Application of the Cornell Nutrient Management Planning System: Optimizing Crop Rotations

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Introduction

Optimizing Crop Rotations is the process of producing feed that matches both the available land resource capability and the feed needs of the herd for optimum production. In the process, the crop rotation must be sustainable so that soil quality is maintained and nutrients are recycled to protect the environment. For long term profitability, the impact of various crop rotation and production costs, combinations of feeds produced, subsequent animal performance and the resources and management required in the overall farming-feeding operation must be considered (1).

We have developed a computer program that can be used to optimize crop rotations. This program is designed to describe the actual crop production system as the sum of individual field crop rotations and amounts of feed produced and stored in each storage unit. The program summarizes the on-farm feed needs of the animals, and computes a balance with feed produced. The program is designed to operate within the whole farm Nutrient Management Planning System in which the feed needs/feed produced can be exchanged with the Cornell Net Carbohydrate and Protein System (CNCPS) and the crop rotation output and crop codes can be exchanged with the crop requirement and manure Nutrient Management System. Once the fields, herd and crop rotations are described, alternatives can easily be evaluated. It can also be used as a stand alone program to compute simple whole farm feed balances, based on current rations and crops produced and stored.

This paper will present an overview of the crop rotation program, using the McMahon Farm case Study as described in the companion papers of T. Tyluki and C. Bannon to demonstrate the application of this software and the interaction with the other components of the whole farm Cornell Nutrient Management planning system.

Organization of the Crop Rotation Computer Program

The software is based on a Microsoft Excel version 7.0 platform that operates under Windows 95. It runs most efficiently when 16 meg are available. The program starts with inputting the number of animals and their groups, and the rations, storage, and crops produced, presently on the farm. The software then determines the whole farm feed balance in both graphic and tabular output. Because the initial inputs are simply a description of the present program, it allows the dairy farmer to become involved at a very comfortable level. A simple balance of animal requirements with feed supply and storage with the present program can be made in the Level I analysis. Then the user can move to Level II, where alternatives such as changes in number of cows and/or acres can be chosen and their impact on the whole farm can be evaluated, using inputs from level I or III. In Level III, feed requirements for each group is imported from the CNCPS and descriptions of each field is imported from the crop nutrient management program to obtain greater accuracy in evaluating feed balances and alternatives. New crop rotation information from alternatives can be exported to the other two programs (CNCPS and crop and manure nutrient management). A more detailed explanation of each of the three levels follows.

Level I analysis

The first step is to enter data that describes of the herd and quantity and quality of forages, and home-grown grains presently being fed to each group of animals. The program then determines how many tons of dry matter of each feed is needed to be produced on the farm under the present conditions. Surprisingly, very few farms have taken the time to make these calculations for all their animals. Gross mismatches of feed supply with the present feeding program can be identified at this stage.

The second step is to determine the storage available for the feed needed. An unbalanced storage system (corn silage amounts vs. haycrop amounts) contributes to poor feed storage (under or over filling and inadequate packing; inadequate feed out rates). The storage available needs to match the tons of haycrop and corn silage dry matter harvested for the rotations chosen. The program will determine from the ration the proportion of the haycrop stored as baled and silage. The storage capacity for silage is directly determined by inputting the silo size for the crop (haycrop silage, corn silage, or corn grain) being stored. Upright and bunk silo capacities are determined by equations. The program reports the feed out rates - a number vital to maintaining feed quality to the point of consumption.

The third step is to determine the tons of each feed that can be grown on the acres available. Utilizing earlier versions of this program over the past five years, we have found that more than 80% of the farms are off by a considerable margin on their acreage. A surprising number underestimate their acreage by more than 30%. When storage supply is divided by acreage to give an estimate of yield/acre, a 30% margin of error can dramatically affect any economic projections, forage supply, and least cost ration analysis. This error is in the fundamental blocks on which decisions for farm profitability are built.

This first evaluation of a farm will give a picture of the present situation; do I produce enough tons of feed to meet the needs of the number of animals I have? Are the tons of corn silage and haycrop forage produced sufficient to meet the sum of the ration components being fed to each group during the year? Do the storage and feed out rates' match the feed being produced and fed? The program's one page summary gives a true balance of the farm's feed needs with production and storage in graphic and tabular form.

Level II Analysis

This level allows the user to examine alternatives, utilizing the data from levels I or III that describes animals, groups, fields and crops. The most unchangeable elements need to be optimized first. The soil's fundamental characteristics can be changed very little. The choice of crops are what best suits the soil in producing high quality forages, at an economical cost, over a range of conditions and time. A rotation choice of 3 years corn to 6 years hay will over the rotation cycle, produce a dry matter ratio of about 46% corn:54% haycrop. A rotation choice of 3 corn:4 hay will produce the opposite dry matter ratio of 54% corn:46% hay and do it costing 5% less / ton of dry matter (figure 1) while at

the same time producing 10% greater yield/acre (figure 2).

Figure #1 Cost/ton of dry matter as affected by rotation choice.

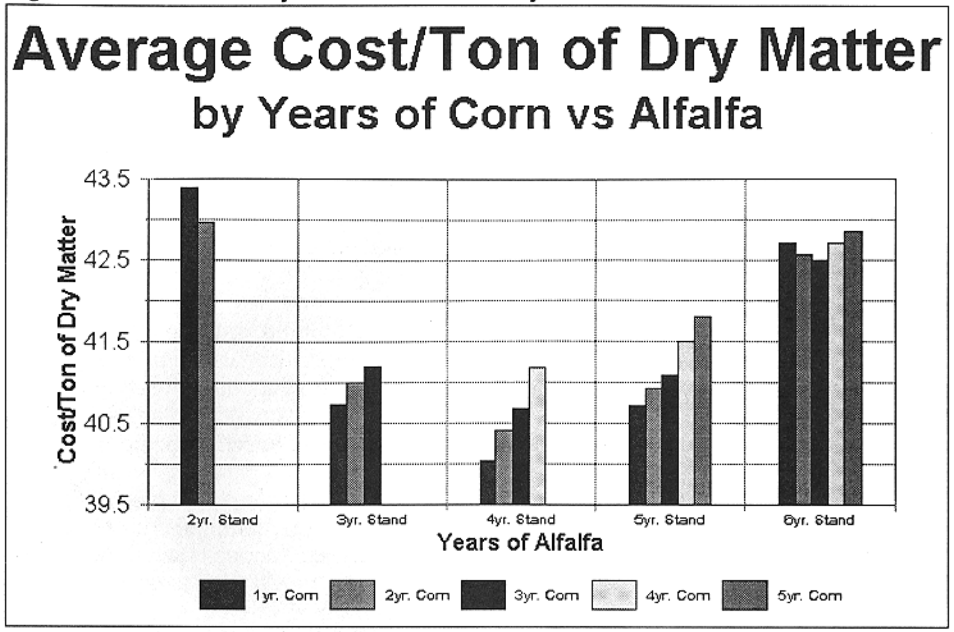
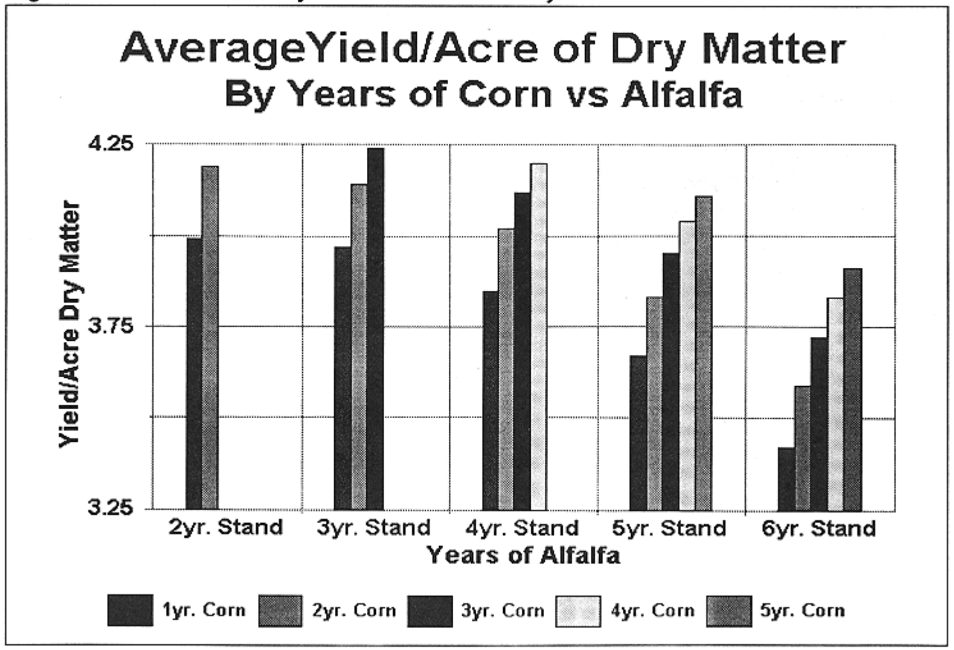


Figure #2 Yield/acre of dry matter as affected by rotation choice.



Rotation choices have a great impact on cost of producing forage and increasing quality and yield/acre. **Thus soils drive the rotation choice which determines what the cows are fed;** dairy cows can be fed rations with forage bases that range from all haycrop to all corn silage as long as they are properly balanced (L.Chase, personal communication)[1].

An additional choice for some farms is whether to produce their own grain. The impact on the rotation is to increase the acres of corn needed to meet both forage and concentrate needs, and to lengthen the rotation. Some will save money this way. For many, dropping the home grown grain program reduces the years of corn and acres of corn to plant in the spring. Both of these increase forage quality, which improves profitability tremendously. Improved forage quality often improves dry matter consumption, which affects total needed.

Each change can have major implications for the feed storage size, allocation, and feed out rates. Daily amounts of that forage fed can be dramatically changed by changing the forage in the rations. By changing storage structures used for each feed and form of storage for each feed (dry vs. silage), these effects can be evaluated. Both of these factors played a key role in the case farm study, which will be discussed later.

One of the most valuable aspects of the program is to evaluate the impact of changes in animals and rations. Common questions involve evaluating a change in rations, number of cows and contract raising of heifers. The impact of these changes on total feed needs, production and storage can be evaluated. Level III uses the CNCPS to compute forage requirements. Level I uses a forage NDF as a % of body weight equation (2) weighted across all feeding groups to set the forage requirement to set the level of forage feeding the farmer plans to use. From minimum to maximum forage feeding level, this can have more than a 46% change in the tons of total dry matter needed. Changing the quality of forage allows for more forage to be fed, which can dramatically affect the amounts of forage needed to be fed. Any of these changes can immediately be compared to the matrix of acres, yield, and storage on the farm.

Level III Analysis

All level III information can be used in level II analysis and answers questions similar to the level 1 analysis. The difference is in the greater accuracy of the data, and thus the decisions. In this level, the rations being fed are imported from the CNCPS. The crop base is established by listing each farm field, its acres, soil type, and past and present crops. Thus this level may take a greater investment in time to set up, but once established can be much more accurate in evaluating alternatives. A rotation is assigned for each field based on what is best for long term production of that soil type. This can be adjusted by making crop changes even if they are outside the original rotation choices. This was heavily used in 1996 when many crop plans were flooded out. Rotations necessary to meet NRCS farm plan erosion limits can also be used. The collective impact of the rotation used for each field on the farm forage base can then evaluated. This answers the critical question of what will the storage needs and the rations be if these individual field rotations are used. For example, if a 3 years of corn and 4 years of hay rotation produces an average 54% corn dry matter and 46% haycrop dry matter, what is the storage necessary for this feed, and what is the rations for each group of animals that will make best use of this feed supply? In addition to the farm base, the year to year crop production is also reported. As fields shift from one crop to another, the acres of the crop, and the percent in each group may shift. This is critical information for allocation of storage needs and utilization in rations. The individual year feed supply as based on the acres of each crop grown that year is another report available. This is being expanded into a crop record keeping system that uses simple or detail data such as G.P.S. coordinates and results of forage yield monitors. The latter will be a major advantage in that the actual feed produced by the crops for the selected year can be checked. The feed produced can then be exported to the CNCPS to determine the best allocation of that feed. We plan to have future versions include capability for scanned in field maps and a field crop record keeping program for nutrient management and pesticide reporting.

With level III, the user will be able to directly export the crop codes, acres, and soil type to a printout necessary for sending in with soil samples. This will be a major time saving for those who need the results in order to use the crop nutrient management program. Level III will directly export to the crop nutrient management program all the fields and the crops to be grown on them. This will allow that portion of the program to be quickly updated with minimal data inputs.

Application of Software; the McMahon Dairy Case Study

The initial version of the software was tested on the McMahon Farm near Scott, N.Y. This 550 cow free stall operation has recently consolidated into one location. The facilities consist of a new free stall barn, dry cow barn, and heifer facilities. The soils resource consists of highly productive, flat, well drained valley soils and sloping, wetter, and heavier soils of the hillsides above the valley. The case study farm was usual in miscalculating the acreage, but unusual in that their estimate of acres was higher than what was available. They estimated 1,500 acres but actually cropped 1075 acres. Level III analysis (individual counting of acres in each field and each crop) was needed to provide accurate field information on acres available for cropping. The 28% difference in actual vs. perceived acreage has a tremendous impact on management decisions to determine steps necessary to increase the competitive position of the farm.

The acreage in the flat lands was reported to be in a 4 years of corn and 4 years of hay rotation. The upland was reported to be less than that in years of corn because of its erosive state and the tendency for wet, heavy soils to lose soil structure quickly if over cropped. Actual analysis found that the average crop rotation for the entire farm was 3.6 years of hay and 4 years of corn. This meant that the actual years of corn were greater than perceived and fewer acres were rotated (plowed for corn, or seeded to haycrop) than needed to maintain the reported rotation. The test farm rotation was better than the average. Use of an earlier version of the software found many other farms with 15 - 18 year rotation cycles. The result of long corn rotations is a crop supply more sensitive to adverse weather conditions. For haycrop, long rotations mean rapidly declining yields, and reductions in quality as "summer grasses" and weeds replace the original crop. On this farm, by the sixth year on most soils the yield is less than seeding year and alfalfa makes up less than 30% of the stand. In 1996, the farm had 494 acres of corn, 318 acres of rotated haycrop, 122 acres of new seeding, 89 acres of continuous hay. The wet conditions of crop year 1996 kept 52 acres from being cropped. This plus yield reductions on the harvested upland fields produced a low total forage supply.

[1]Personal communication. L. Chase, Department of Animal Science, Cornell University, Ithaca, NY

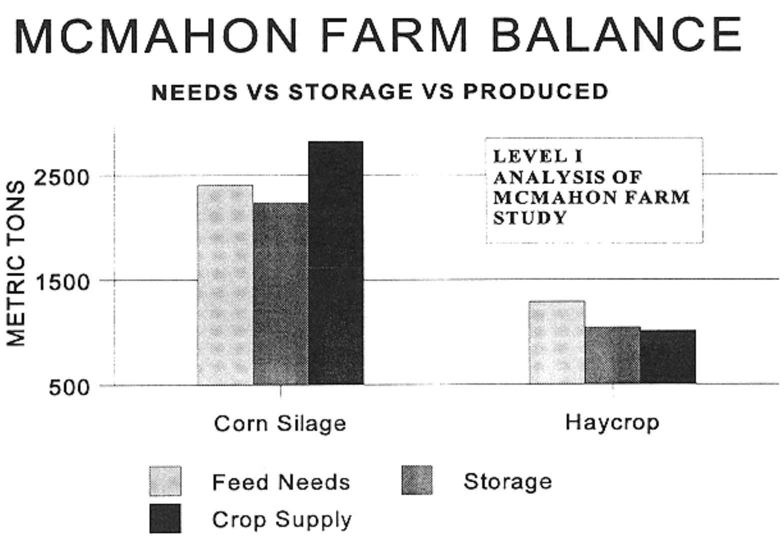
The farm balance with the present program is shown in figure 3 and table 1. This balance is based on a normal year. Feed needs were determined by export from the CNCPS (see previous paper of T. Tyluki). The amounts of each feed for each group was summed and reported in figure 3 and Table 1. For the McMahon farm, the surprise was that the theoretical feed supply was greater than the feed needs (table 1). There was a potential large surplus of corn silage, and a slight shortage of haycrop dry matter.

Another concern was the large difference between the ratios of dry matter of corn and haycrop produced (73.6% corn:26.4% haycrop) compared to the rations consumed (64.8% corn:35.2% haycrop). The big question was why they frequently needed to purchase forage when the balance showed a surplus. When a comparison was made utilizing the CNCPS, the amount of corn silage utilized was much smaller that produced. Yield/acre was questioned, but the test weighing on certified scales of several loads indicated the yield estimates used were within reason. The amount of corn silage utilized

Table #1 Case Farm balance of forage needs and forage supply.

Farm Balance of of Dry Matter	Ration Forage Needs		Home Grown Forage		Surplus/ Deficit
	Metric Tons	%	Metric Tons	%	
Corn Silage	2224	64.8	2589	73.6	+365
Haycrop	1205	35.2	926	26.4	-335
Totals	3429		3515		+86

Figure #3



was very close to what the storage held. The puzzler was that all the corn silage produced, a 26% surplus compared to storage, was made to fit the storage. The storage resources consisted of a 60 foot wide x 200 foot long bunk piled in excess of 20 feet high with corn silage. The height of this bunk was indicated as being much higher when it was initially covered. There was considerable difficulty in maintaining the cover. A second bunk 50 feet wide x 100 feet long x 10 high also held corn silage. Haylage was stored in two bunks each 32 feet wide x 200 feet long x 12 - 13 feet high. Because the corn silage storage was too small, the McMahon's utilized the same technique as on most farms. They filled over the bunk walls until all the feed fit in. By doubling the height of the present walls by piling, the entire harvest fit. This makes for very difficult and dangerous packing and makes it difficult to keep plastic covering it. Poor packing and coverage can increase dry matter loss from a normal of 15% to more than 30% (3). It also makes a large face to feed ahead. The calculations showed that the face on an average is being fed at the rate of six inches/day on the large bunk, and much faster on the smaller corn silage bunk. This is sufficient to maintain forage quality in warm weather (3). The lack of sufficient air exclusion on the upper half of the corn silage bunk produced dry matter losses exceeding the 26% that was in surplus. Feed quality loss of this magnitude was documented by the nutritionist, and will be discussed in the Optimizing Nutrition paper. It appears that the crop was harvested, put into storage, and dry matter losses reduced the pile to approximately what was being fed, incurring a major loss of profits.

Level II analysis of the case study farm

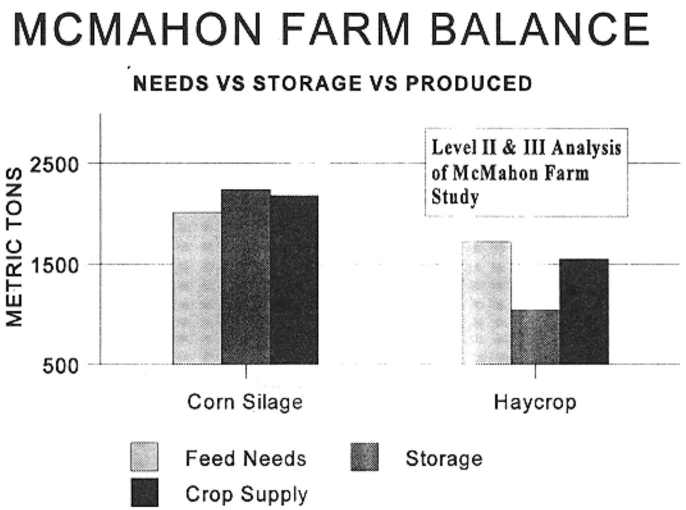
Level II analysis started with the least changeable resource on the farm, the soils. The soil's fundamental characteristics can be changed very little and so crop choices and rotations were examined first to optimize the quantity and quality of forage being produced. Their flat valley land was already being managed at a very high level and was left at their desired 4 years of corn, 4 years of haycrop rotation. However, intensively managed grass was substituted for corn on the wet, erodible hillsides. Because only the flat acreage is rotated, the acres needed to be seeded each year were reduced to 95.3 (22% reduction). By harvesting these grasses early, forage can be produced that rivals alfalfa in milk producing ability. By utilizing manure to fertilize these grasses as a nutrient sink, the nutrient budget of the farm can be improved. This latter point will be covered under the Optimizing the Crop and Manure Nutrient Management. The new plan will have 381 acres of corn (23% decrease), 318 acres of rotated haycrop (11.3% increase), and 313 acres of intensive grass (250% increase), giving a total haycrop of 598.7 (47% increase). Planting these hills to permanent haycrop will change the ratio of corn silage dry matter:haycrop dry matter available to feed the cows. Before making further changes, the CNCPS then evaluated the new supplies of forage and found that they actually improved the amounts of forage able to be fed. This has a tremendous effect on reducing the cost of producing milk. This new plan has the environmental benefit of reducing erosion, which also reduces the potential phosphorus pollution.

Figure 4 and table 2 shows the new cropping program and the ration that is based upon it. The total dry matter of needed vs. produced is nearly in balance. As the crop rotations take hold, a buffering surplus will appear most years. The ratios of corn to haycrop drymatter consumed (54%corn:46%haycrop), are very close to that produced (58.4%corn:41.6%haycrop). The corn silage is in slight surplus under present yields. This surplus will probably increase as higher average yields come into play from corn not being grown on low yielding hill soils. There is also the yield increase due to the rotation effect. First year corn yields 15 - 20% more than 2nd or more corn. With the new program, long term corn is reduced, and 25% of the corn crop is on first year ground. Thus 25% of the crop will yield 15 - 20% more than average. There is a slight deficit in the amount of haycrop produced compared to the amount needed. This will disappear as the intense rotation on the flat ground increases the yield potential of these fields. Before making further adjustments, the overall balance needs to be reviewed when yields are actually monitored and more soundly based yield data is entered into the program. There still is a slight deficit of haycrop. This can be relieved by the higher yields achieved on the flat ground as a result of a tighter rotation. Year to year variation as to haycrop and corn silage crop yields will shift this balance. These adjustments can be made on a yearly basis by

Table 2. New Whole Farm Balance

Farm Balance of of Dry Matter	Ration Forage Needs		Home Grown Forage		Surplus/ Deficit
	Metric Tons	%	Metric Tons	%	
Corn Silage	1851	54	1997	58.4	+146
Haycrop	1578	46	1422	41.6	-156
Totals	3429		3419		-10

Figure #4



the CNCPS.

What is the impact of this program on the storage? In the original level I analysis, it appears that the farm is very short on corn silage storage (26%). As shown in figure 4, with the new crop program based on what is best for the soil, there is now actually a slight

surplus of corn silage storage but a shortage of haycrop storage. This will work out well, because the new storage can hold separately the new crop added to the ration - high quality intensively managed grass. The addition of a 200x14x36 bunk will hold the necessary feed. An less expensive alternative will be to put up two 100x14x36 with a common center wall to reduce costs. The height of 14 feet was used as increased height is the lowest cost increase in storage capacity, and reduces surface area/ton of capacity.

Summary

The computer program has to potential to improve farm profitability through balancing the fundamental components of forage production, storage, and forage feeding, on the dairy farm. This case study analysis illustrates that both the cropping and storage can have a major influence on the choices made in the final level. The software bridges the Cornell Net Carbohydrate and Protein System and the Cornell Nutrient Management Software allowing data to move between both of them. Its ability to implement a range of crop rotations will allow it to conserve the soil for long term sustainable production, while optimizing the feed produced in a competitive, low cost, profitable dairying operation. The use of storage components completes the cycle which starts with the forage produced on the soil, goes through storage to be fed to the animals, and utilizes the manure nutrients generated to produce forage on the soil.

References

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