A CROP ROTATION PLANNING PROCEDURE

Note: this chapter is modified from Chapter 5 of *Crop Rotation on Organic Farms: a Planning Manual* by Charles L. Mohler and Sue Ellen Johnson, NRAES Press. It is intended to be used in conjunction with that manual, not as a substitute for it.

General instructions

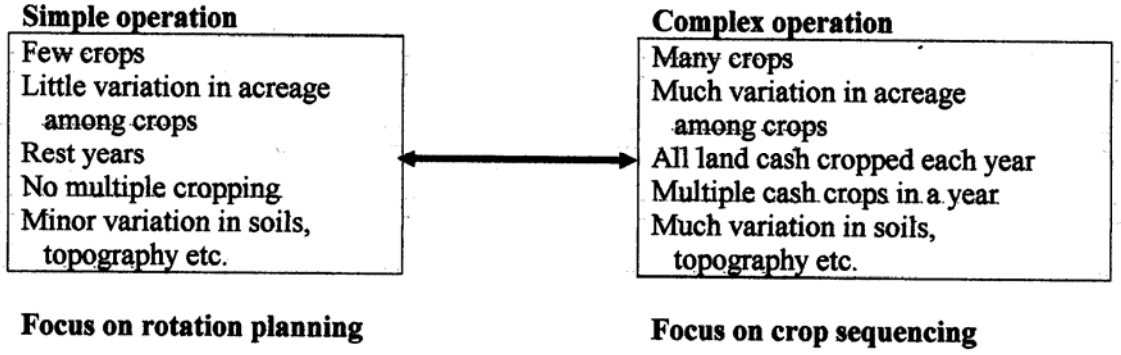
This chapter provides a step –by-step procedure for planning crop rotations on an individual farm. The procedure is based on methods used by the panel of expert farmers discussed in Chapter 2 supplemented with other sources. The procedure distills what experienced growers do based on experience, knowledge and intuition into a systematic method. For the sake of simplicity, the instructions are written as if the person doing the planning is the manager of the farm.

The crop rotation planning procedure works through a series of steps. You will (i) organize your information, (ii) develop a general rotation plan (optional), (iii) construct a crop rotation planning map, (iv) plan future crop sequences for each section of the farm, and (v) refine your crop sequence plan.

The procedure is easiest for a farm that produces only a few crops and has uniform field conditions. Examples include cash grain farms and some wholesale vegetable operations where all of the crops can be grown on all of the fields. The procedure can be used to plan rotations with more crops and multiple soil types, but the process is time consuming. The rewards of systematic crop rotation planning increase, however, with the number of crops and complexity of the fields. On farms that grow only a few crops, reasonable rotations can be maintained using a few rules of thumb. With a complex operation, however, rotation practices may be less than desirable without the farmer realizing that a potential long term problem is developing. Although the plan you ultimately develop may be quite complex, the planning procedure described below is not actually complicated. Simply proceed one step at a time and you will end up with a plan. Besides developing a plan, working through the procedure will likely give you new insights into your farm and how you manage it.

The crop rotation planning process becomes more complex if the crop mix is highly diverse, if you plant the same crop multiple times each season, if you double or triple crop fields, or if the fields vary in their ability to grow various crops. For farms that

Figure 5.1. The complexity of your farm determines how you plan.



require a complex cropping plan, using Microsoft Excel® spreadsheets instead of paper worktables is advised. For any farm, the computer worksheets will simplify data entry and sorting. The version of the planning procedure presented here has been customized to make use of the Excel® spreadsheets.

The procedure is not a cookbook recipe. The procedure will not tell you which crop should follow another. You will not be told, for example, to precede a crop with hairy vetch or follow it with potato. Rather, the procedure will help you organize diverse data on the management and biology of the crops you want to grow to define rotations that work for your particular farm. You need to know your fields and your crop mix to use this planner. Only you know the particular goals, problems and opportunities of your farm operation. The procedure can, however, help you recognize the critical decisions that need to be made, and prompt you to make them in a logical order. The spreadsheets Chrop char0 and Field char0 help you enter, compare, and sort the information you need to plan a good crop rotation, for each field and for the entire farm.

Box 5.1: Rotation planning vs. crop sequencing

Cropping plans have two aspects: development of a general rotation plan and sequencing particular crops. The general rotation plan might specify, for example, that nightshade crops will be followed by mustard family crops, then salad greens other than mustards and finally cucurbits, or that full season crops will be followed by a year of cover crops and then early planted short season crops. The rotation plan provides the framework; the sequencing plan provides the details of what crop goes where in succeeding years. The rotation plan needs to be general enough to allow flexibility in sequencing. The sequencing plan is necessarily tentative and ideally leaves room for alternative crops in case weather or markets force last minute changes.

The relative importance of rotation planning vs. crop sequencing in overall crop planning depends on the farm. In general, as the complexity of the farm operation increases, rotation planning becomes less possible and careful crop sequencing becomes more critical (Figure 5.1). If your farm operation is suited to rotation planning, developing a plan will greatly simplify your crop sequencing. If, however, your operation is highly complex (Figure 5.1) then following a general plan is likely to prove futile. In that case, detailed record keeping and careful placement of crops become key to avoiding rotation problems.

Before you begin . . .

Before you begin, please read through the instructions to see where you are headed with each step. This will also tell you whether the effort involved is worthwhile for your farm. Earlier chapters in this manual provide many suggestions as to how to think about the problem of developing general crop rotation plans and specific crop sequences. Tables in the appendices of the manual provide a wealth of factual information to help you avoid problems and take advantage of opportunities. Familiarity and consultation with those materials will help in working through the following steps. The procedure

may prompt you to rethink your farming operation and crop mix, as you order the sequence of crops on particular fields.

Box .5.2. Small Valley farm: an example to illustrate the procedures

Small Valley farm is a cash grain and beef operation (Figure 5.2). They grow grain and soybeans for human consumption and alfalfa for winter feed for their herd of beef cattle. The farm has 720 tillable acres. Although they can grow all crops successfully on all of the tillable land, 240 acres are sufficiently steep that erosion is a potential problem when they grow row crops. A desire to avoid row crops on their steep land motivates them to undertake rotation planning.

In the past, they have followed a 6-year rotation: oat/spelt spelt/hay hay hay corn soybean and then back to oat/spelt. Their crop mix is summarized in Table 5.1. They establish mixed grass/alfalfa hay by overseeding it into spelt in the spring They plow hay in the fall before corn to allow the sod to break down and sow an oat cover crop to protect the soil over the winter. Red clover is sown with oat cash grain to provide an extra boost of nitrogen for the spelt.

Table 5.1. Crop mix for Small Valley farm.

Crop	Acres
Tofu soybean	120
Corn	120
Oat	120
Spelt/ hay (1st year)	120
Hay (2nd year)	120
Hay (3rd year)	120

Initial steps

1. Copy the spreadsheets

Download the Excel® spreadsheets Crop char0 and Field char0 from the NEON website where you obtained this document if you have not already done so. Also download the spreadsheet called Summer acres Crop char1. It provides a worked example of the procedure.

Make copies of the Crop char0 and Field char0 files. Rename the copies Crop char1 and Field char1. You will work with these new files and leave the original files as back-ups in case you need to start over at some point.

Note: Tables 5.2, 5.3, and 5.4 have been replaced by the Crop char0 and Field char0 worksheets and thus do not appear in this version.

2. Set rotation goals. Identify what you would like your crop rotation to accomplish. Box 2.13 provides a list of potential rotation goals developed by a group of experienced organic farmers.

The rotation planning goals for Small Valley farm are

- Avoid growing the same crop in a location two years in a row (except hay, of course).

- Insure that all crops have sufficient nitrogen, especially corn.
- Avoid planting row crops and spring grains on sloping land.

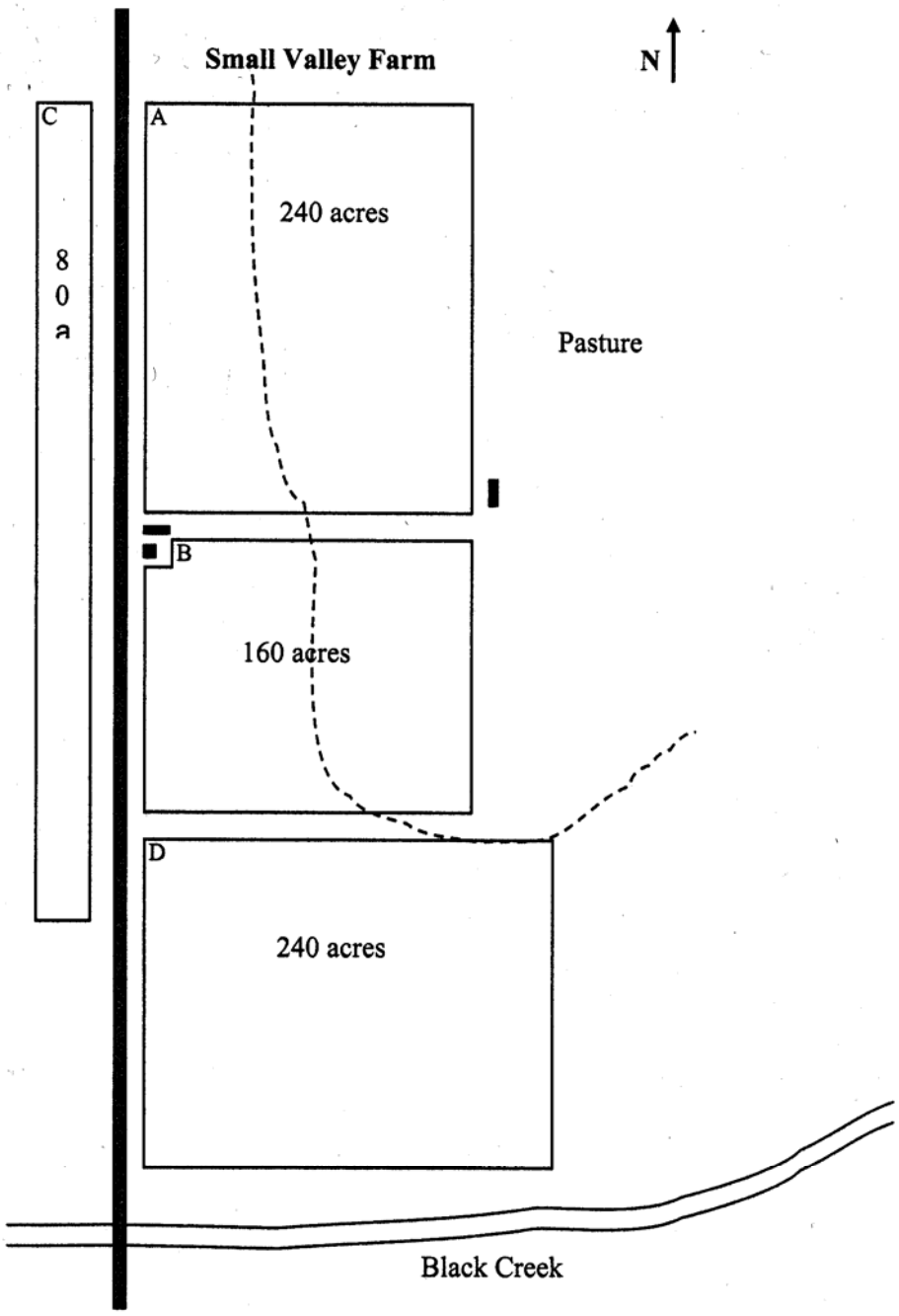


Figure 5.2. General map of Small Valley Farm. Dashed line shows boundary of steep land.

3. Prioritize goals. Order your goals. This is particularly useful if you have a long list of goals, since you may find it impossible to meet all of the goals completely. Some

goals may be so easily met that although they are critical, they need little attention in the rotation planning process. For Small Valley farm, providing N for the crops is economically important, but since one third of the land is in a nitrogen building grass-alfalfa hay each year and a clover cover crop can be interseeded into either oat or spelt, providing sufficient N is easy to accomplish. Consequently, they prioritize their goals as:

(1) Avoid growing the same crop two years in a row.
(2) Avoid planting row crops and spring grains on sloping land.
(3) Insure that all crops have sufficient nitrogen, especially corn.

Fill out your crop characteristics worksheet (Crop char1)

4. Write down your desired crop mix. Use the Crop char1 spreadsheet to make a list of the crops you grow. Begin by going through and deleting any crops or cover crops you do not plan to grow. If you decide to add them back later, you can always copy the information from Crop char0. If you plan to make multiple plantings of a crop, enter each planting of the crop on a separate line with a unique name (for example, lettuce 1 etc.). To do this just insert the necessary number of rows (insert menu), fill down the empty rows with the crop, and then modify the crop name. Separating various plantings in this way is useful because each planting has different planting and harvest times and therefore has different cash and cover crops that can precede or follow it. For crops that remain in the ground for several years, you may find listing each year class useful (for example, strawberry yr 1, strawberry yr 2 etc.) Table 5.1 shows the crop mix for Small Valley farm.

5. Add crop characteristics to the Crop char1 worksheet. Now look at the Crop char0 worksheet and delete any columns that you think are irrelevant for sequencing crops or deciding where to locate crops on your farm. The crop characteristics in the Crop char1 spreadsheet are essentially those listed by expert farmers as useful for crop rotation planning (Box 2.16). Some, however, may not apply to your farm. For example, information on soils will be irrelevant if your fields are all on one soil type. Next, fill in the appropriate information on each crop in those columns. For crops with multiple planting times, fill in the target planting and harvest times. Particularly if you grow many crops, you may find it useful to enter the target planting and harvest time for all of the crops. For crops that are harvested repeatedly, the final harvest is the critical time in this context since that is when the field becomes available for planting the next cash or cover crop. Box 5.3 has codes for planting and harvest times that fit easily on the worksheet. Enter the net income per acre or other convenient unit of land area. This

Box 5.3. Codes for recording planting and harvest times.

Generally, attempting to target particular planting and harvest dates too carefully will prove futile due to the unpredictability of the weather. The following codes may be useful for tracking when you plant and harvest. If you have a long growing season you may want to divide spring and fall into three categories instead of two.

Time	Code
Early spring	espr
Late spring	lspr
Early summer	esum
Mid summer	msum
Late summer	lsum
Early fall	efall
Late fall	lfall

information will be used to help prioritize where crops go. Approximate numbers are good enough – you just need to be able to tell the approximate ranking of values. For now, ignore the column headed MUs/year – you will use that later.

Sort the lines of data into groups by sorting on family and then planting time. Crops within one of these groups will be functionally equivalent in many respects.

6. Check for lack of diversity in your crop mix. Scan your Crop char1 spreadsheet and determine which plant family will have the greatest area. For this computation, ignore the grass family (see Box 5.5). Add up the area for the most widely planted, non-grass family. Now divide the total cropped area of the farm by the area of that family. This number represents the *average rotation return time* for the most common non-grass crop family you grow. For example, if the average rotation return time is 4, then the most prevalent non-grass plant family will occur on a given location once in every 4 years, provided you carefully manage to ensure a maximum lag between planting members of that family throughout the farm. Of course, many factors, including field-to-field variation in soil conditions, production of perennial crops, and changes in cropping plans due to weather will lead to shorter return times at some locations. *If the average rotation return time for the most prevalent family is less than 4, check Appendix 3, and consider renting additional land or changing your crop mix so that a smaller percentage of the farm is planted with that family.*

Box 5.4. Computation of average return time for the most prevalent crop family: an example.

Suppose your farm has the crop mix shown below:

Crop	Family	Number of beds
Lettuce	Lettuce	6
Onion	Allium	6
Leek	Allium	3
Garlic	Allium	3
Tomato	Nightshade	6
Potato	Nightshade	6
Pepper	Nightshade	4
Green bean	Legume	4
Pea	Legume	4
Carrot	Carrot	2
Summer squash	Cucurbit	4
Total		48

The most prevalent crop family is the nightshades, with 16 of the 48 beds. Average return time for nightshades is 48/16 = 3 years. The second most prevalent family is the alliums, with an average return time of 48/12 = 4 years. Consequently, shifting from nightshades to an increase in alliums will not help diversify the crop mix appreciably.

Box 5.5. Minimum return time

A minimum return time of 4 to 5 years will prevent most soil borne diseases (Appendix 3) provided you practice good sanitation measures (See Chapter 3). A shorter return time can be used for grass family crops, particularly if the rotation includes some alternation of corn, small grains and forage grasses. Although these different grass family crops share a few diseases (see Appendix 2), avoiding rapid return to a given grass species is usually sufficient to avoid disease problems.

Identify good sequences to use in your planning

7. Identify crop sequences that you use repeatedly. Look at your planting records and list 2-3 year crop sequences that you have found work well on your farm. These form the backbone around which you will build your rotation plan. You will probably find that these sequences meet certain rotation goals, or make your operation run smoothly. For each sequence, note what that sequence is doing to facilitate your operation. This will allow you to explore alternative sequences that provide the same benefits. For Small Valley farm, sequences and notes might look like:

- spelt/hay – hay – hay: Hay can be established by overseeding into spelt. The spelt provides a good nurse crop and can be harvested before most spring germinating weeds go to seed.
- hay/oat cover crop – corn: Alfalfa in the hay provides a source of nitrogen for the corn, and the decomposing roots maintain good soil structure during the row crop portion of the cycle. The oat cover crop protects the soil after incorporation of the hay sod, but winter kills so that corn can be planted as soon as the weather permits.
- oat/spelt: There is plenty of time for planting spelt after oat harvest whereas the window of opportunity is narrow after soybean and nonexistent after corn. The sequence also provides time for a short summer fallow to clean up weeds.

The rotation diagrams in Chapter 4 provide many examples of sequences that other farmers use successfully. These examples may provide alternative sequences that meet your purposes.

Identify critical variation in field conditions

8. Identify areas of your land that offer special opportunities or pose problems. Identify fields and parts of fields that grow certain of your crops particularly well or that pose production problems for particular crops. Note these areas on a map of your farm. Table 5.5 provides a list of field characteristics that experienced growers take into account when planning crop rotations.

For Small Valley Farm, the main problem area is the east side of fields A and B, which they feel slopes too steeply for safe production of row crops (Figure 5.2). Field D is flat, fertile bottomland that they feel can support intensive row crop production.

Choose a few of these field characteristics that you think are most critical for planning your rotations. Based on these characteristics, categorize the fields into a few basic types. Realize that you will probably need a separate rotation plan for each type of field. Consequently, choose the most important field characteristics on which to focus. Meshing many separate rotations to get your desired crop mix each year will become hopelessly complex, particularly if you are producing many crops. ***Therefore, if you***

have many critically different types of fields or if you grow many crops and all land is cash cropped each year, do not bother developing a general rotation plan. Instead, skip to step 11. In contrast, if you grow fewer than 8 types of cash crops (crop groups discussed in step 5) and have only one to three types of fields, you will probably benefit from development of a general rotation plan. Similarly, if you rest at least 1/3 of your land each year without planting cash crops on it, consider developing a general rotation plan.

Table 5.5. Field conditions: an explanation of the data that can be entered in the field conditions worksheet (Field char1). Experienced growers have identified the factors listed here as factors they note when planning crop sequences.

The table is laid out to show column header codes used in the Field char1 worksheet and abbreviations that are useful when filling out the worksheet (see steps 17 through 19). Management units (MUs) are pieces of land of uniform size, each of which is farmed as a block. The usefulness of dividing the farm into uniformly sized management units is discussed in step 11.

Header	Explanation
Field name	Your name for the field – e.g., SW, upper creek, etc.
Manag. unit	Number of this management unit. Each unit should have a unique number. Number adjacent units sequentially.
Zone	Section of the farm that shares a common rotation plan. See steps 9-10 (optional). <I, II, III, IV etc.>
	Field history
Crop three summers ago	Name(s) of crop(s) (and cover crops) three summers ago.
Crop two winters ago	Name of cover crop or crop two winters ago..
Crop two summers ago	Name(s) of crop(s) (and cover crops) two summers ago.
Crop last winter	Name of last winter's cover crop or crop.
Crop last summer	Name(s) of last summer's crop(s) (and cover crops).
Current winter—crop	Name of the current cover crop or crop.
Current winter —plant	Planting time of the current cover crop or crop.
Current winter —harv.	Expected harvest or incorporation time of the current cash crop or cover crop.
	Field characteristics
Soil series	Name of the soil series from your county Soil Survey
Texture	SaL (sandy loam), SiL (silt loam), CL (clay loam) etc. Obtain this from your county soil survey, but temper it with your judgment
Drainage	E (excessive – draughty), W (well), MW (moderately well), SP (somewhat poor), P (poor)
Slope	% slope of the MU. Enter range if it varies
Aspect	Direction the land slopes. N, NE, E etc., C for complex slopes, F for flat.
Irrig?	Is irrigation available? Y (yes), N (no)
Shaded?	Is the MU shaded by trees or steep hills? Y (yes), N (no)

Air drainage	Air drainage. G (good), I (intermediate), P (poor). Air drainage affects tendency toward late spring and early fall frosts.
Air circ.	E (exposed), I (intermediate), S (sheltered). Exposed fields may be susceptible to wind damage; sheltered fields may be more susceptible to spread of disease.
Access	G (good –e.g., near farmstead), I (intermediate), P (poor – e.g., the other side of the woodlot)
Visibility	VV (very visible) , V (visible), H (hidden). You may prefer to put crops that attract customers near the road, and experiments that may fail where they cannot be seen.
Neighbor issues	Note issues with neighbors – e.g., may not want to spray next to homes; pollen drift from conventional growers etc.
Moist. hold. cap.	Moisture holding capacity. G (good), I (intermediate), P (poor).
Org. matter	Enter range of recent % organic matter values.
Org. matter qual.	Quality of the organic matter. Your judgment of the quality of the organic matter. Is it well decomposed to humus, or is a lot of coarse fiber and wood present. G (good), I (intermediate), P (poor).
Tilth	Your judgment of the tilth of the soil. G (good – tilled soil is loose, with little tendency to crust), I (intermediate), P (poor – tilled soil is cloddy, compacted, tends to crust).
Aggregation	G (good – soil has good crumb structure), I (intermediate), P (poor – soil is massive and blocky, or loose sand with few crumbs).
Nut. release	Ability of soil to release nutrients to the crop. G (good), I (intermediate), P (poor).
Nut. imbalance?	Note any nutrient imbalances – e.g.,poor Ca:Mg or Ca:K ratios.
Erosion	Tendency toward erosion if soil is left uncovered. H (high), I (intermediate), L (low).
Deer pres.	Deer pressure. H (high), I (intermediate), L (low).
Dis. crops	List crops that in this MU have had a recent history of soil borne diseases.
Diseases	Note names of diseases of the crops just listed.
Ann.weed pressure	H (high – many annual weeds will probably be present if not controlled), I (intermediate), L (low – MU has little history of annual weed problems).
Worst ann. spp.	List the problem annual weed species.
Peren.weed pressure	H (high – perennial weeds have posed problems recently), I (intermediate), L (low – MU has little history of perennial weed problems).
Worst peren. spp.	List problem perennial weed species.

Develop a general rotation plan (optional)

9. Divide the farm into production zones. Based on your map and notes from the previous step, block the farm into production zones. All land within a zone should be suitable for growing the same set of crops. Note that if all areas of the farm are reasonably suitable for all crops, then you are lucky to have only a single zone to deal with. Areas in a particular zone do not have to be adjacent, and zones do not have to be the same area (although in the Small Valley Farm example the areas in the three zones were made equal to simplify the illustration).

Small Valley farm has three zones:

I. Field C and the west sides of fields A and B – suitable for all crops.

II. East side of fields A and B – unsuitable for row crops and spring grains due to excessive slope.

III. Field D – particularly good land suitable for intensive row crop production.

10. Propose reasonable crop rotations for each zone. Using your component sequences and other component sequences you think might work, develop a preliminary rotation for each of the zones on your farm. Make the crop rotations in the several zones have the same cycle length or a simple multiple of the shortest rotation length. Otherwise, meshing the rotations to achieve your desired crop mix each year will probably prove impossible.

Although the Small Valley rotation plan discussed below focuses on particular crops, many farmers prefer to focus on crop types. These crop types could be botanical families, or relate to the season when the crop is in the ground. For example, the Nordell's rotation plan discussed in Chapter 4 alternates spring planted crops with a year of fallow and cover crops and then summer planted crops. Basing the rotation plan on planting time can simplify field operations by synchronizing them over substantial blocks of land. If your rotation plan is based on crops grouped by planting time, however, you may need to make additional provisions to ensure that botanically similar crops are not grown too soon in the sequence. This could be accomplished, for example, by repeating the basic planting time sequence with different families in each repetition.

The Small Valley farmers decide on the following rotations:

Zone I. Spelt/hay – hay – hay/oat cc –corn – soybean – oat/spelt. This is the six year rotation they have used previously.

Zone II. Spelt/hay – hay – hay/spelt – spelt/hay – hay – hay/spelt. This is a three year rotation, repeated twice in a six year period. It avoids row crops and spring tillage on the steep land.

Zone III. Oat/clover – corn – soybean – oat/clover – corn – soybean. This is an intensive rotation with row crops two years out of three. Essentially, the Small Valley farmers moved the row crops and spring grain from Zone II to Zone III, leaving only erosion resistant sod and winter grain crops on the erosion prone land of Zone II. Over the course of the six year cycle, the mix of cash crops has not changed at all. Placing these crop sequences on particular plots of land to achieve the desired crop mix in each year, however, requires some additional planning.

Make and use a crop rotation planning map

11. Draw a crop rotation planning map. This map may need to be more detailed than the map you use for organic certification. Begin by noting the dimensions of each field

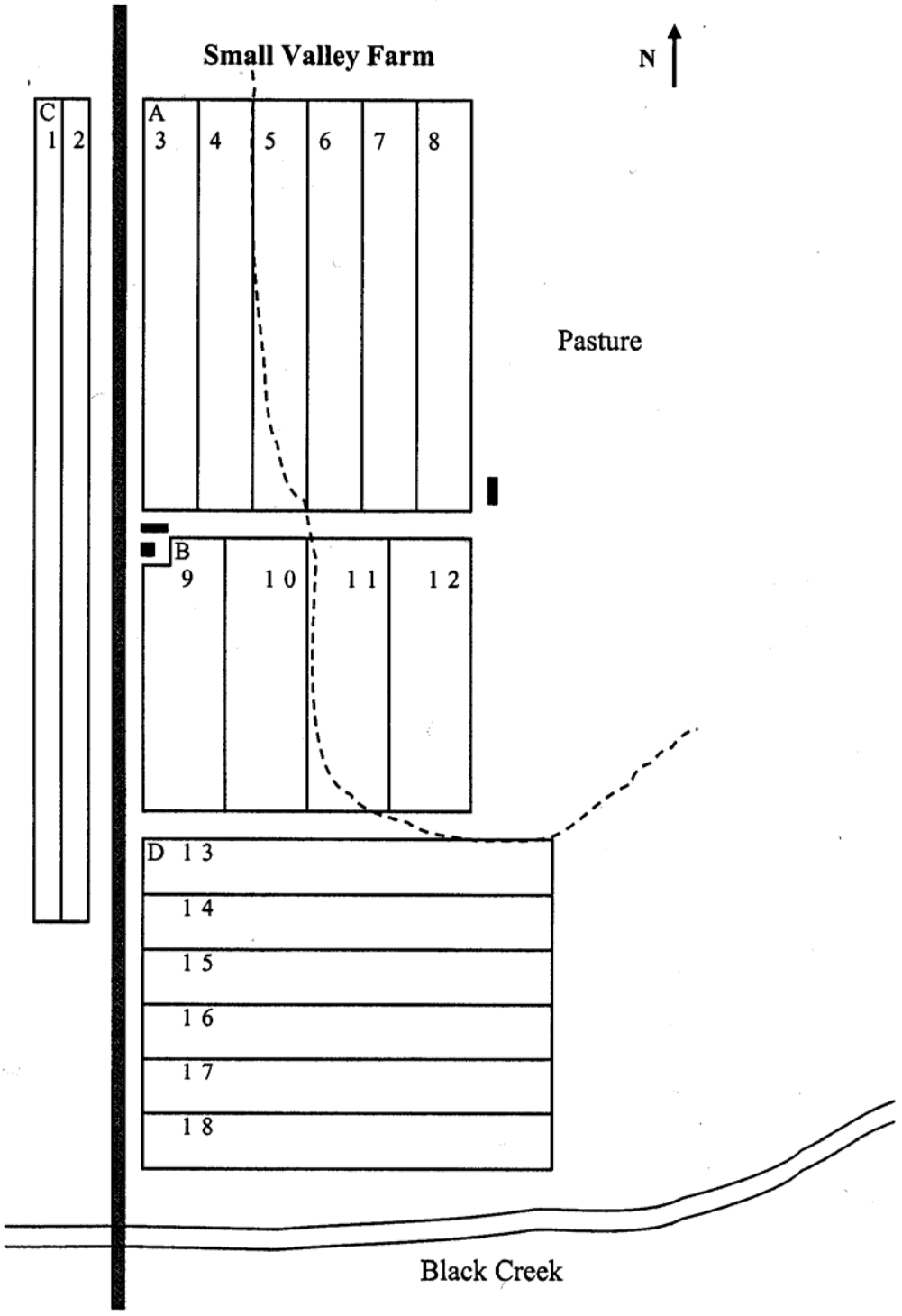


Figure 5.3. Map of Small Valley Farm showing location of management units. Dashed line shows boundary of steep land

on the map. In this step you will subdivide fields into small management units (MUs) of approximately equal size across the whole farm. Only one crop will be grown on any particular MU at a time, and usually several MUs will be required to grow the full

acreage of a crop. Crops will move from one block of MUs to another between years. Dividing the farm into management units allows you to stay organized when moving crops that are grown on differing amounts of land around between fields that vary in size, shape and other important characteristics. Figure 5.3 shows how Small Valley farm laid out their 40 acre MUs across the farm.

Consider the following points when determining size and arrangement of management units.

• Choose a MU size that allows areas of each crop on your Crop char1 worksheet to convert to a whole number of MUs. For Small Valley Farm, since 1 MU = 40 acres they thus grow 3 MUs of each crop per year.

• MUs should be no larger than the area planted to your smallest acreage crop. If some crops that are grown on small acreage (for example, annual herbs) are rotated as a block, the several species could be considered as one "crop" for rotation purposes.

• If you did steps 8 and 9 (rotation planning), the number of MU in a zone should be some multiple of the number of years in the longest rotation sequence for any zone. For example, for Small Valley farm, each zone should have six MUs, or some multiple of six, since the longest rotation sequence is 6 years (in Zone I). They chose to keep things simple and use six MUs per zone (Figure 5.3). If you skipped steps 8 and 9 due to high farm complexity, you can ignore this consideration.

• If you use permanent beds, each bed should be a separate MU. If fields vary in length, subdivide long beds at cross alleys as necessary to ensure that the MUs are approximately equal in area.

• On grain farms and large wholesale vegetable farms, vary length and width of management strips for your convenience, but keep the area of each MU approximately constant and small enough to provide flexibility.

• Although MUs should be relatively small, they should be large enough so that you can perform field operations like tillage or cultivation on a single unit.

. • Make the map at a scale that allows writing information onto the area representing each MU. If necessary, use separate pages for various fields or groups of fields.

Now divide the fields into management units on your map. Note that small variation in the size of management units due to irregularities in field shape are unavoidable, but probably will not matter much since most crops will be grown on several to many MUs.

12. Record your crop mix in terms of management units. On your Crop char1 worksheet record how many management units you want to grow of each crop. You already have the amount of each crop recorded in acres or beds or some other unit, but converting these to MUs will simplify thinking about how you sequence the crops on particular MUs. If you made an error in the previous step, the conversion of area to MUs may result in some crops being grown on fractions of a MU. In this case, adjust your crop mix slightly so that all crops will be grown on a round number of MUs.

13. Number each management unit. Put the number in the upper left corner of each management unit on the map. Make the numbers sufficiently large and legible that they will photocopy well. Blocks of land that you commonly manage together should be numbered sequentially.

14. Make several copies of the maps. You will need at least 5 copies, and a few more may be useful later. Be sure to save the original map in a safe place for making future copies.

15. Record especially valuable MUs on one copy of the map. Note management units that have especially useful properties on one of the copies of the map. You noted the most important field characteristics in a general way in step 8. Now it is time to characterize each MU in detail. Favorable properties may include proximity to the farmstead, access to irrigation if irrigation is limited, slope or drainage characteristics that allow early planting, and many others (see Table 5.5). Note valuable properties of any MUs that have them on the map. Use the abbreviations in Table 5.5 if you are cramped for space.

16. Record problem MUs on one copy of the map. On another copy of the map, note management units with problems that restrict the types of crops that you can grow. Such problems include poor soil drainage, severe animal pressure, shadiness, frost pockets and slope characteristics that lead to slow warming in the spring. For a list of characteristics assembled by a group of experienced growers, see Table 5.5.

Fill out the field conditions worksheet (Field char1)

17. Number the rows your Field char1 worksheet. Put field name and management unit number of each MU onto a line in the Field char1 worksheet. Number the MUs sequentially. See Table 5.6 for an example. If you did steps 9 and 10 above (general rotation planning), fill in the column titled "Zone" also; otherwise, leave this column blank.

18. Put map data on the Field char1 worksheet. Copy the information you noted on the maps into the appropriate columns on the Field char1 worksheet. This puts the map data in a form that allows you to sort management units on the basis of their characteristics.

19. Record recent cropping history. Fill out the columns in the Field char1 worksheet describing cropping history for each management unit. Row 1 of the worksheet has been left blank so that you can fill in the actual year above the column headers. This planning procedure assumes that you are doing the planning in the winter, and hence begins with the current winter's cover or cash crops. Write in the names of current crops and their planting and expected harvest times. Now work backward from the present to preceding years as you go from right to left. If more than one cash or cover crop was grown during a given period, enter the names of both in the cell using a slash (/) as a separator.

Table 5.7 shows the cropping history of Small Valley Farm. Since the period in the history of the farm that is described in Table 5.7 predates division of the farm into management units, the areas cropped do not necessarily correspond perfectly to the management units. For some of the management units in each year the indicated crop was grown on most, but not all, of the land in that MU. You may encounter a similar situation.

Table 5.6. Example of the field characteristics portion of the Crop char1 worksheet for Small Valley Farm

Field name	Zone	Manag. unit	Erosion potential	Soil quality
C	I	1	low	good
C	I	2	low	good
A	I	3	low	good
A	I	4	low	good
A	II	5	high	fair
A	II	6	high	fair
A	II	7	high	fair
A	II	8	high	fair
B	I	9	low	good
B	I	10	low	good
B	II	11	high	fair
B	II	12	high	fair
D	III	13	very low	very good
D	III	14	very low	very good
D	III	15	very low	very good
D	III	16	very low	very good
D	III	17	very low	very good
D	III	18	very low	very good

Table 5.7. Cropping history of Small Valley Farm.

Field name	Zone	Manag unit	3-years ago	2-years ago	Last Year
C	I	1	corn	soybean	oat/spelt
C	I	2	corn	soybean	oat/spelt
A	I	3	soybean	oat/spelt	spelt/hay
A	I	4	soybean	oat/spelt	spelt/hay
A	II	5	soybean	oat/spelt	spelt/hay
A	II	6	oat/spelt	spelt/hay	hay2
A	II	7	oat/spelt	spelt/hay	hay2
A	II	8	oat/spelt	spelt/hay	hay2
B	I	9	corn	soybean	oat/spelt
B	I	10	spelt/hay	hay2	hay3/oat cc
B	II	11	spelt/hay	hay2	hay3/oat cc
B	II	12	spelt/hay	hay2	hay3/oat cc
D	III	13	hay2	hay3/oat cc	corn
D	III	14	hay2	hay3/oat cc	corn
D	III	15	hay2	hay3/oat cc	corn
D	III	16	hay3/oat cc	corn	soybean
D	III	17	hay3/oat cc	corn	soybean
D	III	18	hay3/oat cc	corn	soybean

20. Sort the management units. ***If you did steps 9 and 10 (general rotation planning):*** sort the spreadsheet by management zone. Sort the rows within each management zone so that (i) MUs with similar crop histories are together, and (ii) within each group, adjacent management units are in numerical order. Use the column headed "Extra col" to number the different types of cropping history, and then sort on (i) Zone, (ii) Extra col, and (iii) Manag unit. ***If you skipped steps 9 and 10:*** sort rows so that (i) MUs with similar critical field conditions are together, (ii) within those groups, MUs with similar crop histories are together, and (iii) within each crop history group, adjacent management units are in numerical order. To do this efficiently, sort by the critical field condition columns. Then number each cropping history by placing a number in the column headed "Extra col" – no particular order is needed. Then within each field condition grouping, sort the rows by (i) "Extra col" (that is, crop history and (ii) Manage unit. ***Everyone:*** for this purpose "similar crop histories" means similar in how the history affects what crops you will grow in the future. For example, if one management unit had broccoli and another had cauliflower two summers ago but otherwise their histories do not differ, you may decide that they are not sufficiently different to warrant separating them into different groups for purposes of planning future crop sequences.

After the Small Valley farmers sorted their MUs, units 9 and 10 are grouped with the other flat, ordinary MUs, namely MU 1 to 4 (Table 5.8). Similarly, the steep MUs, 5 through 8, 11 and 12 are grouped together.

Table 5.8. Recent crop history and future crop sequences for Small Valley Farm.

Field	Zone	MU	3-years ago	2-years ago	Last Year	Next Year	2-years from now	3-years from now	4-years from now	5-years from now	6-years from now
A	I	1	corn	soybean	oat/spelt	spelt/hay	hay2	hay3/oat cc	corn	soybean	oat/spelt
A	I	2	corn	soybean	oat/spelt	spelt/clover cc	oat/spelt	spelt/hay	hay2	hay3/oat cc	corn
B	I	3	soybean	oat/spelt	spelt/hay	hay2	hay3/oat cc	corn	soybean	oat/spelt	spelt/hay
B	I	4	soybean	oat/spelt	spelt/hay	oat/spelt	spelt/hay	hay2	hay3/oat cc	corn	soybean
C	I	9	corn	soybean	oat/spelt	spelt/clover	corn	soybean	oat/spelt	spelt/hay	hay2
C	I	10	spelt/hay	hay2	hay3/oat cc	corn	soybean	oat/spelt	spelt/hay	hay2	hay3/oat cc
B	II	5	soybean	oat/spelt	spelt/hay	hay2	hay3/spelt	spelt/hay	hay2	hay3/spelt	spelt/hay
B	II	6	oat/spelt	spelt/hay	hay2	hay3	hay4/spelt	spelt/hay	hay2	hay3/spelt	spelt/hay
B	II	7	oat/spelt	spelt/hay	hay2	hay3/spelt	spelt/hay	hay2	hay3/spelt	spelt/hay	hay2
B	II	8	oat/spelt	spelt/hay	hay2	hay3/spelt	spelt/hay	hay2	hay3/spelt	spelt/hay	hay2
C	II	11	spelt/hay	hay2	hay3/oat cc	oat hay/hay	hay2	hay3/spelt	spelt/hay	hay2	hay3
C	II	12	spelt/hay	hay2	hay3/oat cc	soybean	oat hay/hay	hay2/spelt	spelt/hay	hay2	hay3
D	III	13	hay2	hay3/oat cc	corn	soybean	oat/clover cc	corn	soybean	oat/clover cc	corn
D	III	14	hay2	hay3/oat cc	corn	soybean	oat/clover cc	corn	soybean	oat/clover cc	corn
D	III	15	hay2	hay3/oat cc	corn	oat/clover cc	corn	soybean	oat/clover cc	corn	soybean
D	III	16	hay3/oat cc	corn	soybean	oat/clover cc	corn	soybean	oat/clover cc	corn	soybean
D	III	17	hay3/oat cc	corn	soybean	corn/ryegrass	soybean	oat/clover cc	corn	soybean	corn
D	III	18	hay3/oat cc	corn	soybean	corn/ryegrass	soybean	oat/clover cc	corn	soybean	corn

Plan future crop sequences

21. This step is not needed when using Excel® spreadsheets.

22. Plan next summer. Look at your completed Crop char1 worksheet, and note how many management units of each crop you plan to grow. Fill in the names of the crop you will grow on each MU next summer. If more than one crop will be grown on a MU next summer, write them all in the cell in the sequence they will be grown (for example, lettuce/buckwheat cc/fall broccoli). Place crops in the following order, and refer to your base map as needed.

(A). Begin by writing in cash crops that are already planted but that will not be harvested until next summer or later. Examples include garlic, strawberries, winter grains, and hay.

(B). Now place high value crops that require special field conditions. For example, melons may produce a large net income per acre but you can only grow them well on one field. So, place melons and other high value crops with special needs first.

(C—vegetable farms). Next, place crops that have the shortest family return times as computed in step 6. Begin with the most valuable crop in the family with the shortest average rotation return time. Work through all crops in families with average return times of less than four years.

(C—grain & livestock farms). Next, place other crops that produce a large net income for the farm but that can be grown almost anywhere.

(D). Place less profitable and low acreage crops that require special MU characteristics.

(E). Finally, place all remaining crops.

Things to take into account when placing crops:

• Be careful not to repeat crops of the same family too soon. This is especially important if you have noticed symptoms of soil-borne diseases. If you have noticed such disease in the past, check Appendix 3 to see how many years to wait before repeating a crop with similar susceptibility. If soil-borne diseases have not been noted, try to use a minimum separation of at least one year between similar crops, and remember that a longer separation is a good preventative measure. Growing the same crop in close succession may be an acceptable practice if you then rotate into other crops for many years. Even in this case, however, it is advisable to grow at least one cash or cover crop in between to minimize direct transmission of diseases on crop residue. Note that most of the example rotations used by experienced farmers shown in Chapter 4 have return times for crops in a family of 4 years or longer.

• Refer to Appendix 2 as you work to check for problems and opportunities in the crop sequences you are choosing.

• If an MU has special uses, try to plant it with a crop that takes advantage of its special properties, but remember that that may not be possible every year.

• Separate early and later plantings of the same crop to avoid disease build up through the season. Alternating strips of different crop types with similar planting and harvest times (for example, lettuce and mustard greens) is a way to stay organized while still separating succession plantings of a given crop type. To be effective, however, the intervening strips must be wide enough to act as an effective barrier to dispersal of diseases and insects. Consult Appendix 3 to see how particular diseases are spread.

For those developing a general rotation plan (you did steps 9 and 10 above);

others can skip to step 23: most of the considerations discussed above are essentially covered by your general rotation plan. The key for placing crops next summer for you is to begin converting from the previous cropping history to the general rotation plan. This requires looking forward more than just one year. Getting each MU on track requires some imagination and a lot of trial and error (on paper). Remember, however, that once you have the desired crop mix within a zone, the future crops follow ore or less automatically. If your general rotation plan is based on crop categories (for example, early season greens, full season nightshades etc) rather than specific crops, place the crop categories onto the MUs first. Then go back through and place the specific crops within each category.

Consider the example of Small Valley farm in Table 5.8. In Zone I last year they planted three management units of oat/spelt. Ultimately, they would like to get one MU of Zone I into each of the 6 crop-years of the 6-year rotation. The spelt, however, is already planted and they are loath to plow it under. This results in three MUs of spelt in Zone I and none in Zone II where they would ultimately like to have it.

In MUs 1, 3, and 6 they simply proceed into the planned next crop. Instead of overseeding hay into the spelt in MU 2 they overseed with clover next spring and then plant oat followed by spelt 2-years from now. Similarly, instead of overseeding hay into the spelt in MU 9 they overseed clover, and then plant corn the following year. To get MU 4 on track, they treat the overseeded hay as a cover crop and plant oat followed by spelt next summer. Thus, by 2-years from now, they have one of each of the 6 crop-years on one MU of Zone I, and the rotation plan is in place for that zone of the farm.

Similar slight departures from their desired sequences are necessary in the other two Zones. Most notably, they grow oat as a hay crop on one MU in Zone II in each of the next two years to make up for the shortage of grass-alfalfa hay. Except for the substitution of oat hay for their usual grass-alfalfa hay, note that they grow the desired crop mix in each future year. Note also that they meet their explicit goal of avoiding the same crop immediately in succession. By 3-years from now, the rotation plan has been implemented for the whole farm.

23. Check next summer's crop mix. After you have assigned crops to all MUs, add up the number of MUs of each crop. Compare these with the number of MUs you intended to grow as indicated on your Crop char1 worksheet. If the two numbers do not agree, either assign some MUs to other crops or change the planned number of units on the Crop char1 worksheet.

If you think it will be helpful, enter the planting and harvest times for next summer's crops. The planting and harvest times are most useful when you plant the same crop multiple times during the season (for example, succession plantings of lettuce, spring and fall broccoli crops etc.). See Box 5.3 for a simple system of codes for recording planting and harvest times.

24. Plan next winter and two summers from now. Fill in any cash crops that will be present next winter (for example, garlic, spelt). Do not assign winter cover crops yet.

Fill in cash and cover crops for two summers from now as you did for next summer (see step 21 above). When making your decisions, always look back over the whole cropping history of the management unit up to this point, as well as the special properties of the MU. Refer to Appendix 2 to check for potential problems and opportunities.

Check your crop mix as in step 22 to be sure that the field plan provides the correct amount of each crop.

Now fill in cover crops for next winter that make sense given the crops that precede and follow them. Consider especially, (i) the harvest time of the preceding crop, (ii) the planting time of the following crop, and (iii) the needs of the following crop (N demand, ability to incorporate cover crop before planting etc.).

25. Plan future years. Repeat as in step 23 for each succeeding year. Plan as far ahead as you feel will be useful. Realize that your plans may need to change due to weather events and market conditions.

Refine your plan

26. Put your plans on maps. Copy the information from the Field char1 worksheet onto blank maps. Put next summer on one map and winter followed by summer pairs on other maps, with one year per map.

27. Take the maps to the field. Take these maps and walk through the fields. For each cluster of adjacent MUs, farm the cropping sequence through in your head. Compare the maps with your feel for the various management units and how they have preformed in the past. Take notes on what seems right and what may not work.

Write down what you could do if problems arise. This is an important consideration. Think about what will happen if rain delays timely incorporation of a cover crop or timely planting of a cash crop. What will you do if cultivation is delayed and the crop becomes excessively weedy? Consider other such potential problems and whether they may require a change in the planned sequence. Make notes on potential alternative strategies to meet circumstances you may encounter.

28. Modify planned sequences. Return to your office and lay out your maps and notes. Based on insights gained from walking the fields, modify the planned sequence where necessary on the Field char1 worksheet.

29. Recheck your crop mix. When you appear to again have a reasonable plan, add up the number of MUs of each crop in each year and check this against your intended production as indicated on the Crop char1 worksheet. Make further adjustments on the Crop char1 worksheet or Field char1 worksheet if necessary. Remember, however, that year-to-year variation in productivity per MU may swamp out slight variation in the number of MUs grown for major crops.

30. Note contingency plans. When you have the Field char1 worksheet adjusted the way you want it, add notes indicating your contingency plans. Enter these in the columns at the far right of the Field char1 worksheet. Adjust column width as necessary.

Note that the Small Valley example has multiple possibilities for meeting contingencies. For example, if weather hopelessly delays planting of oat, the farmer can substitute corn. Similarly, soybean can be substituted for corn if corn planting is not feasible. If plowing down the hay or planting spelt proves impossible, then the hay can be left for an extra year. Each of these essentially moves the rotation ahead one year, which is fairly easy to compensate for in the future. Obviously, all of these

circumstances result in a crop mix that is different from the original plan, but that is necessarily the case when a crop cannot be planted.

The Small Valley example also illustrates potential for adjusting the crop mix to meet market demand without significant modification of the basic rotation plan. For example, barley could be substituted for oat, dry bean for soybean, or a heavy feeding processing vegetable crop like cabbage or sweet corn for corn.

31. Make your crop placement maps match your revised Field char1 worksheet. Finally, modify the maps for each year so that they match the Field char1 worksheet. Make several copies of these maps so that you can take them into the field when preparing seedbeds and planting.

Congratulations! You have created a complete cropping plan for your farm! Be sure to back up your Crop char1 and Field char1 worksheets.

A more complex example: Summer Acres vegetable farm

Table 5.9 shows the crop mix for Summer Acres Farm, and Figure 5.4 shows a map of the farm divided into management units. The Excel® spreadsheet "Summer acres Field char1" gives a completed Crop char1 spreadsheet for for the farm. The example is fictitious, but is based on an example crop mix and planting and harvest times provided by a New York vegetable grower.

In this example, the farmers are growing 51 management units of cash crops on 50 MUs of land. This example farm is sufficiently land limited, to constrain the cropping sequences, but not so land limited as to force serious departure from good rotation practices.

Because of the land area constraint, the farmers' primary rotation goal is maximizing the time between crops in the same or similar families. Within this constraint, the farmers choose sequences that supply cover crop nitrogen whenever possible, especially before heavy feeding crops. The farmers attempt to keep the ground

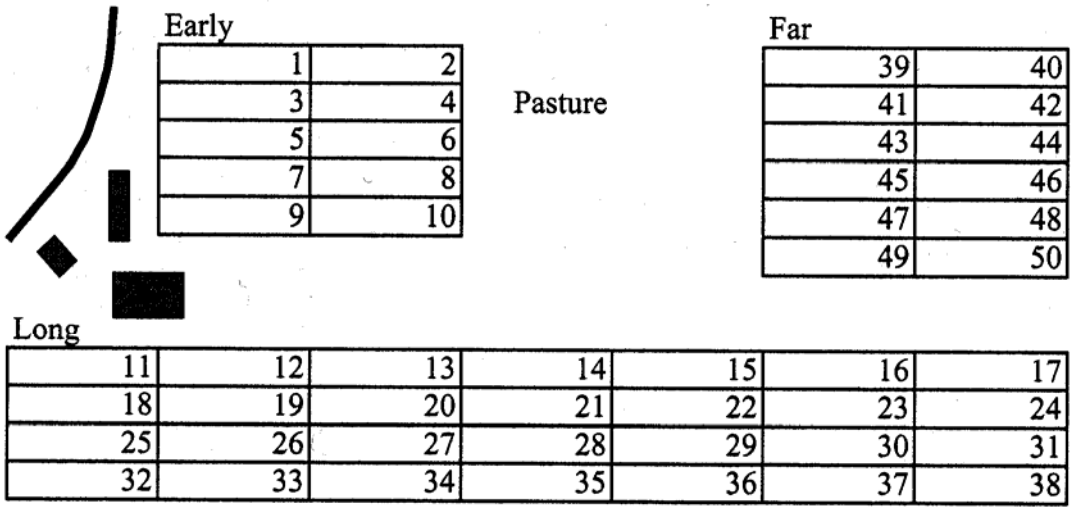


Figure 5.4. Map of Summer Acres Farm

covered with a cash or cover crop throughout the year to prevent erosion and improve soil quality, even when the opportunity for biomass production by a cover crop is limited. The exception is that they include a one-month fallow period in late spring/early summer for weed control whenever this is convenient.

Table 5.9. Crop char1 worksheet for Summer Acres vegetable farm

Crop[1]	Area /yr	MUs/yr	Family	Plant Time[2]	Harvest time[2]	Harvested part	Cold tolerance
Garlic	0.16a	2	Allium	lfall	msum	root	very hardy
Pea	0.32a	4	Legume	espr	msum	fruit	hardy
Lettuce5	0.16a	2	Lettuce	espr	esum	leaf	half-hardy
Lettuce6	0.16a	2	Lettuce	esum	msum	leaf	half-hardy
Lettuce7	0.16a	2	Lettuce	msum	lsum	leaf	half-hardy
Lettuce8	0.16a	2	Lettuce	lsum	efall	leaf	half-hardy
Lettuce9	0.16a	2	Lettuce	efall	lfall	leaf	half-hardy
Potato	0.32a	4	Nightshade	esum	lsum	root	half-hardy
Tomato	0.48a	6	Nightshade	lspr	efall	fruit	tender
Pepper	0.24a	3	Nightshade	lspr	efall	fruit	tender
Carrot	0.16a	2	Carrot	espr	msum	root	half-hardy
Kohlrabi	0.08a	1	Mustard	espr	msum	leaf	hardy
Broccoli	0.16a	2	Mustard	lspr	lsum	Flower bud	hardy
Summer squash	0.24a	3	Cucurbit	esum	efall	fruit	tender
Winter squash	0.48a	6	Cucurbit	lspr	efall	fruit	tender
Spinach5	0.16a	2	Beet	espr	esum	leaf	hardy
Spinach8	0.16a	2	Beet	lsum	efall	leaf	hardy
Spinach9	0.16a	2	Beet	efall	lfall	leaf	hardy
Beet5	0.08a	1	Beet	lspr	msum	root	half-hardy
Beet7	0.08a	1	Beet	msum	efall	root	half-hardy
Total units	4.08a	51					

1. The number after the names of some crops refers to the planting month.
2. Abbreviations for planting and harvest times follow Box 5.3.

Mostly the example farmers manage to plant a given crop in adjacent MUs. However, since they grows most crops in even numbers of MU.s, the configuration of field Long, with its strips of seven MUs poses a problem. If they cannot manage to plant the same crop in a long strip, they try to plant pairs of MUs that are side by side. This reduces time spent planting and managing the crop. Pepper, tomato, summer quash, and winter squash are less bothersome to have in multiple locations since they grow several varieties of each of these crops. To the extent possible, they attempt to separate successive plantings of lettuce and spinach with one or more MUs of other crops. When successive plantings are forced onto adjacent MUs by other considerations they try to provide a time lag within the season so that insect pests and diseases cannot easily spread from one planting to the next.

Before the planning process, the growers often double cropped short season crops (for example, an early lettuce planting with a late spinach planting). This allowed them

to produce 51 MU of crops on 50 MU of land. It also allowed planting a soil building full season cover crop of oat (mowed in June) and red clover, on a few MU each year. However, it made including shorter season legume cover crops like cowpea and field pea difficult on an even greater number of MUs, thereby requiring substantial use of compost to meet N needs. Consequently this practice was discontinued. In order to continue to grow more MUs of crops than they have land, they began intercropping early lettuce or spinach with tomato (see Chapter 7). The lettuce or spinach is planted at the same time as the tomato in an adjacent row on the same bed. The lettuce or spinach is harvested in early summer before the tomatoes crowd it. Although double cropping and intercropping allows intensive use of the land, it also means more different families are grown within a given number of years on those MUs. This can increase the difficulty of separating families in time.

The only MUs with special properties are in the field called Early. That field is well drained and has a south-facing slope that warms early in the spring. Consequently, the farmers attempt to grow their earliest crops on this field whenever possible. These crops include pea, carrot and kohlrabi, and early plantings of lettuce and spinach. Since kohlrabi requires only one MU, whereas the other early crops use two or four MUs, the farmers sometimes use the first planting of beet (beet5), which also requires only one MU, as a "fill in" crop to balance the rotation. When possible, they also like to grow pepper on the field since this is a high value crop that takes advantage of the warm temperatures provided by the southerly aspect of the field.

The rotation on field Early is complicated, however, by the need to grow four MUs of pea and the use of cowpea and hairy vetch cover crops (close relatives of pea) as nitrogen sources for the other crops. To minimize problems, they decide to only plant pea on a given MU one year out of three, and to avoid preceding pea with a cowpea cover crop during summer the year before. Since nitrogen fixing cover crops are limited by these decisions, they also decide to use a purchased amendment, if necessary, to supply N needs. To meet the first of these decisions, in some years they plant two MUs of pea on MU 11 and 12 of field Long. Even with the precautions, the frequency of pea and pea relatives may eventually lead to disease problems in pea.

Many of the early season crops grown on field Early are harvested in time for a late planting of lettuce, spinach or beet. Lettuce, however, shares diseases with pea (see Appendix 2), which is the crop most dependent on field Early. Similarly, the early season beets and spinach make adequate rotation lengths difficult if late season plantings of these species are grown after carrot, pea, or kohlrabi. Consequently, the spring cash crops on field Early are followed by summer cover crops.

The principal limiting factor on the remaining 40 MUs in fields Long and Far relate to the need to grow 13 MUs of species in the nightshade family (tomato, potato and pepper). The farmers have to juggle their crops carefully to avoid growing a nightshade crop more often than one year in three ($40/13 \approx 3$). A longer interval between nightshade crops is desirable (see Appendix 3), and they sometimes manage this on some MUs by growing peppers in field Early. To minimize the problem of finding locations for nightshades that maximize return times, they begin the placement process for fields Long and Far by locating these crops first.

They then proceed to place the winter and summer squashes. Squash also occupies a large percentage of fields Long and Far, and therefore providing adequate breaks between squash crops is difficult. In addition, they grow 6 MUs of winter squash, and management is easier if it is planted in a block of adjacent MUs. Other crops are then

filled in wherever they can fit given the goals discussed above.

With the exception of the nightshades, which are probably planted too frequently, the farmers in this example manage a reasonable separation in time for most families on most MUs in most years. Accomplishing this, however, requires considerable juggling of crop placement: regular repetition of particular crop sequences is largely impossible and development of a general crop rotation plan would probably require a shift in the crop mix. Increasing the land base could simplify the rotation and avoid the problem of too many MUs of nightshade crops. In addition, increased land would allow greater use of legumes to supply nitrogen for heavy feeding crops, and allow more convenient placement of crops on the farm.