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ECR: A Revolution in the Retail Food System

Robert P. King and Paul F. Phumpiu

America's retail food system is in the middle of a dramatic but behind-the-scenes revolution. Far-reaching changes in food manufacturing, distribution, and retailing are following the advent of the Efficient Consumer Response (ECR) initiative. This industry-wide collaborative effort tries to increase efficiency and responsiveness to consumers through new forms of cooperation and coordination, in addition to new applications of information technology.

In this article we present a brief introduction to ECR and report findings from a study of ECR adoption by Minnesota grocery stores. These findings suggest that while ECR adoption is associated with superior financial performance, not all stores are participating equally in this food-system revolution.

What Is ECR?

The ECR initiative focuses on four fundamental, interrelated processes in the retail food supply chain: (1) selection of product assortments, (2) product replenishment, (3) product promotions, and (4) new product introductions. The objective is to trim costs and waste while effectively serving the customer. Because actions at one level of the chain can affect costs at another, the development of trading partnerships and the coordination of investments across different levels of the supply chain are desirable outcomes of ECR.

Consider, for example, manufacturers who periodically offer significant price reductions in one of their product lines. Such offers might be motivated by a desire to use production facilities at full capacity and thereby lower costs. But encouraging distributors to "buy on deal" can lead to costly fluctuations in warehouse inventories. This in turn might reduce distributor profits or increase costs that are passed on to retailers and consumers. Wasteful traps like this can often be broken out of through new forms of cooperation between trading partners who once viewed themselves as adversaries.

Another example shows the potential benefits from new cooperative relationships. The yogurt section of a typical supermarket can easily have more that fifty individual stock-keeping units — each a unique combination of brand, flavor, and package size. Choosing the right assortment for each store can cut down on spoilage, use limited shelf space more effectively, and ensure that customers will find the items they want.

Choosing the proper assortment not only requires knowledge about the store and its customers, but also about broader market trends and product interrelationships that store managers might not possess. By working more closely with distributors and manufacturers — and by sharing scanner data with them — retailers can make better assortment decisions.

Moving back through the system, this collaboration and data sharing helps firms manage their warehouse and distribution systems more effectively and sends better signals to manufacturers about the mix of products and package sizes they should produce.

*(See **ECR** page 2)*

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Minnesota Farmland Drainage: Profitability and Concerns

Vernon Eidman

Farmers in Minnesota have been draining cropland since the first settlers started building open ditches in the mid-1800s. Current interest in improving drainage is so high that drainage contractors had as much work as they could handle last year and are already committed through most of 1997.

Improving cropland drainage benefits farmers by increasing profitability and reducing the risk of lower crop yields during wet years. What is not known is the impact of improved field drainage on off-site stream flows. In this article we examine the benefits of farmland drainage and discuss some issues of concern.

Improved Drainage and Agricultural Production

Current drainage activity in the state focuses on existing systems — farmers are not draining wetlands, but they are improving drainage of land that has been farmed for many years.

*(See **Drainage** page 4)*

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(*ECR continued from page 1*)

New interfirm relationships include category management teams of employees from each trading partner, shifting day-to-day replenishment decisions from a retailer to a supplier, and unbundling product and service costs to give trading partners an incentive to consider the effects their actions have on each other.

As firms experiment with these new relationships, questions emerge about who will participate and how the benefits will be shared. Our study of ECR adoption in Minnesota grocery stores provides some initial insights on the answers to these questions. You can find a more complete analysis of our study at *http://agecon.lib.umn.edu/mn.html*. Search for "ECR." Or you can contact the Waite Library (the address is on the back page of this publication) for TRFIC paper 97-1.

Minnesota Grocery Stores

In the spring and summer of 1996 we interviewed forty Minnesota store managers, focusing our questions on store and manager characteristics, inventory management, ordering processes, store layout, shelf-space allocation, product assortment, product pricing, and promotion decisions.

This forty-store selection was not intended to be a representative, random sample of Minnesota groceries. Rather, it was designed to ensure a wide range of store sizes, locations, and types for our interviews. So while our findings cannot be used to make formal statistical inferences about all stores in Minnesota, they can be used to highlight patterns of technology adoption and organizational change that generally reflect important trends in the industry.

We created an "ECR readiness" score to measure the level of its adoption. This score is simply an unweighted adoption rate for 17 technological, organizational, and managerial practices considered necessary for the implementation of ECR. These readiness indicators are listed in Figure 1, along with average adoption rates for our sample stores.

The overall ECR readiness index would be 100 for a store that has implemented all of the seventeen technologies and practices listed in Figure 1. It would be 0 for a store that has not implemented any of these technologies and practices. An average ECR readiness score is also calculated in the same way for each of the four subareas listed in the table.

Ultimately, the success or failure of the ECR initiative depends on the impact it has on performance in each segment of the retail food supply chain. Data collected during the interviews permitted us to construct estimated values for three important store performance or productivity measures: sales per labor hour, weekly sales per square foot of selling area, and annual inventory turns. All three are commonly used in the industry, although the particular calculation methods reported here are unique to our study.

The sales-per-labor-hour measure was calculated as weekly sales (as reported by the manager) divided by an estimate of weekly labor hours, assuming that full-time employees work 40 hours per week and part-time employees work 20 hours per week. The weekly sales per square foot of selling area measure was calculated as weekly sales divided by store selling area, using figures reported by the store manager. Finally, annual inventory turns were calculated as annual sales — average weekly sales as reported by the manager multiplied by 52 — divided by the average inventory value reported by the manager.

The values calculated for these measures are only approximations and should be interpreted with caution. Nevertheless, they mirror key performance indicators that store managers monitor regularly.

We used three criteria to group and compare stores: location, organizational form, and the level of ECR readiness. Each classification scheme provides a different perspective on patterns of ECR adoption and store performance.

Store Location

Twenty-six of the stores in this study are located in the Minneapolis-St. Paul metropolitan area; fourteen are outside this area, in small towns or in larger cities such as Duluth and Rochester. Differences in ECR readiness for metropolitan and non-metropolitan stores are shown in Figure 2. Out-state stores have slightly higher average levels of ECR readiness for store and manager characteristics and for inventory management and ordering, though the differences are small. The specific indicators for these areas are, for the most part, related to the adoption of information technologies such as scanning, electronic data interchange, and the use of personal computers to analyze store level data. These results suggest that an out-state location does not hinder technology adoption.

In contrast, metropolitan area stores have higher average levels of ECR readiness in store layout and product assortment and in product pricing and

Figure 1. ECR Readiness Indicators and Adoption Rates

ECR Readiness Indicator	Adoption Rate (%)
Store and Manager Characteristics	
Scan merchandise	88
Scan coupons	33
Scan incoming shipments	40
Telxon units used for price verification	80
Manager has access to personal computer	15
Scanning coordinator has training on scan data quality	60
Store & Manager Readiness Index	**53**
Inventory Management and Ordering	
Electronic transmission of orders	98
Electronic transmission of movement data	60
Weekly sales forecasts based on scanner data	65
Shelf tags have movement and/or reorder information	20
Inventory & Ordering Readiness Index	**61**
Store Layout and Product Assortment	
Resets based on formal planograms	20
Manager has category management training	43
Non-DSD resets coordinated with outside parties	38
Non-DSD product assortment decisions coordinated with outside parties	60
DSD reset & product assortment decisions coordinated with outside parties	40
Product Assortment Readiness Index	**40**
Product Pricing and Promotions	
Pricing and promotion decisions coordinated with outside parties	53
Store uses competitor price information	68
Pricing & Promotions Readiness Index	**60**
Overall ECR Readiness Index	**52**

promotions. These ECR readiness categories are more closely related to relationships with suppliers than they are to technology adoption. This suggests that a non-metropolitan location may make it more difficult for stores to benefit from the ECR initiative in these areas.

Locational differences in the overall ECR readiness index are small. The average for metropolitan stores is 53 and for non-metropolitan stores is 49.

Performance levels in metropolitan stores are considerably higher than in non-metropolitan stores (Figure 4). Metropolitan stores have higher sales per labor hour, higher weekly sales per square foot of selling area, and higher annual inventory turns. Lower sales per labor hour and weekly sales per square foot of selling area do not necessarily imply lower profitability for non-metropolitan stores, though, because real estate and labor costs are also lower outside the metropolitan area.

Organizational Form

Seventeen of the stores in this study are part of corporate chains, defined as eleven or more stores under common ownership. Eight others are part of independent chains with between two and ten stores each. This leaves fifteen stores that are independently owned and not part of a chain.

Differences in ECR readiness for stores in these groupings are shown in Figure 3. Stores that are part of corporate chains rank highest in each category, and differences are dramatic in all areas except pricing and promotions. Average ECR readiness is similar for stores that are part of an independent chain and single stores for store and manager characteristics, for inventory management and ordering, and for store layout and product assortment. Stores that are part of independent chains are much more likely than are single stores to coordinate pricing and promotion decisions with outside parties. In this last area, then, the key difference is between chain stores and single stores.

Average levels of the overall ECR readiness index are 70 for stores that are part of a corporate chain, 43 for stores that are part of an independent chain, and 35 for single stores. Clearly, stores that are part of a chain, especially a large corporate chain, are making faster progress than single stores toward implementing ECR. This is to be expected, since large chains are able to spread the fixed costs of ECR adoption over a larger number of stores.

If ECR adoption does lead to superior performance, this could point to difficulties for independent chains and single stores in the future.

That such a link exists is suggested by our performance indicators (Figure 4). Corporate chain stores score higher in all three measures, although independent chains perform on average just about as well on the sales per labor hour indicator.

Figure 2. ECR Readiness by Location

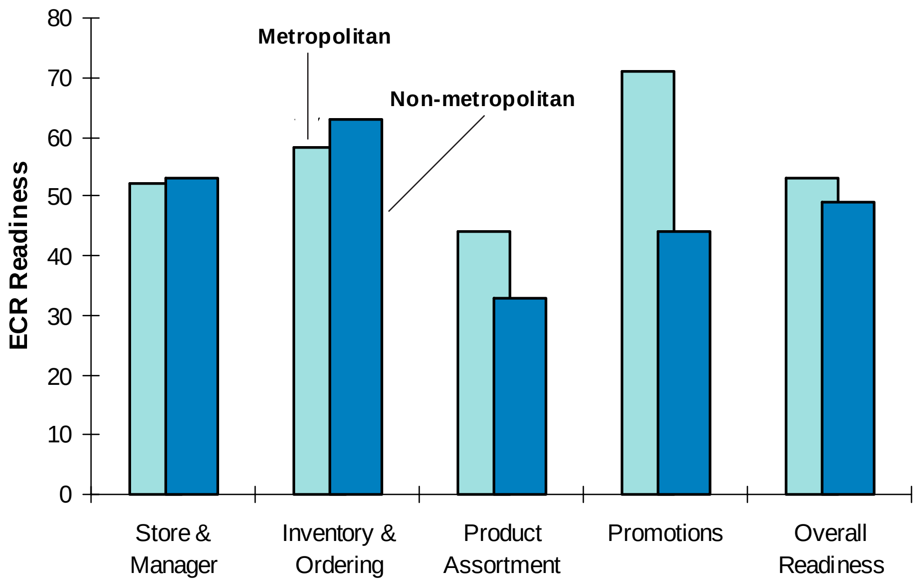
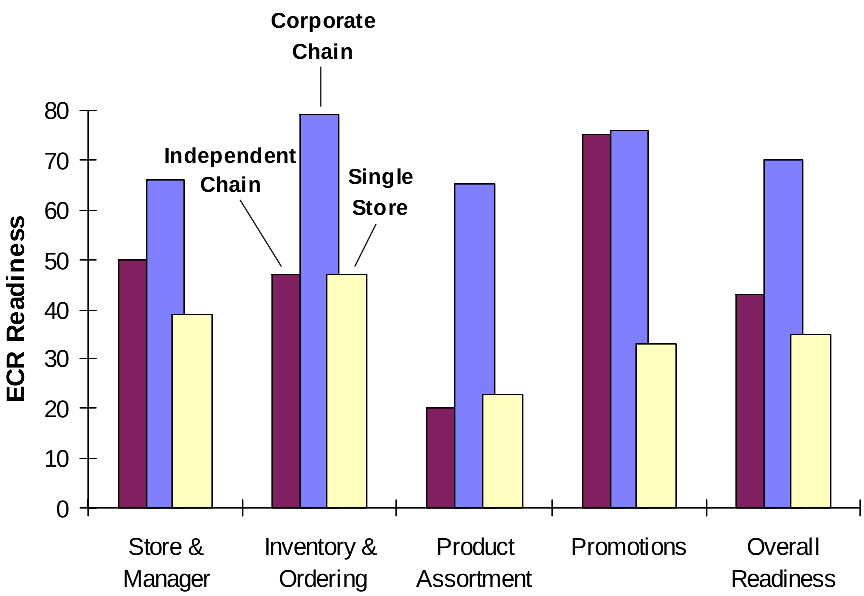


Figure 3. ECR Readiness by Organizational Form



ECR Readiness

The overall ECR readiness score was the basis for the third grouping of the forty stores in this study. Stores were placed in the high ECR readiness category if they had scores of 75 or more. Stores in the moderate group ranged from 40 to 75. Finally, stores in the low ECR readiness group had scores below 40. There were eleven stores in the high group, fifteen in the moderate group, and fourteen in the low group.

Summary information on store productivity measures is presented in Figure 4. For each measure, average performance levels for stores in the low ECR readiness group are only about half the average levels for stores in the high ECR readiness group. Our study was not designed to help us determine whether adoption of ECR practices leads to better performance or strong performance facilitates adoption of ECR practices. It is clear from our findings, however, that there is a strong association between adoption of ECR practices and superior performance.

Conclusion

The ECR initiative is the focal point for a revolution in the modern retail food system. The industry's hope is that new technologies, new business practices, and new forms of coordination will both lower industry costs and serve consumers more effectively.

Our study focused on changes the ECR initiative is bringing to store level operations and business practices. ECR readiness and superior performance are closely associated, though we cannot determine which causes the other.

Two broad conclusions can be drawn from our interviews with managers of retail food stores in Minnesota. First, metropolitan stores are adopting some components of the ECR initiative — especially those based on closer cooperation between stores and their suppliers. Second, stores that are part of chains, especially large corporate chains, are implementing key elements of the ECR initiative faster than single stores.

There are exceptions to this pattern, though. Some of the most innovative stores we visited were independently owned and operated stores. In these stores, it appears that a visionary, energetic owner/manager is able to respond quickly and effectively to new opportunities. While it may be more difficult for the single store to take advantage of the ECR initiative, it is not impossible for them to do so. ▲

Figure 4. Store Productivity Measures . . .

by Location:	**Metropolitan**	**Non-metropolitan**	
Sales per Labor Hour	$109	$87	
Sales per Square Foot of Selling Area	$10.54	$8.71	
Annual Inventory Turns	27	22	
by Organizational Form:	**Corporate Chain**	**Independent Chain**	**Single Store**
Sales per Labor Hour	$117	$114	$75
Sales per Square Foot of Selling Area	$12.42	$9.80	$7.10
Annual Inventory Turns	30	23	22
by ECR Readiness Level:	**High**	**Moderate**	**Low**
Sales per Labor Hour	$124	$105	$78
Sales per Square Foot of Selling Area	$13.65	$10.70	$6.06
Annual Inventory Turns	37	26	16

(***Drainage*** *continued from page 1)*

Tile drainage came into use in southern Minnesota in the early 1900s and gained popularity with the development of public and private ditches as outlets. (Field drainage is only efficient if suitable off-field outlets can be secured.)

The first tile systems (called a random system of drainage) usually ran a single line to the low areas to remove excess water (Figure 1). These systems were installed through the 1960s, and many are operational today.

Good surface drainage involves the removal of standing surface water within 24 hours after a rainstorm. Providing this level of surface drainage for the rolling topography on many southern Minnesota farms requires either deep ditches, which may restrict farming operations, or tile with inlets to help remove ponded water. Many of the random tiling projects were installed to enhance surface drainage and continue providing good surface drainage today.

In addition to removing surface water, a well-designed tile drainage system lowers the water table and aerates the soil. This allows plant roots to absorb nutrients and encourages root growth. As scientists and farmers gained an understanding of how excess moisture affects crop yields, farmers with slowly permeable soils and high water tables began installing pattern (or systematic) tile layouts (Figure 2).

Minnesota farm fields typically include a combination of moderately drained, poorly drained, and very poorly drained soils. Improving the drainage on the poorly and very poorly drained soils reduces stress to crops on those soils, increasing the yields obtained from those areas. It also allows more timely planting of the entire field, increasing yields on the moderately drained soils as well. While these are the most tangible benefits, they also are among the most difficult to estimate.

An estimate of the potential yields of well-drained soils on a particular farm can be obtained from the local Natural Resources and Conservation NRCS office. NRCS indicates that potential yields of many poorly and very poorly drained soils in southern Minnesota, when provided with good drainage, are 135 to 150 bushels of corn and 40 to 50 bushels of soybean per acre. These potential yields require both good surface drainage and good subsurface drainage.

In Northwestern Ohio, long-term studies of the effect of improving drainage on poorly drained soils found that good surface drainage resulted in corn and soybean yields that averaged 76 percent and 80 percent of potential, respectively. Applying these percentages to the range in potential yields in southern Minnesota suggests average yields with good surface drainage of 103 to 114 bushels of corn and 32 to 40 bushels of beans on poorly and very poorly drained soils. Achieving the remaining 24 percent of corn yield and 20 percent of soybean yield requires the addition of good subsurface drainage.

The excess water that soaks into the soil during a rainstorm displaces air and hinders the growth of most field crops. Gravity drains excess water from the soil over time, leaving the capillary water that is of primary use for crop production. Properly installed subsurface tile systems remove gravitational water from the upper one foot of many soils, reducing the crop stress from excess soil water levels.

Applying the results of the Ohio experiments suggests that good subsurface drainage of poorly and very poorly drained soils can increase per acre corn yields 32 to 36 bushels and soybean yields 8 to 10 bushels above the levels obtained with good surface drainage alone.

In addition to increasing crop yield, improved drainage reduces the number, size, and duration of wet spots in the field, reducing the time needed to till, plant, and harvest crops. That is because reducing the amount of turning, miring, and returning later to plant the wetter areas reduces the labor required and machinery expenses associated with crop production. Earlier planting lets crops mature more completely before harvest, reducing the cost of artificial drying.

The combination of higher yields and reduced machinery and drying expenses enhances the value of well-drained land. Real estate agents report that tenants and buyers are willing to pay more for farmland with good drainage. But better drainage isn't free.

Landowner Costs

Improved drainage requires access to a suitable outlet for the drainage water under an effective drainage plan. It also requires compliance with local, state, and federal guidelines intended to protect the state's wetlands and other property owners, particularly those downstream who may be affected by modifications to an existing system. Landowners considering drainage investments can get help with state and federal wetlands restrictions by contacting the local NRCS office, or the local soil and water conservation district.

Figure 1. A Random Tile System

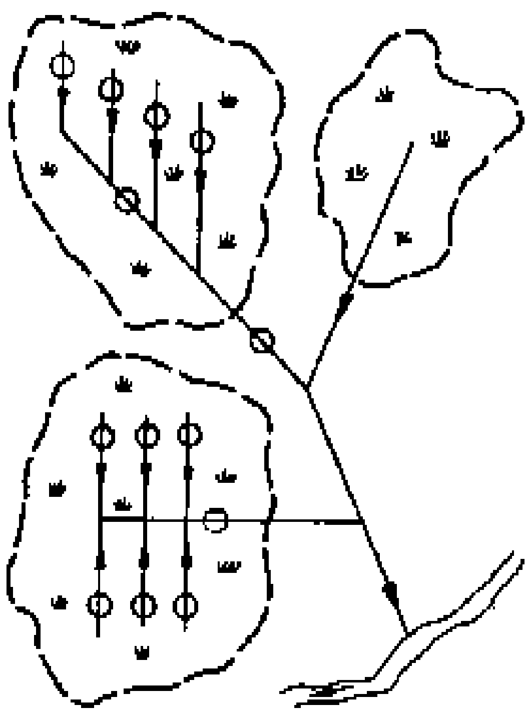
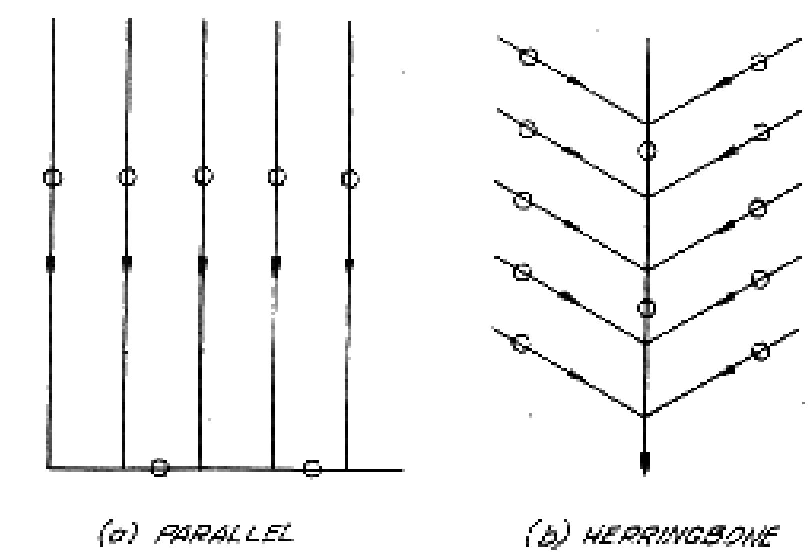


Figure 2. Two Pattern Tile Systems



Securing the benefits of good surface and subsurface drainage frequently requires substantial capital investments and some increase in annual crop production expenses by the farmer. Good surface drainage requires additional ditches, subsurface collector tiles, and blind inlets to permit movement of ponded water to subsurface drains (Figure 3).

Providing good subsurface drainage for field crops typically requires a system to remove around one-half inch of water per day. Tile spacing to provide this capacity varies by soil type, but is often in the range of 40 to 80 feet for the clay loams and silty clay loams that constitute many of our poorly and very poorly drained soils. The footage of tile required per acre can be approximated as the number of square feet in an acre (43,560) divided by the lateral spacing. Thus an 80-foot spacing requires (43,560/80) = 544 feet of tile per acre, while a 40-foot spacing requires twice that much.

The investment in the tile and its installation depends on factors such as the number of acres to be drained, the length of run, the type of tile, and the installation depth.

Will It Pay Off?

The relative profitability of different drainage investments varies widely. Estimates of profitability can be prepared following a two-step process: (1) estimate the expected change in annual net cash income from the investment, and (2) calculate the internal rate of return on an after-tax basis. The calculation of the change in annual net cash income shown in Figure 4 illustrates the procedure. These results are used with the data in Figure 5 to provide some information on the profitability of certain drainage investments.

The example in Figure 4 assumes a quarter section (160 acres) with good surface drainage and 150 tillable acres. It includes 50 acres of moderately drained soils and 100 acres of poorly and very poorly drained soils. The purpose of the analysis is to estimate the profitability of installing a pattern tile system with 80-foot lateral spacing to improve subsurface drainage on the 100 poorly drained acres. The plan is to continue producing a corn-soybean rotation on the entire 150 acres. The analysis for each of two potential yield levels (135 bushels of corn and 40 bushels of soybeans, and 150 bushels of corn and 50 bushels of soybeans) shows the likely range of increase in annual net cash flow and profitability.

As noted before, estimating the improvement in yield is an important part of calculating the increase in net cash income. It is better to base the estimate of increased yield on the difference between actual yields (obtained by a yield monitor on the combine) and the potential yield of well-drained soil (obtained from NRCS). In the example, the yield increases are 24 percent of the potential yield of corn and 20 percent of the potential yield of soybean. Some subsurface systems are developed to improve both surface and subsurface drainage, which may result in larger yield increases.

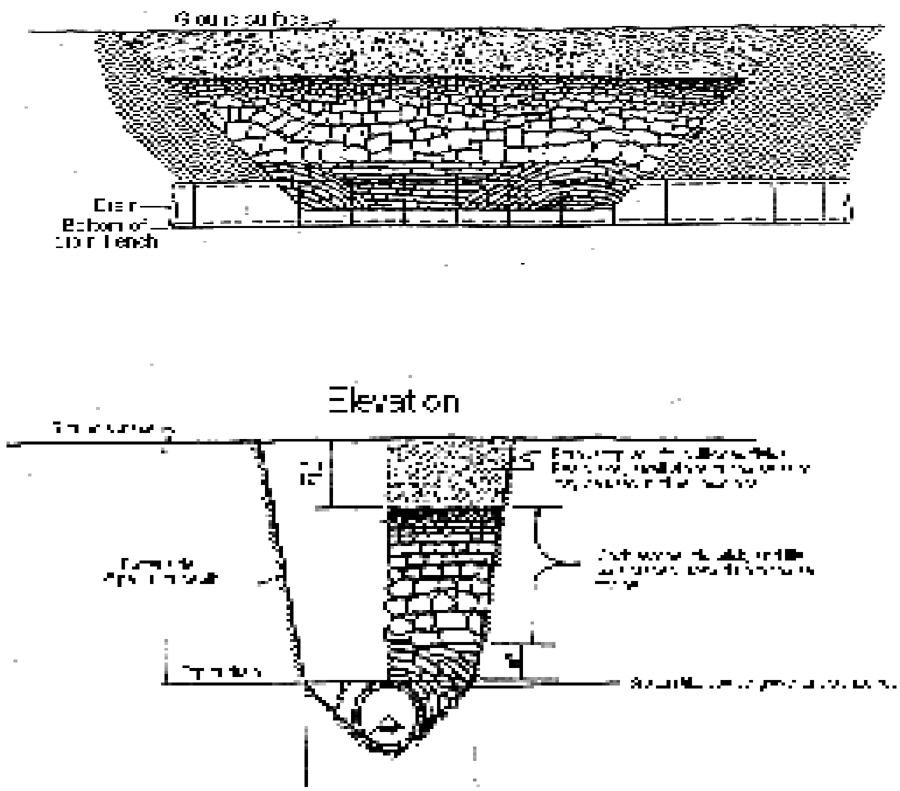
Caution should be exercised to reflect average yield increases over the weather cycle. Improving the subsurface drainage may have only a small impact on yield during drought years, meaning that the increase in wet years must be much greater than the average. Much larger increases than the yields shown here may be reported during high rainfall years. In estimating the change in revenue per acre for crops such as sugar beets, it is important to show the influence improved drainage has on the quality (sugar percentage) as well as quantity.

Figure 4 shows an increase of three bushels of corn and one bushel of soybeans per acre on the 50 acres of moderately drained soils. This increase reflects the effect of improved timeliness of planting (three days in this example) that results from the improved drainage on the other 100 acres in the quarter section.

The change in drying costs in Figure 4 is based on off-field removal of one percent less moisture because of more timely planting. Thus, the reduction in drying costs on the current corn production partially offsets the drying costs for the additional bushels produced.

The investment in tile can be roughly estimated by approximating the feet of tile required and multiplying by approximate installed prices. For the

Figure 3. Blind Surface Inlet



Source: Minnesota Drainage Guide, Soil Conservation Service

Figure 4. Change in Annual Net Cash Income Attributable to Improved Drainage

Item		Potential Yield/Acre: 135 Bu Corn 40 Bu Soybeans		150 Bu Corn 50 Bu Soybeans	
Change in Cash Income	**Price**	**Increase (Bu/acre)**	**$**	**Increase (Bu/acre)**	**$**
50 acres corn on poorly drained soil	$2.40	32	$3,840	36	$4,320
25 acres corn on moderately drained soils	2.40	3	180	3	180
50 acres soybean on poorly drained soils	5.75	8	2,300	10	2,875
25 acres soybean on moderately drained soils	5.75	1	144	1	144
Increased Revenue			**$6,464**		**$7,519**
Change in Cash Expenses	**(Cost $/unit)**	**Units**		**Units**	
Reduced drying expense	$ 0.025	8,525	$-213	9,200	$-230
Increased drying	0.225	1,675	377	1,875	422
Hauling additional grain	0.07	2,100	147	2,400	168
Change in machinery, seed, & fertilizer			*		*
Maintenance of new tile	0.0025	45,000	112	45,000	112
Increased Expenses			**$423**		**$472**
Expected change in annual net cash flow			**$6,041**		**$7,047**

*The reduction in machinery expense for field operations is expected to be offset by the increase in fertilizer cost to produce the higher yields.

example, an installed price of $.65 for four-inch rough corrugated plastic lateral lines and prices of $1 to $2 per foot for several sizes of mainlines were assumed. The average installed price is assumed to be $.83 per foot of tile. Annual maintenance cost for properly installed tile is usually estimated as .25 percent of the investment.

The analysis in Figure 4 indicates that the investment is expected to increase annual net cash income ($6,041/100 tiled acres) approximately $60 per tiled acre for the soils with a potential yield of 135 bushels for corn and 40 bushels for soybean. The expected return per tiled acre is approximately $10 greater for the soils with the higher potential yields.

The profitability of a drainage investment can be calculated from the after-tax annual net cash flow over the life of the investment. The analysis considers the way the investment is depreciated for tax purposes, the owner's marginal tax rate, and the effect of the investment on the sale value of the property. The marginal tax rate should include the sum of state, federal, and social security rates.

The Internal Revenue Service considers tile investments as 15- or 20-year property for depreciation purposes. Both landlords and owner operators may use the 150 percent declining balance depreciation method. Owner operators (and landlords who participate in production) may elect to depreciate the investment more rapidly by writing off part of the investment as a Section 179 Expense Deduction in the first year. The upper limit for the deduction is $18,000 for 1997, but the limit will increase next year.

From Figure 5, we find an investment of $450 per acre and an expected return of $60 per acre have an internal rate of return of 9.1 percent. The same investment with $80 of average annual return per acre results in average profitability of 12.3 percent. Other combinations of increase in net income per acre and per acre investment in the drainage system can be determined the same way.

In general, many of the drainage investments in Figure 5 provide returns in the range of 10 to 15 percent, using rather conservative assumptions. Higher rates of return could be generated for the examples by changing some of the assumptions. For example, any of the following changes in assumptions would increase the stated rate of return on the investment: higher commodity prices, depreciating the investment more rapidly, or assuming the market value of land increases by more than one-half of the investment.

Farming investments generating 10 to 15 percent rates of return compare favorably with rates earned in many parts of the business. For example, members of the Southwest Farm Management Association averaged a 10 percent rate of return to equity capital over 1990-1996, while the average of the upper 10 percent of the farmers in the Association averaged a 14 percent rate of return on equity capital. So, for this farm at least, improving drainage is a good investment.

Downstream Effects

Downstream effects of cropland drainage have received a great deal of attention recently, especially following this spring's floods. The direction of the effects on the quantity and quality of water seems clear, but our understanding of the magnitudes of these effects is limited.

Improving surface drainage to remove ponded water within 24 hours clearly seems to move a larger proportion of the water from a heavy storm to the stream over a short period of time. This increases peak flows, increases the energy in the stream resulting in more stream-bank erosion, and leads to greater transport of soil and waterborne nutrients in the stream.

Improving subsurface drainage probably does not contribute greatly to peak flows leaving a field or farm, but it probably does increase the total flow over a period of several days. Removing gravitational water from the root zone with subsurface drainage should increase the capacity of the soil to hold more rain from the next storm, but the impact of this increased storage capacity on the peak flow depends on the timing of subsequent storms.

Most of the sediments and phosphorus removed from cropland are transported by surface runoff. Activities that increase surface drainage tend to move more of both into waterways, but subsurface drainage has little effect on their movement. Nitrates are leached by water moving through the soil. When subsurface tiling is intensified, more of the groundwater moves through the tile, carrying some of the nitrates into the tile lines and into streams. Thus it appears that improved subsurface drainage moves more total water into streams and adds more nitrates to the stream flow.

More work is needed to understand the effect of improved drainage on the flow of water draining from a farm over time, and the combined effects of the farms in a watershed on stream flow.

Figure 5. After-Tax Internal Rate of Return for Alternative Levels of Per Acre Drainage Improvement Investment and Increased Income*

Increase in Net Cash Income Per Acre	Per Acre Investment in Improved Drainage				
	$100	**$200**	**$450**	**$800**	**$1,200**
$20	13.8	6.5	1.8	0.0	-0.8
40	26.9	13.8	5.6	2.3	0.8
60	39.3	20.5	9.1	4.5	2.3
80	51.7	26.9	12.3	6.5	3.8
120	76.4	39.3	18.3	10.3	6.5

*Analysis assumes that the investment is depreciated over 15 years using the straight line method and the half-year convention, that the marginal tax rate is 38% (federal, state, and social security), and that the land value in year 20 increases by one-half of the drainage investment.

Conclusion

Improving surface and subsurface drainage potentially provides important benefits to many farmers in southern Minnesota. It increases profitability and reduces the impact of wet years on crop yields, thereby reducing risk to the farmer. The impact of improved drainage on stream flow is not as well documented. More study is needed to quantify the effect of good surface and subsurface drainage on the flow of water, sediment, phosphates, and nitrates from individual farms. When we better understand the flows from a farm, then we can begin answering the more important questions about the contribution crop production makes to total stream flow. ▲

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