United States Department of Agriculture
NATURAL RESOURCES CONSERVATION SERVICE
Crop Production
Agronomy Technical Note No. 150.14
March 2001

ECOLOGICAL SCIENCES—AGRONOMY TECHNICAL NOTE

CROP ROTATION INTENSITY RATING AND DIVERSITY INDEX[1]

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BACKGROUND

Historically, crop rotations were much more diverse than they are presently. The loss of crop rotation diversity can be attributed to many factors including economics, farm programs, mechanization, and development of commercial fertilizer, pesticides, and specialization in livestock production leading to fewer cattle operations.

Proper application of a crop rotation can increase yields and reduce costs. A diverse crop rotation can also improve soil health and have a positive affect on the whole farm by reducing weeds and insect infestations and resistance, spreading workloads, diversifying income and spreading weather risks.

The ability of crops to produce to the physical and chemical limits of the cropping is largely related to the health of the root system. The health of the root system, in turn, is directly related to the length of the crop rotation, ideally up to 3 or possibly 4 years or more.

The yield of all crops has long been known to decline with monoculture to some level significantly below the original yield of the same crop grown in some rotation system. In the case of small grains grown in Montana, this decline can be attributed primarily to root disease and hence loss of absorptive capacity of the root system because of increasing populations of root pathogens.

Any cropping system—rotation or monoculture—depletes the soil of nutrients, starting with nitrogen and then eventually phosphorus, sulfur, potassium, trace elements, and others. Organic matter content of the soil is also reduced as nutrients are mined from the soil. Organic matter is a natural form of slow-release fertilizer for plant growth and it provides the glue or supports the microorganisms that provide the glue for the aggregate structure essential for soil aeration, soil and water conservation, and healthy roots.

Alternating crops that result in an intense, diversified cropping system allows time for the natural soil microbia to displace or destroy root pathogens and other pests of any one crop enabling maximum production while maintaining soil health.

INTRODUCTION

A crop rotation is not something you can simply call "good or bad." Rather, it is best to think of on rotations as having differing characteristics in terms of their impacts on various aspects of the crop production system used in any given environment by a particular producer. Designing appropriate crop rotations is a mix of art and science. All aspects—agronomic, environmental, economic, engineering, etc.—must be considered simultaneously.

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[1] These procedures were developed from research conducted at Dakota Lakes Research Farm, Pierre, SD. This procedure and associated data is an introduction to the thought processes involved in developing the skill needed to take advantage of the power of proper rotational planning.

Factors that are most important to consider initially include:

- crop water use patterns
- historic rainfall patterns
- disease organisms
- phytotoxic effects of residue
- profit potential
- optimum row widths
- workload spread
- soil properties
- snow catch ability
- insect cycles
- weed habits
- equipment needs
- seeding and harvesting dates
- access to markets

For any given situation there will be range of rotations that will be agronomically appropriate. Within this range are rotations that have differing characteristics in terms of the risk they pose which 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.**

The Crop Rotation Intensity Rating and Diversity Index offers a method that can be used to assist in the development of appropriate rotational alternatives. It provides field staff, watershed planners, and land users with a tool to assess various crop rotations for potential to improve profitability and soil health. The Rotational Intensity Rating and the Diversity Index identifies crop rotations where intensity and diversity may be relatively higher than other rotations. The Intensity and Diversity worksheet can be used to develop planning considerations that can be provided to the land user. From these planning considerations alternatives are provided to the producer to maintain or increase soil health while maximizing profitability.

Rotational Intensity Rating

The Rotational Intensity Rating is an assessment tool that ranks the relative potential for soil water storage and crop water use. 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, the current rotation lacks intensity. If fields are frequently dry, intensity is too high. Using rotations that have both high and low intensity segments or incorporating 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 example, a wheat-millet-canola rotation has the same average intensity as a wheat-sorghum-fallow rotation. However, 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 sorghum. Similarly, the first rotation would not be appropriate on a deep soil with high water holding capacity since none of the three crops is capable of exploring sufficiently deep in the soil to fully utilize its capability.

Tillage causes water loss from soil. Therefore, the less tillage completed, the more intense a rotation must be. Failure to use extra water in a soil increases weeds and diseases; lowers profits; increases saline seep problems, etc. In Montana, where cropping systems include tillage based rotations with fallow or crops with proportionately low water use, intensity can be increased by eliminating or decreasing 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.

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. It does mean that the probability of these problems occurring are 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 a combination of rotational intensities to spread risks.

The native vegetation growing in a particular area is characteristic of crop intensity potential. The following are moisture conserving system intensity ratings for Rangeland Resource Units in Montana. Farming systems that include intensive tillage should limit intensity rating at least .5 points below those shown.

- **Northern Rolling High Plains (58A) & Pierre Shale Plains (60B) = 1.0 - 1.5**
- **Brown Glaciated Plains (52) & Northern Dark Brown Glaciated Plains (53A) = 1.3 - 1.75**
- **Northern Rocky Mountain Valleys (44) = 1.2 - 1.75**

Efforts to attain proper rotational intensity may include commitment to create adequate diversity in the crop rotation. Diversity 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 disease, insects, or lack of nutrients.

Crop Diversity

The Diversity Index provides a relative indication of the ability of a combination of crops to compliment each other to prevent disease, weed and insect infestations, and maximize productivity, profitability, and soil quality. Having less diversity than needed can eventually lead 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.

The first step in understanding crop diversity 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 have different growth and maturity habits, nominal seeding and harvesting periods, water use characteristics, pest problems, etc. Initially, diversity planning should focus on gains achieved by using different crop types in the rotation. Subsequent fine tuning can be made using specific crops since some crops from different groups share common diseases (i.e. most broadleaf crops whether cool or warm season are susceptible to white mold). On the other hand, some crops of the same group can be used to break a disease cycle (i.e., sunflowers are not susceptible to soybean cyst nematode) or compete better with a specific weed (winter wheat or rye provides better opportunity to control wild oats than growing tame oats).

Crop substitutions can be made with a given crop type for added flexibility and allow the producer to maintain an agronomically sound rotation. For example, if conditions are too wet to plant corn timely, an alternative warm season grass could be planted could be planted at a later date such as grain sorghum or millet.

The diversity index calculations are intended to demonstrate the potential impact differing rotations can have on reducing the probability that weeds, diseases, insects, or workload problems, etc. will become problems. It assumes good management practices are being used throughout the system.

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

- 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.

The following are some points to consider when completing the Crop Rotation Intensity Rating and Crop Diversity Index worksheets.

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.
- 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.
- 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 crops.
- When calculating a crop rotation intensity rating, summer-fallow counts as "0" because it does not use soil water. Tilled fallow does, however, destroy organic matter, resulting in a temporary release 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.

Crop Rotation Intensity Rating

COOL OR SHORT SEASON CROPS	WARM OR FULL SEASON CROPS
SCORE: 1 POINT	SCORE: 2 POINTS
Barley	Alfalfa
Canary seed	Amaranth
Canola	Buckwheat
Crambe	Chickpea
Durum wheat	Corn
Field pea	Dry edible bean
Flax	Perennial grass
Lentil	Potato
Lupine	Safflower
Mustard	Sorghum
Oat	Soybean
Spring wheat	Sunadgrass
Sugarbeet	Sunflower
Winter rye	
Millet	
Winter wheat	
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 7 = **1.2 Intensity Rating**
TOTAL NUMBER OF YEARS 6

WORKSHEET

CROP ROTATION	INTENSITY POINTS
----------	☐
----------	☐
----------	☐
----------	☐
----------	☐

TOTAL INTENSITY POINTS ___ = **Intensity Rating**
TOTAL NUMBER OF YEARS ___

Diversity Index

- Crop rotation diversity means growing a combination of crops that compliment each other a 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, lentils, canola, mustard, crambe, flax, safflower, chickpea, sugar beet, sunflower, dry edible beans, soybeans, alfalfa
- 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 or grass as occurring once in a rotation even though they may occupy more than one year of time in the rotation.
- Note that ITEMS 7 and 8 result in negative numbers and affect the total accordingly.
- *Strive to achieve a diversity index of at least 2. An index of 3 or more is a good goal!*

Diversity Index (SAMPLE)

Crop rotation: barley / winter wheat / field pea / corn / millet / canola

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

SEE #1 BELOW.

- Barley interval value is 4.5. This is derived by determining the **last cool season grass** (winter wheat) grown/planned and counting the number of crops between winter wheat (cool season grass) and barley (cool season grass). This period = 4. Then add 0.5 for barley being a different cool season grass than winter wheat.
- Winter wheat interval value is 0.5. There are no crops between winter wheat and barley. However, winter wheat is a different cool season grass than barley.
- Field pea interval value is 2.5. This is determined by identifying the last **broadleaf** in the rotation, which is canola, and counting the number of crops between canola (broadleaf) and field pea (broadleaf). This period = 2. Add 0.5 for field pea being a different broadleaf than canola.
- Continue this process for all the crops in the planned rotation. Then sum the interval values and divide by the total number of years for the average rotation interval. This value goes on line 1.

1. **Crop Interval Value**. 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 0.5 to each grass-type crop if the rotation includes **different grass crops of the same crop type.** Also, add 0.5 to each **broadleaf-type crop if the rotation includes a different broadleaf crop.** Enter each value in the "Interval Value" row above. Add values together and divide by the number of years of rotation. 2.5

   X = sum of interval values
   Y = number of years **x / y = z**
   Z = average rotational interval

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

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

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

5. **Broadleaf Crop Interval** (DO NOT USE INTERVAL SCORES CALCULATED FROM NUMBER 1 ABOVE).

   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 **0**

   In the example field pea to canola is 2 years; therefore, a score of 0 is assigned. Canola to field pea interval is also 2 years, so a 0 is assigned. 0 + 0 = 0 divided by 2 = 0

6. **Grass Crop Interval** (DO NOT USE INTERVAL SCORES CALCULATED FROM NUMBER 1 ABOVE).

   Score **1** if 4 or more years between any grass crop (do not distinguish between cool and warm season grass), **0.5** if 3 years, **0** if 2 years, **-0.5** 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 number of grass crops in rotation ..... **-.75**

   In our example barley to winter wheat is 0 years, therefore score = -1 for this interval. Winter wheat to corn interval is 1 year and scores = -0.5. Corn to millet interval is 0 years and scores -1. Millet to barley is 1 year and scores -.5. Total is -1 + -.5 + -1 + -.5 = -3.0 divided by 4 = -0.75

7. **Seeding Time Conflict.** Identify the number of seeding time conflicts in the rotation divided by the total number of crops in the rotation. In the example, barley field pea, and canola need to be seeded at the same approximate time; therefore, the number of seeding conflicts is 3. Divide 3 by 6 (total crops) **0.5**

8. Other Conflicts. Identify the number of other conflicts that will occur with t4eh planned rotation including planting vs. harvest, or harvest vs. harvest conflicts, then divide by the total number of crops in the rotation. In the example, barley, winter wheat, field pea, and canola have harvest 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) ..... -0.42

Total of items 1 through 8 = 2.33

Diversity Index

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

Interval Value: _____ / _____ / _____ / _____ / _____

1. **Crop Interval Value**. 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 0.5 to each grass-type crop if the rotation includes **different grass crops of the same crop type.** Also, add 0.5 to each **broadleaf-type crop if the rotation includes a different broadleaf crop.** Enter each value in the "Interval Value" row above. Add values together and divide by the number of years of rotation. ..... ☐

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

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

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

5. **Broadleaf Crop Interval** (DO NOT USE INTERVAL SCORES CALCULATED FROM NUMBER 1 ABOVE).

   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 SCORES CALCULATED FROM NUMBER 1 ABOVE).

   Score **1** if 4 or more years between any grass crop (DO NOT DISTINGUISH BETWEEN COOL AND WARM SEASON GRASS), **0.5** if 3 years, **0** if 2 years, **-0.5** 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 number of grass crops in rotation..... ☐

7. **Seeding Time Conflict.** Identify the number of seeding time conflicts in the rotation divided by the total number of crops in the rotation. In the example, barley field pea, and canola need to be seeded at the same approximate time, therefore the number of seeding conflicts is 3. Divide 3 by 6 (total crops). ..... ☐

8. Identify the number of other conflicts that will occur with t4eh planned rotation including planting vs. harvest, or harvest vs. harvest conflicts, then divide by the total number of crops in the rotation. ..... ☐

Total of items 1 through 8 = ☐

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 yields.
- 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.
- Usually it is easier to control grassy weeds in a broadleaf crop, and broadleaf weeds in a grass crop.
- Incorporate cover crops and green manure into rotations to increase crop rotation 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 or with minimal soil disturbance.
- Evaluate various crops a producer is willing to grow, manage, and market.