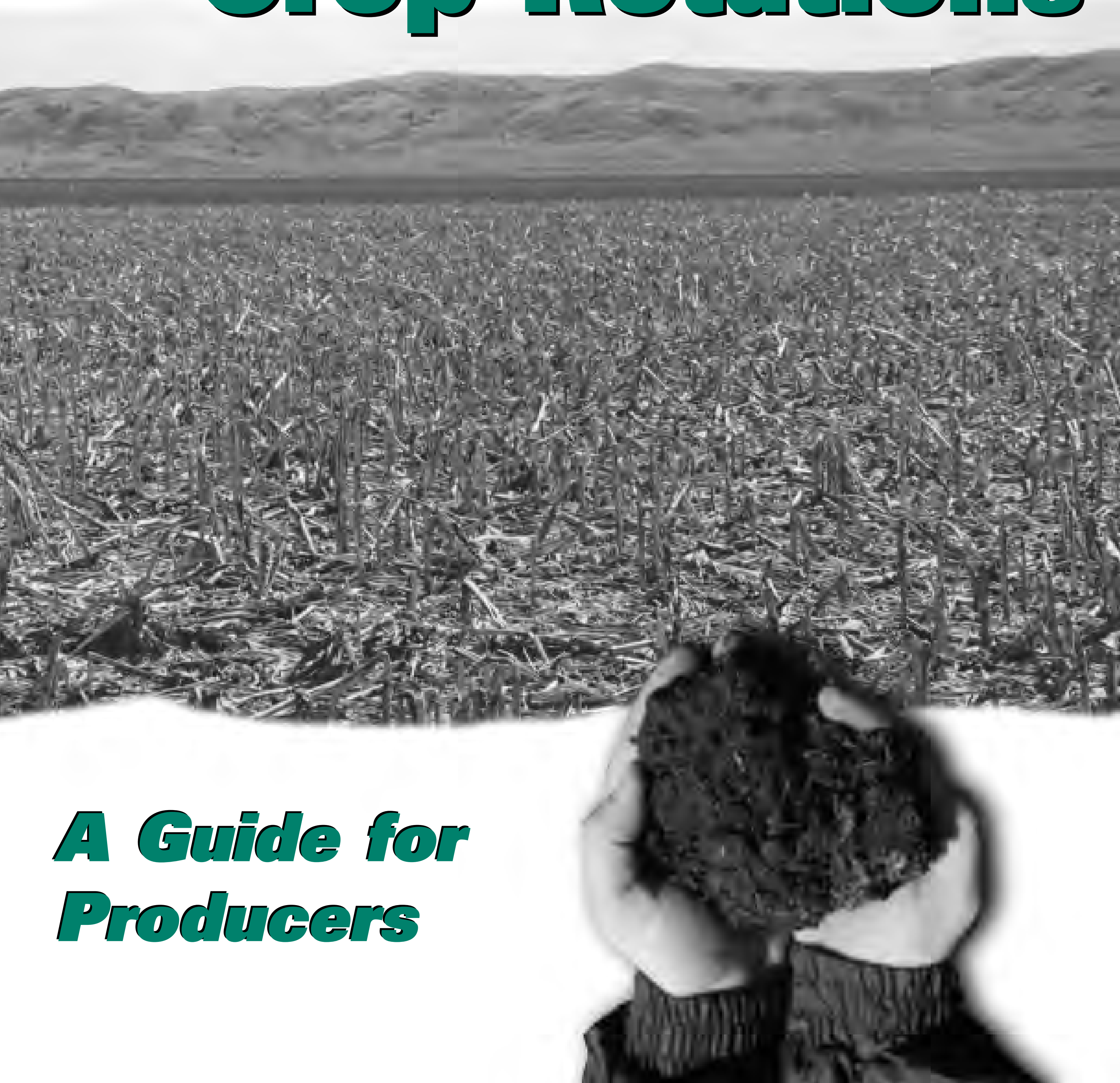
The Power Behind Crop Rotations



A Guide for Producers

Crop Rotations
The Lost Art

A diverse crop rotation system consists of growing different kinds of crops in planned sequences. This contrasts with the use of only one or two crops on all acres or haphazardly varying crop acreage ratios and sequences without regard for agronomic and environmental factors.

Historically, rotations have been much more diverse than they are at the present time. This loss of diversity was due to a myriad of economic driving factors including farm program characteristics; mechanization; development of nitrogen fertilizer sources and pesticides; and specialization in livestock production.

Interest in diversifying crop production systems has increased recently due to many factors. Commodity prices that are low relative to the costs of fertilizer, machinery, labor, and pesticide inputs, have led producers to examine means of reducing these costs. In addition, natural selection pressure resulting from longer histories of tight rotations and monocultures have led to species shifts, resistance, and/or changes in pest's traditional habits that have resulted in yield losses and/or use of higher priced technologies. Present farm legislation allows use of more diversity without loss of government payments.

Proper application of rotational planning can increase yields and reduce costs. Maintaining and improving soil health and fertility positively affects whole farm economics by reducing weed, disease, and insect pressure and resistance; spreading workloads to reduce fixed machinery and labor costs; providing more optimum planting and harvesting timing; and diversifying income and spreading weather risks.

Photo:

Winter wheat growing in flax stubble harvested with a stripper header. Two-year-old corn stalks are visible.

The Systems Approach

It is over simplistic to classify rotations as good or bad. Rather it is best to think of rotations as having differing characteristics in terms of their impacts on various aspects of the crop production system used by a particular grower in any given environment.

Designing appropriate crop rotations is a mix of art and science. Since all aspects (agronomic, environmental, economic, engineering) must be considered simultaneously, a systems approach is required.

Initial factors of most importance include:

- crop water use patterns (critical periods, rooting depths, and peak use periods),
- soil properties,
- historic rainfall patterns,
- snow catch ability,
- disease organisms,
- insect cycles,
- phytotoxic effects of residue,
- weed habits,
- profit potential,
- equipment needs,
- optimum row widths,
- seeding and harvesting dates,
- workload spread,
- individual attitudes, and
- access to markets.

For any given situation, there will be a range of rotations that will be agronomically appropriate. Within this range are rotations which have differing characteristics in terms of the risk they pose (market availability; labor or machinery requirements, etc.) which may make some more suitable for use in a particular location. **Management decisions must be made by individual producers to select the rotation or combination of rotations that is most appropriate for them.**

Economics

Proper crop rotation is a potentially powerful tool that can be used to manage risk and improve efficiency. Each operation must tailor the crop rotations used to the needs of that specific operation. Different fiscal and physical circumstances will dictate using different rotations. The goal of this publication is to offer methods that can be used to develop some of the skills needed for proper rotational planning.

Rotational Intensity

Rotation intensity is the level of demand for water created by the rotation. Cropping more frequently and including a larger proportion of high water using crops in a rotation will increase intensity. The level of water use by the system should match the water available under "normal" conditions. If fields are consistently too wet, then the current rotation lacks intensity. If fields are frequently too dry, intensity is too high. Using rotations that have both high and low intensity segments or employing multiple rotations which vary in intensity helps to protect against variable weather conditions.

Soil water holding capacity and water release characteristics are major considerations in determining proper rotational intensity. Deep soils with medium soil textures and high organic matter content will support the most intensity in any given climate. Shallow soils and soils with limited rooting depths, sandy textures, and/or low organic matter content limit the amount of rotational intensity that is possible.

Soil and climatic characteristics play a major role in determining how proper intensity is attained. For instance, a wheat-millet-canola rotation has the same average intensity as a wheat-sorghum-fallow rotation. The latter rotation would not be proper on a soil with limited water holding capacity since this soil can not store deep carryover moisture from the fallow and wheat years for use by the sorghum. Similarly, the first rotation would not be appropriate on a deep soil with high water holding capacity since none of these crops is capable of exploring sufficiently deep in the soil to fully utilize its capability.

Since tillage uses water, no-till rotations (in almost all cases) **must** be more intense than where tillage is used. Failure to use the extra water in a soil under no-till management increases weeds and diseases; lowers profits; increases saline seep problems; etc. In arid and subhumid areas where tillage based rotations contain fallow and/or a substantial proportion of low water use crops, intensity can be increased by eliminating or decreasing the amount of fallow; using cover crops in lieu of fallow (green fallow); shortening the fallow period; and/or growing or increasing the proportion of high water-use crops. In humid areas where conventional rotations consist entirely of high water use crops, intensity is increased by using double crop and/or cover cropping practices.

Several generations of experience in an area have probably found the appropriate level of intensity for tillage-based systems. This is not so with no-till cropping systems; other approaches are needed to determine and test initial rotational intensities when tillage is not going to be used.

One approach is to utilize local no-till rotational research results and experiences of neighbors who no-till under similar soil and climatic conditions.

The other approach is using a simplified method of calculating average rotational intensity (demonstrated on page 4). This approach allows comparisons of rotations that differ from the rotations used locally.

For those producers where no-till research and grower experience is not readily available, two methods are useful:

- The best draws on experiences of no-till producers in areas that have native vegetation characteristics similar to the area of interest. The native vegetation types that develop on any given site are indicative of the relationship that exists between the climate (rainfall, heat, etc) and the soil characteristics. Since these are the factors that determine proper rotational intensity, locations that share similar native vegetation also will require similar rotational intensity. Crops and methods used to obtain this intensity level may differ appreciably, however, depending on the circumstances.

- Another method has been successfully used on the land in question with conventional tillage. The starting point is calculating the intensity using the procedure on page 4. Then, increasing the rotational intensity by a factor of 33 to 300 percent. The lower amount applies where soil characteristics, climate, or crop choices severely limit the ability to store water or utilize water at deeper levels in the soil profile. The larger increase applies to situations with excellent soil characteristics, where surface residue levels are maintained at high levels, and the operator has the ability to withstand occasional low-income years in exchange for potentially higher average profitability.

Attaining proper crop intensity for any particular soil-tillage-operator situation assures that the most efficient amount of water is available for the crops in the rotation. It does not mean that there are never water deficits or that problems with excess water will not occur; just that the probability of these problems occurring has been minimized as much as possible in light of the available climate and soil characteristics, the tillage system used, and the operator's preference. Some operators may opt to use intensities at the low end of the appropriate range that increases the probability of excessive wetness while decreasing the chance of drought. Others may choose intensities near the high end of the range. Still others will use combinations of rotational intensities to spread risks.

It has been assumed that efforts to attain proper rotational intensity will be paralleled by a commitment to create adequate diversity in the crop rotation. This assures plants are healthy with healthy root systems that can take full advantage of the moisture available without having to share that resource with excessive numbers of weeds or lose yield potential to diseases, insects, or lack of nutrients.

Crop Diversity

The term diversity when applied to crop rotations means more than simply adding another crop or crop type to the rotation. In attempting to increase rotational diversity, an operator needs to focus on how crops interact with each other, with other species present, with the soil, with the environment, and with the operator's short and long-term goals. The reasons for increasing crop rotational diversity include: to spread weather and price risks, to manage weed populations, reduce plant diseases, manage workloads, create the proper environment for subsequent crops, reduce fixed costs per unit of production, access alternative markets, etc.

Producers should strive to achieve levels of diversity that are **adequate** to attain the goals established for their situation. Having less diversity than needed eventually leads to production and profitability problems. Adding more diversity than needed can reduce efficiency since it increases the number of crops that must be managed, handled, and marketed. Outside influences such as government subsidies, crop insurance, etc. tend to discourage diversity.

Defining and evaluating rotational diversity is much more challenging than dealing with intensity. This is partially due to the fact that rotations that lack adequate diversity to be successful over the long-term may perform very well for periods of 4 to 10 years before their weaknesses are exposed. Consequently, it is important that the method developed for quantifying rotational diversity which is outlined in this publication (pages 5&6) be seen as an exercise to improve understanding of some of the factors important to developing proper rotational diversity. It is not meant to be a comprehensive treatment of all of the factors involved in this subject. By necessity, many areas have been simplified to make this demonstration more straightforward.

The first simplification is to classify crop plants into one of four morphological and growth habits: cool season grass, warm season grass, cool season broadleaf, and warm season broadleaf. These different plant types will have different growth and maturity habits; nominal seeding and harvesting periods; water use characteristics; pest problems; etc. It is easier in the initial phases of diversity planning to focus on the gains that can be made by using differing crop types in the rotation. Subsequent fine-tuning must be made using specific crops since some crops from different groups share common diseases (most broadleaf crops whether cool or warm season are susceptible to white mold). On the other hand, some crops of the same type can be used to break a disease cycle (sunflower are not susceptible to soybean cyst nematode) or compete better with a specific weed (winter wheat or rye provide better opportunity to control wild oats than growing tame oats).

Crop substitutions can be made within a given crop type for added flexibility and allow the producer to maintain an agronomically sound rotation. For example, if conditions are unexpectedly too wet to plant corn timely, an alternative warm season grass could be planted at a later date such as grain sorghum or millet depending on the producer's current equipment (planting and harvesting), expected weed pressure, grain handling facility, market price, etc.

The diversity index calculations contained in this publication are intended to demonstrate potential impact differing rotations can have on reducing the probability that weeds, diseases, insects, workload problems, etc. will become a problem. It assumes good management practices are being used throughout the system. It also assumes that factors such as government subsidies, marketing opportunities, crop insurance coverage, agronomic information, labeled pesticides, operator knowledge, etc. are equivalent for all crops in the rotation. These assumptions are not necessarily true.

Briefly, the crop rotation diversity index as calculated on this scale increases according to the:

- years separating the same crop type,
- presence of both grass and broadleaf crops,
- presence of both spring and fall sown crops, and
- presence of warm and cool season crops.

Diversity index decreases if crops must be seeded and/or harvested during the same time period.



INTENSITY

The following are some points to help you complete the attached "Intensity Rating for Crop Rotations for soil water storage and use" and "Diversity Index for Crop Rotations" worksheets for crop rotations you are considering for your farm.

Intensity

- **Crop rotation intensity** means growing a combination of crops that will match soil water storage with crop water use under your local climatic conditions.

- The native vegetation will show what the long-term climate is like in your area. Adjust *crop intensity rating* to match a score that reflects the native vegetation in your area. (The ratings below are based on no-till farming methods that conserve moisture through residue management.Farming systems that rely on tillage should limit intensity ratings to at least .5 to 1.5 points lower than those shown below).

  Western & Central South Dakota - short/mixed grass prairie = intensity rating of 1.0 to 1.5
  Eastern South Dakota - mixed/tall grass prairie = intensity rating of 1.5 to 3.0

- Include enough warm season/full season, perennial, or deep-rooted crops in the rotation to achieve appropriate water use of stored soil water left by cool season/short season annual crops.

- When calculating a crop rotation intensity rating, summer-fallow counts as "0" because it does not use soil water. However, tilled fallow does cause organic matter to be destroyed, resulting in the release of significant amounts of nitrogen.

- Score 1 point for cool or short-season crops, and 2 points for warm, full-season crops. Total the points for the rotation, and divide by the total number of **years** in the rotation.

Intensity Rating for Crop Rotations for Soil Water Storage and Use

Cool or Short Season Crops
Score 1 point:

barley
canary seed
canola
crambe
durum wheat
field pea
flax
lentil
lupine
mustard
oat
spring wheat
sugar beet
winter rye
millet
winter wheat

Warm or Full Season Crops
Score 2 points:

alfalfa
amaranth
buckwheat
chickpea
corn
dry edible bean
perennial grass
potato
safflower
sorghum
soybean
sundangrass
sunflower

Summer-Fallow
Score 0 points

SAMPLE

Crop Rotation	Intensity Points
Barley	1
Winter Wheat	1
Field Pea	1
Corn	2
Millet	1
Canola	1

Total Intensity Points / Number of Years = 7 / 6 = **1.2** Intensity Rating

WORKSHEET

Crop Rotation	Intensity Points
______________	☐
______________	☐
______________	☐
______________	☐
______________	☐
______________	☐

Total Intensity Points / Number of Years ____ = ______ Intensity Rating

DIVERSITY

Diversity Index for Crop Rotations

- Crop rotation diversity means growing a combination of crops that compliment each other as much as possible to prevent disease, weed, and insect problems and maximize productivity and profitability. The rotational time interval between like crops is critical in preventing disease, weed, and insect problems.
- Include as wide a variety of crops and crop types as possible. Below are some commonly grown crops among three main crop types:
  Cool Season Grass: spring wheat, winter wheat, barley, durum wheat, oat, winter rye
  Warm Season Grass: corn, sorghum, sudangrass, millet
  Warm and Cool Season Broadleaves: field pea, lentil, canola, mustard, crambe, flax, safflower, chickpea, sugar beet, sunflower, dry edible, bean, soybean, alfalfa

Diversity Index for Crop Rotations (sample)

(Planning Tool Only - Procedures may change based on latest research)

Crop Rotation: **barley / winter wheat / field pea / corn / millet / canola**

Put crop rotation here; starting from left to right and in sequence.

Interval Value: = **4.5 + 0.5 + 2.5 + 4.5 + 0.5 + 2.5**

See #1 below.

- The interval value for barley is 4.5. This is derived by looking at the last cool season grass (winter wheat) and counting the number of crops between winter wheat (cool season grass) and barley (cool season grass) period = 4. Then add 0.5 for barley being a different cool season grass than winter wheat.
- The interval value for winter wheat is 0.5 because there are no other crops between winter wheat and barley, however, winter wheat is a different cool season grass than barley.
- The interval value for field pea is 2.5. This derived by looking at the last **broadleaf** in the rotation which is canola and county the number of crops between canola (broadleaf) and field pea (broadleaf) period = 2. Then add 0.5 for field pea being a different broadleaf than canola.
- Continue to do this for all the crops in the rotation. Then sum the interval values and divide by the total number of years for the average rotation interval which is placed on line 1.

1. To obtain each interval value count **the number of crops since the same type of crop** was last used in the rotation for each crop (not to exceed 4), add .5 to each grass-type crop if rotation includes **different grass crops of the same crop type. Also add .5 to each broadleaf-type crop if rotation includes a different broadleaf crop. Enter each value in the "Interval Value" row above. Add values together and divide by total number of years for average rotation interval** **2.5**

x = sum of interval values
y = number of years
z = average rotation interval

$$\frac{x}{y} = z$$

2. Score **.5** if rotation includes both **grass and broadleaf crop types:** **0.5**

3. Score **.5** if rotation includes both **fall and spring seeded crops:** **0.5**

4. Score **.5** if rotation includes both **cool and warm season crops:** **0.5**

5. Broadleaf crop interval: (Do not use interval value scores calculated in step 1 here)

- Score **2** if 4 or more years between broadleaf crops, **1** if 3 years, **0** if 2 years, **-1** if 1 year,and **-2** if there are 0 years between broadleaf crops in the rotation. Total scores for each broadleaf crop interval and divide by the numberof broadleaf crops in the rotation: **0**

To determine the broadleaf crop interval; find your first broadleaf in the rotation and then count the number of years to your next broadleaf crop in the rotation. Continue to do this for each broadleaf crop in the rotation. In our example, field pea to canola is 2 years therefore a 0 is assigned for this interval. Also, the canola to field pea interval is 2 years and also receives a value of 0. Then total scores for each broadleaf crop interval and divide by the number of broadleaf crops in the rotation. In our example the broadleaf crop interval is: 0 + 0 = 0 divided by 2 = ... **0**

6. Grass crop interval: (Do not use interval value scores calculated in step 1 here) Score **1** if 4 or more years between any grass crop, **.5** if 3 years, **0** if 2 years, **-.5** if 1 year, and **-1** if there are 0 years between grass crops in the rotation. Total scores for each grass crop interval and divide by the number of grass crops in the rotation: . . . . **-0.75**

To determine the grass crop interval; find the first grass crop in the rotation and then count the number of years to your next grass crop **(do not distinguish between cool or warm season grass)** in the rotation. Continue to do this for each grass crop in the rotation. In our example, barley to winter wheat is 0 years therefore a -1 is assigned for this interval. The winter wheat to corn interval is 1 year and receives a value of -0.5. The corn to millet interval is 0 years and receives a value of -1. The final grass interval is millet to barley which is 1 year and receives a value of -0.5. Then total scores for each grass crop interval and divide by the number of grass crops in the rotation. In our example, the grass crop interval is: -1 + -0.5 + -1 + -0.5 = -3.0 divided by 4 = ... **-0.75**

Diversity Index for Crop Rotations

- Avoid conflicts among seeding and harvest times of different crops (for example: trying to seed one crop when harvesting another, or harvesting more than one crop at a time).
- Count perennial crops, such as, alfalfa and/or grass as occurring once in a rotation even though they may occupy more than one year of time in the rotation.
- Follow the scoring instructions for each of the eight items on the "Diversity Index for Crop Rotations" worksheet. Note that items 7 and 8 result in negative numbers and will affect the total accordingly.
- **Strive to achieve a diversity index of at least 2. An index of 3 or more is a good goal!**

7. Seeding time conflict score: . . . .**3** ÷ **6** . . . . **= -0.50**

(*Number of seeing time conflicts* ÷ *Number of crops in the rotation*)

In the example; barley, field pea, and canola need to be seeded at the same time, therefore, the number of seeding conflicts is 3. Divide 3 by 6 (total crops) to give the seeding time conflict value of 0.50 which is always a negative value.

8. Other conflict score: . . . . **5** ÷ **6 x .5** . . . . **= -0.42**

(*Number of planting vs. harvest, or harvest vs. harvest conflicts* ÷ *Number of crops in the rotation*)

In our example; barley, winter wheat, field pea, and canola have harvesting conflicts. Winter wheat planting and millet harvesting have a planting vs. harvest conflict for a total of 5 conflicts. Divide 5 by 6 (total crops) = 0.83. Then multiply 0.83 by 0.5* to give a total harvest and harvest vs. planting conflict of 0.42 which is always a negative value. The 0.5 value is included in the equation due to the number of custom grain harvesters available.

Total of items 1 through 8 = 2.33

Diversity Index for Crop Rotations (worksheet)

Crop Rotation: _____ / _____ / _____ / _____ / _____ / _____

Interval Value= _____ + _____ + _____ + _____ + _____ + _____

1. To obtain each interval value count **the number of crops since the same type of crop** was last used in the rotation for each crop (not to exceed 4), add **.5** to each grass-type crop if rotation includes **different *grass* crops of the same crop type.** Also add **.5** to each **broadleaf-type crop if rotation includes a different *broadleaf* crop. Enter each value in the "Interval Value" row above. Add values together and divide by total number of years for average rotation interval** . . . . ____

x = sum of interval values
y = number of years
z = average rotation interval

$\frac{x}{y} = z$

2. Score **.5** if rotation includes both **grass and broadleaf crop types:** . . . . ____

3. Score **.5** if rotation includes both **fall and spring seeded crops:** . . . . ____

4. Score **.5** if rotation includes both **cool and warm season crops:** . . . . ____

5. Broadleaf crop interval: (Do not use interval value scores calculated in step 1 here)
Score **2** if 4 or more years between broadleaf crops, **1** if 3 years, **0** if 2 years, **-1** if 1 year, and **-2** if there are 0 years between broadleaf crops in the rotation. Total scores for each broadleaf crop interval and divide by the number of broadleaf crops in the rotation: . . . . ____

6. Grass crop interval: (Do not use interval value scores calculated in step 1 here)
Score **1** if 4 or more years between any grass crop, **.5** if 3 years, **0** if 2 years, **-.5** if 1 year, and **-1** if there are 0 years between grass crops in the rotation. Total scores for each grass crop interval and divide by the number of grass crops in the rotation: . . . . ____

7. Seeding time conflict score: . . . . ______ ÷ ______ . . . . **=** ____

(*Number of seeing time conflicts* ÷ *Number of crops in the rotation*)

8. Other conflict score: . . . . ______ ÷ ______ **x .5** . . . . **=** ____

(*Number of planting vs. harvest, or harvest vs. harvest conflicts* ÷ *Number of crops in the rotation*)

Total of items 1 through 8 = ____

Crop Rotation Intensity and Diversity
Additional Planning Considerations

- Use soil survey information to evaluate soil potentials for soil water storage.
- Manage crop residues to facilitate soil water storage.
- Manage crop nutrients to ensure strong crop competition with weeds and achieve crop yield goals.
- Utilize legume crops and available animal wastes to manage nutrients and improve soil quality.
- Minimize wind and water erosion.
- Evaluate available equipment and labor and anticipate different or additional equipment or labor requirements to grow new crops.
- It is usually easier to control grassy weeds in a broadleaf crop, and broadleaf weeds in a grass-type crop.
- Incorporate cover crops into crop rotations grown in the tall grass prairie region to increase crop rotation intensity and diversity.
- Perennial crops such as grass or alfalfa provide excellent weed suppression in a rotation, particularly if the crop following them is planted no-till with minimal soil disturbance.
- Evaluate various crops you are willing to grow and the management and marketing that goes with them.

The material in this publication is presented as a result of the South Dakota No-Till Systems Technology Transfer Project. Project sponsors are South Dakota State University, Cooperative Extension Service and Agricultural Experiment Station; USDA Natural Resources Conservation Service; South Dakota Department of Environment and Natural Resources; Hughes County Conservation District; South Dakota No-Till Association, and Ducks Unlimited, Inc.

Funding for this publication is through a US EPA Section 319 Nonpoint Source Pollution Grant provided through the South Dakota Department of Environment and Natural Resources.

The procedures for calculating intensity rating and diversity index of crop rotations was developed from research conducted at Dakota Lakes Research Farm; South Dakota State University. Developing a complete understanding of these characteristics and how to apply them to attain the results desired requires substantial knowledge and experience and goes beyond the scope of material that can be covered in a short publication. This publication should be considered as an introduction to the thought processes involved in developing the skills needed to take advantage of the power of proper rotational planning.

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For the latest information on intensity rating and diversity index procedures and sample calculations, visit *www.abs.sdstate.edu/aes/dakotalakes*.