crop affecting the next. Two or more crops grown in a repetitive sequence on the same land constitute a crop rotation. Rotations may allow erosion, plant diseases and other problems to possibly be controlled while these same problems in a monoculture environment may explode into disastrous situations. For example, soil loss from a field of cotton might be cut in half when the cotton is grown following a forage crop rather than another row crop where more soil is exposed to wind and water erosion. Rotations can break insect and disease cycles, control persistent weeds and even knock down nematode populations that could rise to dangerous proportions in a monoculture.

Crop rotations may also provide more continuous cover than if the same annual crop is grown year after year. If the rotation is fixed and repetitive, management strategies can be planned so that annual cropping practices can be optimized. A crop rotation scheme over several fields will allow the farmer to diversify and have the various fields in a different crop within the rotation so that rotations among the crops can happen simultaneously on each field and among the fields. Flexibility even within these fixed rotations may be needed occasionally, depending on climate conditions on each field, crop prices and abilities of the farmer and his operation each year. For instance, long residual herbicides that may affect the crop rotation or even changes in the plans for the rotation must be considered if weather or crop prices for the year suggest that alternative plans for the crop rotation must be made. Also, if the labor situation or age of the farmer demands that less labor and management intensive crops be grown, the rotation program should be flexible enough to accommodate the needs of the family or corporation.

In some areas, fallow is recognized as an alternative within the rotation scheduling on land. Wheat studies through the Great Plains have shown that only 16-30 percent of the moisture that occurs while land is being fallowed is retained for future crop use. However, in some situations—especially on dryland, this water reserve may be critical to the next crop rotation. To optimize the use of fallowing, the maximum amount of water that can be retained and stored is encouraged by preventing vegetative growth, water runoff and surface evaporation on the land. The most difficult management is preventing weed growth without increasing soil erosion. Thus, when using a fallow program within the rotation remember the critical concerns are: weed control, keeping the soil surface porous to water infiltration but at the same time protecting the surface from excess evaporation and erosion.

### ***Sustaining Crop Systems***

Ultimately, the goal in farming is to have a cropping system that is sustainable. In order for a system to be sustainable, it must meet several criteria. Sustainable agriculture refers to an agricultural production and distribution system that:

- Achieves the integration of natural biological cycles and controls,
- Protects and renews soil fertility and the natural resource base,
- Optimizes the management and use of on-farm resources,
- Reduces the use of nonrenewable resources and purchased production inputs,
- Provides an adequate and dependable farm income,
- Promotes opportunity in family farming and farm communities, and
- Minimizes adverse impacts on health, safety, wildlife, water quality and the environment.

In order for a farm to meet all of these goals, the tillage system, the rotation scheduling, the crops choices, the timing of planting, the timing of harvesting and all the processes in between planting and harvesting should be viable and economic for the farmer. The systems should encourage at least maintenance if not build-up of soil tilth and nutrients to promote future crops or land uses. Soil should allow water to infiltrate easily during a downpour and drains well. The field should provide sufficient water to plants during dry spells or be supplemented with irrigation sources. The soil system should allow crops to fully develop healthy root systems and ultimately lead to sustainable yields. The cropping system should suppress root diseases and limit the advance of parasitic nematodes while limiting all other pest problems. Some questions you might ask for each field to determine how well the cropping system is working are the following:

1. Are yields declining?
2. Do crops perform as well as those on neighboring farms with similar soils?
3. Do the crops quickly show signs of stress or stunted growth during wet or dry periods?
4. Does the soil plow up cloddy and is it difficult to prepare a good seedbed?
5. Does the soil crust over easily?
6. If you are no-tilling, is it difficult to get the planter to penetrate the ground?

If any of the previous questions were answered as a “yes” then a closer observation on system needs and better management toward those identified needs on the field should be employed. Here in New Mexico, the Natural Resource Conservation Service has devised a checklist for soils that will indicate whether more intensive management to correct problems in the field should be employed based on a soil quality assessment. The checklist may have additional items added to it as you deem necessary.

***New Mexico Soil Health Card***

| Indicator | Poor | Better | Best |
|---|---|---|---|
| 1. Does the soil have structure and tilth? | Cloddy, powdery, and/or tight | Moderate amount of pores, tight | Porous, friable and crumbly |
| 2. Are there compacted layers in the soil profile? | Obvious hard pan; turned roots; poor plant growth | Moderate shovel resistance and root penetration | Easy penetration of wire flag or shovel beyond tillage layer |
| 3. Is the soil easily worked? | Many passes to create nice seedbed; requires lots of horsepower | Workable | Tills easily; requires little power to pull tillage implements |
| 4. Is the soil full of living organisms? | Little or no observable soil life | Some moving soil critters | Soil is full of soil organisms |
| 5. How fast does surface water infiltrate? | Water on surface for long periods after light rain or irrigation | Water drains slowly; some ponding after rain or irrigation | No ponding after heavy rain or irrigation |
| 6. How much plant residue do you see in and on the soil? | None | Small amounts of plant residue | Moderate to large amounts of plant Residue |
| 7. Is salt or alkali present in the soil? | Visible salt/alkali and/ or dead plants | Stunted growth, signs of leaf burns from salts, especially after rains | No visible salt, alkali, or plant damage |
| 8. What is the appearance of the crops? | Stunted growth, yellowing, low yields | Signs of stress, fair crown structure | Healthy and vigorously growing plants, high Yields |
| 9. How well do the plant roots grow? | Poor root growth and structure | Reasonable root growth and structure | Vigorous, healthy root system with desirable root color |
| 10. –Write in your indicators-- | | --Write in your own descriptions-- | |

Besides using the soil and the crop as indicators for sustainability of the land, other factors must also be considered. Some of these factors include: field selection and rotation; cash flow, return on investment, records and budgets; soil testing; setting yield goals (using historic data, water-yield relationships, and productivity indexes for the area); variety selection; seed quality; seed treatments, if needed; tillage-residue management; soil tilth; moisture management; seeding dates; planting rates (and any replant needs); fertilizer management (primary, secondary and trace nutrients); fertilizer application (needs and considerations); weed control (cultural, mechanical, biological, economic thresholds, herbicide effectiveness); disease control (influenced by rotation, controls, economics); plant lodging control; other efficient yield considerations; insect control (rotations, controls, economics); quality production management; growing degree days; scouting; use of integrated pest management; harvesting; storing; marketing; enterprise budgeting; economics versus cash cost budgets; direct costs; indirect (fixed) costs; and, putting all the needs, management and economics together.

Farming is one of the most complicated businesses to manage. Climatic, soil, crop, cropping system, management and economic factors all interplay to determine the final yield results. A farmer must combine his talents as an agronomist, a climatologist and an economist to farm sustainably. How well he pools these talents together each season with some luck, some knowledge and by limiting his risks as much as possible will determine how well he chose the crop, the field, the management tools, the timing and the harvesting within his cropping system.

***Post-Study Questions for Review***

1. Inclusion of a legume is commonly recommended within a long-term rotation sequence as legumes fix atmospheric _____ and also serve as an organic source of _____.
    a. Phosphorus
    b. Oxygen
    c. Nitrogen
    d. Sulfur
2. Yields of crops grown in rotations can be _____ percent higher than monoculture systems.
    a. 10
    b. 20
    c. 30
    d. 40
3. A goal of a minimum of at least _____ different crop species within a rotation will encourage soil tilth.
    a. one
    b. two
    c. three
    d. four
4. One of the general principles to consider before incorporating in another crop into your rotation includes following legumes with _____ nitrogen-demanding crops.
    a. high
    b. low
    c. grass
    d. broadleaf
5. One way to determine crop _____ is to determine how much water from the soil profile (replenish by irrigation) is used to complete the life cycle of the crop.
    a. dry matter accumulation
    b. water use efficiency
    c. water table depth
    d. dry matter total weight
6. In most crops, the key stage when moisture is needed for yield is during _____.
    a. germination
    b. emergence
    c. flowering
    d. seed maturity
7. Water can be lost to the environment through _____ demand (solar radiation effects, temperature effects, relative humidity effects, wind effects) which make semi-arid or arid environments more demanding on plants, testing plant water use efficiency.
    a. atmospheric
    b. sunlight
    c. wind velocity

    d. heat
8. The _____ the range of seasonal ET for a crop plant, the less moisture that is required to maintain the crop.
    a. more medium
    b. higher
    c. lower
    d. wider
9. Often in either system (cover crop before the main crop or both grown in tangent or intercropped), adjustments to _____ has to be carefully managed, especially for nitrogen.
    a. irrigation
    b. depth of planting
    c. seeding rate
    d. fertilization
10. There are disadvantages to growing cover, green manure, trap or even companion crops within a cropping system. Some of the disadvantages may include: the potential for _____ and an increased water use requirement across the field will probably add to the expense of seeding of the companion crop.
    a. decreased competition
    b. increased plant material over the field
    c. increasing pests
    d. decreasing pests

Check your answers before proceeding into the unit to find out how much you already know about the basic concepts on cropping systems. Each correct answer is worth 10 points, based on a total of 100 points for the ten questions. Answers: 1. c.; 2. a.; 3. c.; 4. a.; 5. b.; 6. c.; 7. a.; 8. c.; 9. d.; 10. c.