Kansas Rural Center
SUSTAINABLE AGRICULTURE
MANAGEMENT GUIDES

CROP ROTATION

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Crop rotations are fundamental to sustainable cropping systems. A well-designed crop rotation creates farm diversity and improves soil conditions and fertility. Unfortunately, too few farmers benefit from good crop rotations. Some farmers rotate corn or sorghum with soybeans or employ a rotation of wheat, sorghum and soybeans, but it is common for fields to remain in the same crop for three or more years. In spite of the importance of legumes to a good rotation, many fields have not been planted to a soil building legume such as alfalfa or clover as a green manure crop for many years.

Although widely advocated for centuries, the disciplined use of good crop rotations was never widely practiced in American agriculture. Beginning in the 1950's, as chemical fertilizers and pesticides became more readily available, the need to practice crop rotations declined and the use of rotation-based farming systems seemed obsolete. But the changing character of today's farming - the high cost of off-farm inputs, the growing incidence of pesticide and fertilizer contamination of water, the increasing resistance of certain weeds and insects to pesticides, soil conservation requirements for farm programs, and surplus production of major crops - points to the need for a renewed effort to adopt rotation-based farming systems.

Rotations are also an important management tool for no-till systems. Rotations build the foundation for integrated weed management to reduce herbicide costs.

Many agricultural researchers have outlined the benefits of crop rotation. But few have written in detail about planning or designing suitable systems. The rotation system must be tailored to suit the particular farm and farmer, and it involves many variables. Finding guidelines to tailor the rotation system and to organize the many variables is necessary for implementing an agronomically and economically sound crop rotation. Creativity and imagination also play an important part in shaping the system to suit the individual nature of the farmer and the farm.

The benefits of and barriers to adopting crop rotations are listed first. Following this summary is an outline of principles, guidelines, and design of crop rotation planning.

Benefits of Crop Rotations

A simple definition of crop rotation is the planting of different crops in recurring succession in the same field. Research findings support the many benefits attributable to good crop rotation systems (Francis et al. 1990). A specific crop rotation plan will not necessarily lend itself to every attribute, but farmers can try to get as many benefits as possible. The benefits usually associated with good crop rotations are:

- Maintains good soil physical condition and organic matter
- Improves distribution of plant nutrients in the soil by varying the feeding range of roots
- Improves fertility with legume nitrogen and, when using green manure crops, makes other plant nutrients more available
- Fosters the most effective use of manure and fertilizer
- Helps control weeds, some plant diseases and insect pests
- Reduces need for purchased herbicides and fertilizer
- Can enhance soil moisture management
- Promotes income diversity and stability through increased marketing options
- Better allocates farmer's labor and equipment usage through the year
- Improves crop quality and yields by 10 - 15%
- Provides low cost forages for livestock with return of manure on cropland
- Reduces the cost of conservation compliance
- Improves diversification and soil quality to reduce drought impact
- Reduces soil erosion. Increases flora, fauna and wildlife diversity and numbers
- Improves water quality through reduction in loss of agricultural chemical off-field

Barriers to Adopting Crop Rotation Systems

Various factors restrain farmers from adopting more extensive crop rotations. Technological developments such as fertilizers and herbicides, inadequate research, tax and credit programs and livestock consolidation have stimulated more monocrop farming.

Barriers to the adoption of rotation-based farming systems exist at both farm and institutional levels. Institutional barriers have included farm programs, research priorities, and market outlets. Farmers can more easily influence the farm level barriers, while solutions to the institutional barriers require public policy changes. Check off the barriers from the following list for which you will need to create solutions to implement your own crop rotation plan.

- ❑ Herbicide carry-over
- ❑ Farm rental arrangements make management decisions more complicated
- ❑ Need increased management skills and information
- ❑ Need altered or new equipment to match changed farming practices
- ❑ Additional storage units needed for wider variety of crops produced
- ❑ Need to add livestock to utilize forages

While technological developments played a key role in expanding the use of monocropping, technological advances also can help farmers more effectively use crop rotations. Modern, higher horsepower tractors and the more precise and effective tillage, planting, cultivation, harvesting and forage equipment work much better in rotation-based systems than the equipment commonly used 30 years ago. The advances in plant breeding, entomology, ecology, livestock breeding and computerized information systems are also very important.

The Key Role of Legumes In Crop Rotation Systems

Legumes play an essential role in obtaining many of the benefits from crop rotations (Gustafson, 1941, Hambridge, 1938, Leighty, 1938, Smith, 1911). A wide range of legumes allow a farmer to custom fit the most appropriate legume for various soil, climate, seasonal and cropping conditions. The more prominent forage and soil improving legumes in Kansas include: alfalfa, red clover, sweet clover, lespedeza, hairy vetch, soybeans, Austrian winter peas and cowpeas.

Key attributes of forage legumes include nitrogen fixation, erosion control, soil structure improvement, forage, cash hay and seed production. Legumes also can help farmers meet conservation compliance on highly erodible land. In rotation with other crops, legumes help break pest and disease cycles. Legumes can fit well into cropping schemes and also can enhance pasture production. Grasses interseeded with legumes can increase quantity and quality of forages and soil improvement over forage legumes seeded alone.

The soil improving character of legumes is increased when the legume is used as a green manure crop. Each small grain is an opportunity to introduce another legume in the rotation. Clovers and alfalfa overseeded in small grains can extend the annual productivity of the field as a double cropping strategy, while also helping to control weeds and soil erosion. In recent years, farmers and researchers have studied the potential of overseeding winter annual legumes such as hairy vetch and winter peas in row crops for soil improvement and erosion control.

The soil structure improvements associated with legume-based rotations increase the moisture holding capacity and drought tolerance of soils (Goldstein, 1989). However, in dry situations, legume sods used as green manures pose a risk of moisture depletion and must be managed accordingly. Any well-designed crop rotation should include legumes used as green manure crops.

Principles of a Sound Crop Rotation

Crop rotations can provide the basis for effective non-chemical weed control, much of a farm's soil fertility needs, and a stable business profit. To do so, the rotation should meet many of the principles listed below. Check off those principles that you want to incorporate into your rotational plan.

- ❑ Maintaining and improving soil productivity
- ❑ A legume for nitrogen fixation
- ❑ A grass or sod crop, alone or with a legume, for organic matter
- ❑ Targeting legume credits to the most responsive or high cash value crops
- ❑ Taking advantage of interseeding and cover crop opportunities
- ❑ Optimizing field residue cover
- ❑ Utilizing necessary soil conservation practices such as terraces, grassed waterways, windbreaks, contour strips, etc.
- ❑ Optimizing the symbiotic relationships between crop and livestock production

For rotation purposes, crops are typically divided into three main categories: (1) cultivated row crops, (2) small grain crops and (3) legume hay crops. Soil improving crops should alternate with soil depleting crops to maintain organic matter and soil fertility. Cultivated row crops should rotate with small grain and legume forage or green manure crops to conserve soil and break pest cycles. Likewise, rotating fall and spring planted crops helps to break weed cycles.

Designing the Plan

1. Set goals

The first step in any planning process is to identify and rank specific goals the plan should accomplish. While crop rotation systems can enhance all of the below goals, prioritizing them will help identify priority crops and suggest the most appropriate cropping sequence. Examples of crop rotation goals are listed below. Check off those goals that apply to you. Add additional goals as needed.

- ❑ Increase farm profitability and improve cash flow
- ❑ Reduce fertilizer costs
- ❑ Reduce herbicide costs through the disruption of weed cycles
- ❑ Diversify commodities to spread market and weather risks
- ❑ Enhance livestock profitability
- ❑ Improve soil conservation
- ❑ Spread labor and equipment usage throughout the year
- ❑ Improve soil structure and fertility
- ❑ Enhance interseeding and cover cropping opportunities
- ❑ Better utilize available land

2. Identify priority crops

The second step is to identify the priority crop or crops. Rotation plans are usually built around one or two leading grain crops and one or more legumes. The one or two leading grain crops may be for cash sale or feed and are often row crops such as corn, sorghum or soybeans. In lower rainfall areas, small grains such as wheat or barley are more important. T he leading crop will be the one you most want to grow on your own farm for cash sale or feed. If for feed, it is the crop more profitable to grow than purchase. Use this same criteria, with other agronomic factors, in selecting subsequent crop priorities. It is good to follow a row crop with a small grain. Legumes can often be interseeded in the small grain crop and may be grown for feed, cash sales, and soil improvement.

3. Calculate the needed quantity of priority crops

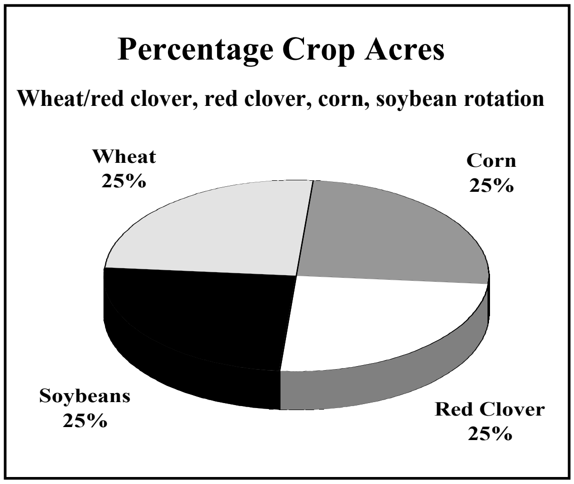
The third step is to determine the quantities of priority crops needed in pounds, bushels, tons and acres. One can then calculate the percentage of total acres required, such as 30% of acres for corn, 25% for alfalfa, etc. Considering economic and agronomic factors, one should then explore uses for remaining acres, looking for the options that best serve the rotation system and farm profitability.

4. Establish sequence and length of crops in the rotation

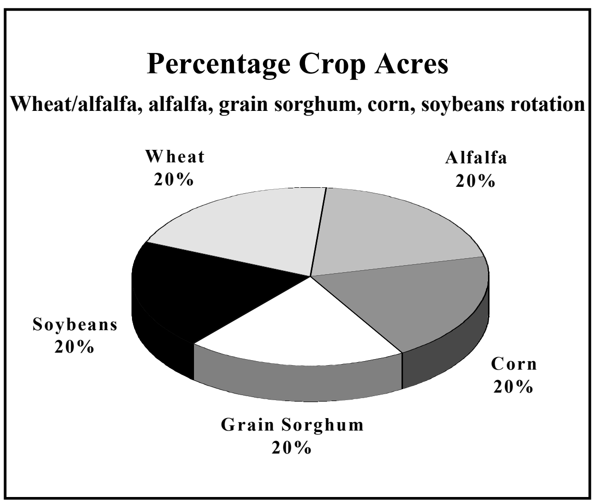
The fourth step is to establish the crop rotation sequence and length, taking into account the priorities, principles and considerations outlined above. If specific grain crops are more important, the rotation will tend to be shorter. Giving row crops and small grains more equal importance lengthens the rotation. And if forages are more important, or of equal importance with grain crops, rotations will be longer with more years of legumes and/or grasses.

To obtain the needed acres of cash, feed and forage crops, vary the number of years in the rotation, the number of times the crops occur in the rotation, or identify substitute crops. Corn and sorghum can substitute for one another depending on rainfall. Wheat, oats or barley can substitute for each other. Barley also can substitute for corn or sorghum as a feed grain.

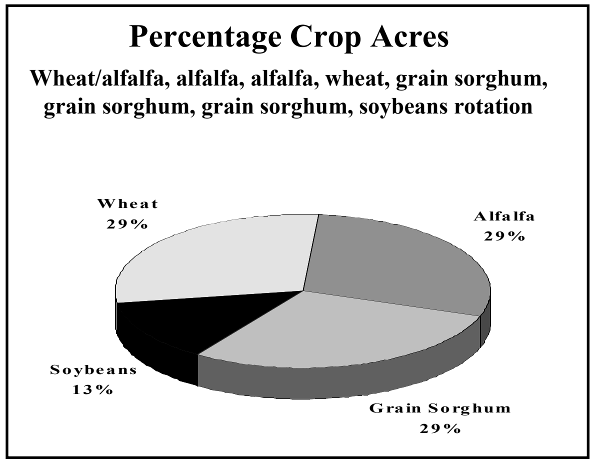
Alfalfa practically uses all of the available soil moisture for its own growth, thus leaving little moisture for the following crop. In KSU research, alfalfa ground contained four to six inches less soil water than wheat or corn ground measured to a depth of six feet. In KSU rotation research in the 1910's, sorghum was found to be the best crop to follow alfalfa because of its drought resistant qualities unless the cropland was bottom land or had high rainfall. In second and third years corn was more profitable. Small grains were chosen before the land was rotated back to alfalfa. This research preceded the popular introduction of soybeans in rotations (Jardine and Call, 1914). Introducing deep rooted crops in a rotation will require a higher level of soil moisture management. The following are examples of how crop percentages from different rotations can work.

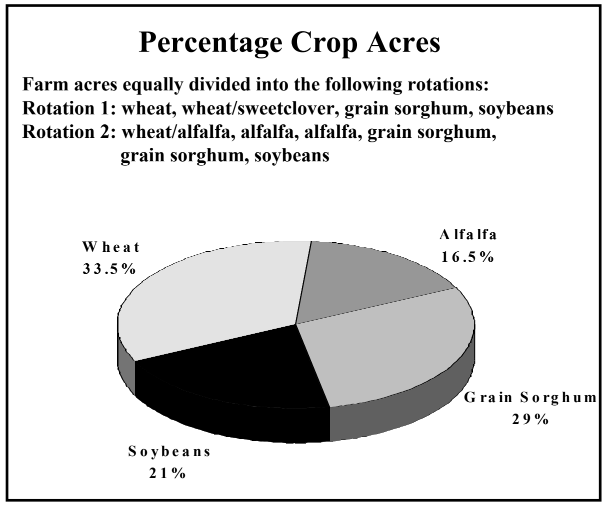


A farm may have more than one crop rotation. In areas such as central Kansas, where annual rainfall averages between 20 and 30 inches, wheat and sorghum are primary crops. Alfalfa, soybeans and corn are also common, and many farms still have livestock. Using two different rotations, one wheat based and one sorghum based, may be a way to retain larger acreage in wheat and sorghum, while also integrating more legumes into the rotation. A farm using a wheat/alfalfa, alfalfa, alfalfa, wheat, grain sorghum, grain sorghum, soybeans rotation would create this first mix of crops.



Introducing two rotations can dramatically change the overall crop mix. For example, substituting two rotations in place of a single rotation so that these two rotations split acres between a rotation of wheat, wheat/sweet clover, grain sorghum, soybeans and a second rotation of wheat/alfalfa, alfalfa, alfalfa, grain sorghum, grain sorghum, and soybeans would combine the rotations in the lower overall mix.





Under the two rotation systems in this example, wheat acres increase by 16%, grain sorghum acres remain the same, alfalfa acres decrease by 43%, and soybeans acres increase by 62% over the original crop acres in the single rotation. These examples show that the choices of possible crop rotations are indeed large.

Some of the rotations above may not be the best agronomic choices, such as milo following milo. In selecting a crop rotation sequence farmers must sometimes choose between conflicting agronomic and economic benefits. A farmer must strike a balance between agronomic and economic conflicts, while continuing to seek design features that resolve those conflicts.

Over time, modern farming systems have placed stronger emphasis on cash grain production, which is part of the trend toward concentration of livestock production. It is easier to design a good crop rotation for those farms that can profitably use legume forages. This lengthens the rotation, putting more acres in legume sods with corresponding benefits of conservation, improved soil fertility and condition, and better weed, insect pest and disease control.

5. Identify the strengths and weaknesses of the plan

As the rotation plan takes shape, one should identify the strengths and weaknesses of the plan in terms of priorities, and plan for compensating measures. These measures may include supplementing fertility with manure or fertilizer, purchasing additional "cheap" feed grains so more legume forages can be planted, adding livestock to utilize additional forage, or using legume hay for a cash crop. (The Crop Rotation Summary included in the back will help you plan a given crop rotation and evaluate the various components of the rotation system.)

When comparing the economics of alternative plans, give appropriate credits to fertility improvements, weed control, and other benefits. Allocating legume nitrogen credits, nutrient testing of manure, soil testing, crediting forage production along with income statement and cash flow analysis are some tools farmers can use for economic comparisons.

6. Establish the field plan on paper

The next step in designing a crop rotation is establishing the field plan. One may need to change the number of fields, field size and field boundaries to fit the rotation plan. If consistent acreages of each crop are needed each year and if the rotation plan provides the needed acres, then the minimum number of fields would be the same as the number of years in the rotation. One can then divide the crop acres by the number of years in the rotation to establish approximate field sizes.

For instance, if there are 200 crop acres and a six year rotation of wheat/alfalfa, alfalfa, alfalfa, corn, corn, soybeans provides the needed quantities of each crop each year, then having six fields with each field representing a different year in the rotation is needed to provide the appropriate crop quantities. By dividing 200 crop acres by six years, field size in this example should be approximately 33 acres each. In this example if rough terrain or other factors suggest smaller field size, dividing the farm into twelve fields of approximately 16.5 acres may work better. If the number of fields varies significantly from the number of years (or a multiple of the number of years) in the rotation, it will be impossible to get the needed quantities of each crop each year without diverging widely from the basic rotation plan.

The terrain of some farms is not so uniform as to make it easy to establish new field boundaries. If this is the case and the rotation system will not fit a field plan, the rotation plan needs further adjusting. Where there are one or two fields not suited for a rotation that otherwise works well, applying a different, better suited rotation only to the one or two fields may work best.

Field maps and charts are very helpful in establishing the field plan and in deciding if, when and how to change field size and numbers. FSA or NRCS can provide a copy of field maps from which to make duplicates. If the maps are too small, enlarge them to a workable size. Also, obtain or develop a field chart to show the field number and size and have columns to project the rotation over a period of years - at least through one rotation cycle. (See the Crop Rotation Field Plan in the back.)

A field chart is very helpful in determining the actual acreages of each crop each year over a period of years and in knowing exactly what to plant where in implementing the plan. Such long-term crop rotation planning also provides a plan for marketing, input purchases, utilization of manure and fertilizer, soil conservation compliance, and livestock production.

7. Test your plan

To tailor a crop rotation plan to a specific farm, one must consider several questions about the land, the farm, specific crops, available equipment and labor, and markets. As one adjusts the design of a specific rotation plan, he or she should revisit the following questions. Check off these questions you have satisfactorily addressed after you have drafted your rotation plan.

- ❑ Does this plan fit well with your rotation and farm goals?
- ❑ Are the cash crop and feed needs of the farm addressed?
- ❑ After figuring the market prices and production costs for the crops, is the projected profitability of the overall crop rotation plan satisfactory? (See attached Crop Rotation Economic Summary.)
- ❑ Are the planned crops suitable to the land and the climate?
- ❑ Does the farm have adequate equipment for the overall plan?
- ❑ Is the seasonal distribution of labor workable?
- ❑ Are the pest and crop disease problems manageable?
- ❑ Is there adequate land available for the rotation plan?

8. Implement the field plan

Once rotation planning is completed, one is ready to implement the plan. A farmer can phase in a rotation system over a period of years. If the field plan fits the rotation well, one can start with the legume phase of the rotation bringing in a new field into the rotation each year. Identify priority crops with the legume/soil building phase of the rotation and bring a different field into the rotation plan each year.

Remember that legumes drive the rotation system. A year before planting legumes a farmer should soil test and adjust soil pH to maximize the chances of successfully establishing the legume crop. As fields come out of the legume/soil building phase, the benefits of improved soil condition and fertility makes weeds easier to control. By phasing in the rotation, one also will find it easier to experiment with appropriate reductions in fertilizer and herbicide rates as well as other alternative practices.

9. Monitor implementation and redesign the rotation as necessary

The implementation phase will likely reveal the need for additional adjustments to the plan. Monitor the effectiveness of your rotation against the goals of your plan, changes in needs of your overall farm management and marketing strategy, and the rotation guidelines suggested earlier.

Conclusion

A good crop rotation is typically based on a long-term plan, though, within limits, it need not be inflexible. It may vary in details from year to year, and modifications can be made without disturbing the essential rotation plan (Leighty, 1938). Establishing goals and priorities and having a well-designed plan are necessary to practice rotation-based farming with discipline and flexibility. One must keep in mind the key role of soil building legumes and include them in the rotation. If the plan cannot be practiced with discipline and year to year variations are too great, the goals, priorities and the plan itself should be reconsidered. The importance of having an appropriate field plan should be recognized. Field sizes and boundaries will likely need to change. Finally, it takes time to discover and implement the best rotation plan for a particular farm and farmer. It is this path of discovery that makes rotation-based farming interesting and challenging, and it is one reason farmers who have switched to sustainable systems say they now enjoy farming more.

Farming has much room for improvement in the use of crop rotations, many good reasons exist for using more crop rotations, and modern technology makes rotation-based farming easier than in the past. The changing conditions of farming require farmers to rethink the design of their farming systems. The cost of resources, changing farm policy, soil conservation compliance and the prospect of greater environmental regulation are important factors farmers must consider. Disciplined, well-designed crop rotations have much to offer in meeting these critical constraints.

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CREDITS

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