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AGRICULTURAL LAND DRAINAGE COSTS AND RETURNS IN MINNESOTA

Jay A. Leitch and Daniel Kerestes

Department of Agricultural and Applied Economics

University of Minnesota
Institute of Agriculture, Forestry and Home Economics
St. Paul, Minnesota 55108

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Jay A. Leitch & Daniel Kerestes*

I. INTRODUCTION

Drainage of Minnesota's wetlands[1/] is proceeding at a rate that is alarming to proponents of wetland preservation. The primary reason for drainage in rural Minnesota is to improve the land for crop production. The majority of wetland drainage done today is by contractors hired by farm owners and operators.

Minnesota once had over 10 million acres of swampland. This was roughly 19 percent of the state's area. The extensive swampland in the state can be attributed to glaciation that took place over 10,000 years ago during the ice age.

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*Assistant professor, Department of Agricultural Economics, North Dakota State University and former research assistant, Department of Agricultural and Applied Economics, University of Minnesota.

[1/]Wetlands as used in this paper refers to Types 1, 3, 4, and 5 as classified by Shaw and Fredine (1971). These are:

Type 1 - Seasonally flooded basins or flats. The soil is covered with water, or is waterlogged, during variable seasonal periods but usually is dry during much of the growing season. They may be filled with water during periods of heavy rain or melting snow.

Type 3 - Inland shallow fresh marshes. The soil is usually waterlogged during the growing season; it is often covered with seven inches or more of water.

Type 4 - Inland deep fresh marshes. The soil is covered with six inches to two feet or more of water during the growing season.

Type 5 - Inland open fresh water. Water is usually less than ten feet deep and is fringed by a border of emergent vegetation.

Wet land(s) will be used to refer to soils with excess soil moisture. The ongoing controversy is about drainage of wetlands and not wet lands.

Early settlers found the wet prairie regions desirable because the flat, treeless land was very good cropland when drained. The population of Minnesota grew, leading to the demand for more tillable land. Farmers, realized that their productivity could be increased by draining wetlands more easily than by clearing forested lands. Today approximately 50 to 60 percent of the original prairie wetland acreage remains. In some areas drainage has eliminated all of the wetlands.

There is a variety of government programs to preserve wetlands for their social values which include direct dollar benefits (i.e. value of game and fish harvested, native hay harvest) and indirect benefits to society (i.e. flood control, erosion control, waste assimilation, nutrient recycling, water supply, groundwater recharge, historical value, primary productivity, education, aesthetics, ecological diversity). Landowner participation in these programs is often less than desired by wetland proponents. The reasons for this may be a lack of complete information regarding preservation program conditions or payments (Leitch and Danielson, 1979; Farmer, 1981). Landowners often base the decision to drain wetlands on the potential crop production they expect to obtain, without fully considering preservation alternatives or actual drainage costs. Alternatively, preservation program payment levels are normally set to offset only the explicit dollar benefits of drainage and do not account for all nonmonetary benefits of drainage.

The entire wetlands issue is replete with unknowns -- from the cost to drain to the value of environmental amenities. This study provides up-to-date information on both drainage costs and returns to aid both the landowner and public decision makers. The last study of this type for Minnesota wetlands was done in the early 1960's in Blue Earth and Stevens counties (Goldstein, 1967). Conditions in the agricultural sector have changed considerably since that time, namely the discontinuance of drainage subsidies and large-scale agricultural subsidies.

History of Drainage in Minnesota[2/]

Drainage in Minnesota can be traced back to 1858, the year in which the first drainage legislation--"an act to encourage the drainage of lands"--was enacted. The majority of drainage done through 1960 was accomplished between the years 1858 and 1920. This was a period of rapid settlement in Minnesota when the wet prairie lands invited land-hungry settlers to bring them into production.

By 1867 Minnesota had a law that provided protection for waters in the state. These early laws were vague and usually favored the landowner who wished to drain. During the period of 1920 through 1960 the attitudes of people toward drainage of wetlands began to change. The Depression, the Second World War, and the high cost of construction following the war slowed the rate of drainage considerably. By 1925 the state had begun to exert more control over its water bodies by requiring a permit to drain meandered waters.

After 1960, environmental concerns began to show their influence in Minnesota's water law. In 1976 a state Water Bank program patterned after the federal ASCS program was developed. Three years later, in 1979, a law allowing a tax credit and exemption for maintaining drainable wetlands on private property was enacted.

Study Objectives

The objectives of this study are to (1) introduce some of the topics relative to on-farm drainage decisions in rural Minnesota, (2) briefly describe on-farm drainage methods, (3) estimate the current costs of constructing on-farm drains, (4) estimate the returns to agricultural land drainage, and (5) examine the economic feasibility of on-farm drainage in Minnesota.

[2/] This section was condensed from King (1980). See Leitch and Saxowsky (1981) for a list of references on current Minnesota drainage legislation.

Study Area

Much of western and southern Minnesota lies within the Great Plains Prairie Pothole region.[3/] Two areas within the Prairie Pothole region that represent predominant drainage methods were selected for analysis. Two of the three general types of agricultural land drainage are represented by the study areas. General field drainage by surface ditch and land smoothing is practiced in the Red River Valley. Most of the drainage work has been completed in the Valley however, with only periodic maintenance required today. The two drainage types that are represented are random wetland drainage and general field drainage.[4/]

An area in west central Minnesota was selected to represent random wetland drainage, while an area in south central Minnesota was chosen to represent subsurface tile drainage. There is a significant difference in wetland habitat area preserved in the two study areas. Approximately 2.3 percent of the area in the west central area is preserved through U.S. Fish and Wildlife Service easement or purchase or Minnesota Department of Natural Resources programs. Only 0.3 percent of the south central area is in any of these three programs. The relative abundance of wetlands remaining after these programs became effective is the predominant reason for the difference. south central Minnesota farmlands were drained much earlier than west central farmlands.

[3/] The Prairie Pothole region of North America covers about 300,000 square miles in the prairie provinces of Canada and the upper midwest of the United States. The United States portion, approximately 115,000 square miles, is bounded on the southwest by the southern limits of Wisconsinian glaciation, and on the northwest, north, and east by woodland. See Miller and Lee (1966) or Harmon (1971) for a description of the prairie pothole region.

[4/] Random wetland drainage is the drainage of scattered wetlands or low areas, using surface ditches or subsurface tile to remove excess water from the immediate areas. In an effort to provide each isolated wet spot with a suitable outlet, ditches or tile lines, in random type drainage systems, run in any and all directions, as shown in Figure 2. General field drainage layouts are used where large continuous field areas are to be drained. In such systems the subsurface tile lines and ditches are usually placed parallel to each other to form a gridiron, herringbone or other type of geometric pattern.

The west central area, where random wetland drainage is common, consists of Becker, Clay, Douglas, Grant, Otter Tail, Pope, and Stevens counties (Figure 1). This seven-county area has 9,800 farms and a total land area of 6,810 square miles. Fergus Falls, Detroit Lakes, Alexandria, and Moorhead are the major municipalities. Clay County is fourth in the state for sunflower and wheat production. Becker, Grant, and Stevens counties each produce about 60 million pounds of sunflowers annually. Otter Tail, Grant, and Stevens counties each produce over 2 million bushels of wheat per year, which places them among the leading producers in the state. Corn and soybeans are produced in large quantities throughout this area.

Otter Tail County is third in the state in numbers of cattle, with 60,000 or more head; second in milk production; and third for sheep and lamb numbers. Grant and Stevens counties contain mostly cash crop farms. Corn, wheat, sunflowers, and oats are the major crops grown. Stevens County has some cattle and hog producers. Douglas and Pope counties have both dairy and beef farmers. Approximately 20 to 60 percent of the cropland in the west central area has been drained by artificial means (Allred and Geiser, 1978).

South central Minnesota is an area of fertile farmland, a high percentage of which is made tillable by subsurface tile lines. Approximately 60 percent of the land in this region has had a wetness problem but is presently drained (Allred and Geiser, 1978). South central area counties[5/] include Fairbault, Freeborn, LeSueur, Martin, Nicollet, Waseca, and Watonwan (Figure 1), for a combined total land area of 3,850 square miles. There is a total of 8,571 farms in the area. The primary crops grown are corn and soybeans. Beef cattle and hogs are important livestock raised in this area

[5/] Three additional counties (Blue Earth, Rice, and Steele) were included in the survey to expand the sample of drainage projects.

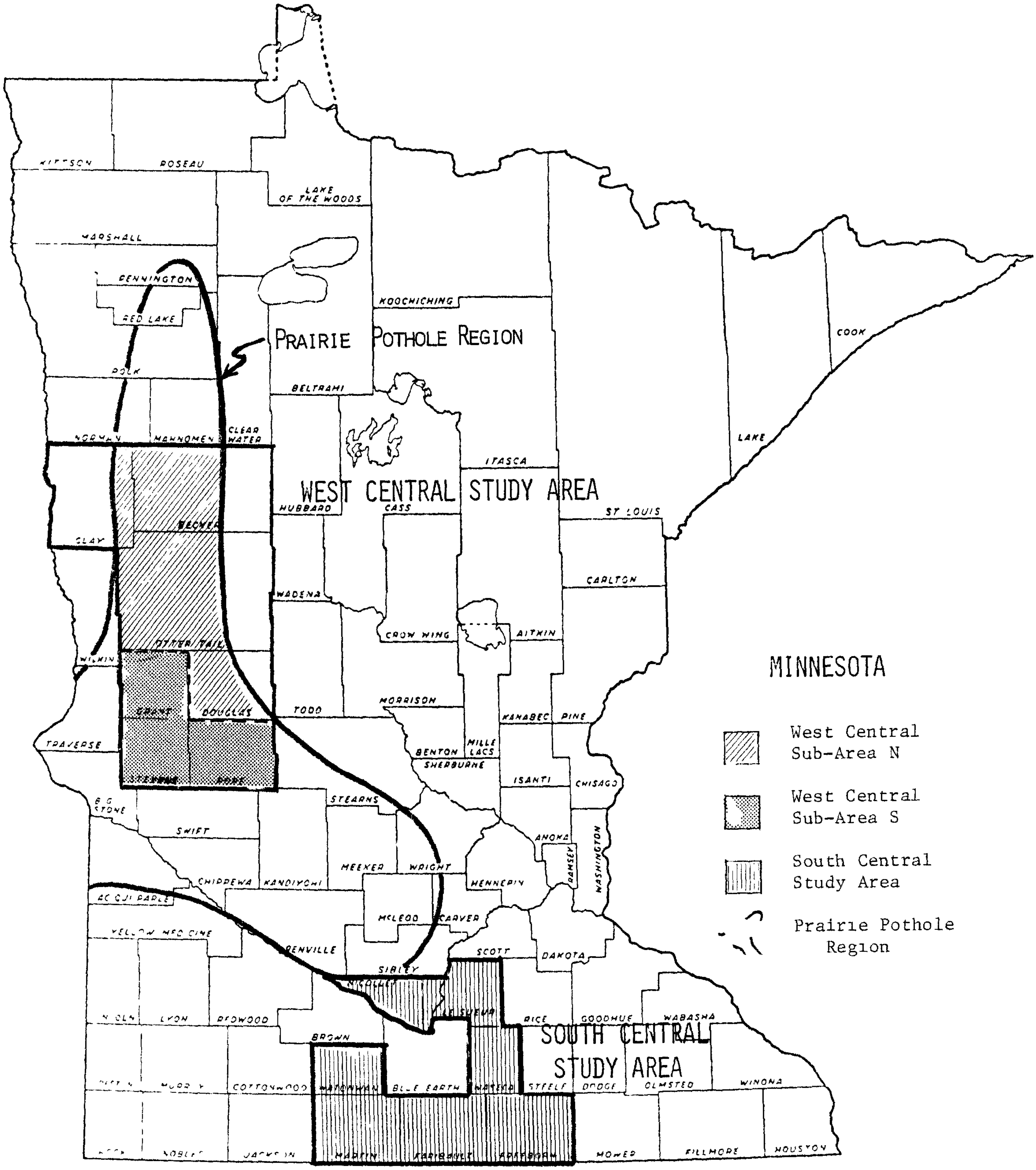

Figure 1. Drainage Costs Study Area

Land values in the south central region play an important role in stimulating drainage. Average market value of cropland was $1,850 per acre in 1980, 40 percent above average statewide value of cropland.

Drainage Methods[6/]

As indicated earlier, some fields may be drained using the random drainage system layout while other fields may use the general field drainage type of system. Random drainage is illustrated in Figure 2 and general field drainage in Figure 3. With the exception of the Red River Valley, surface ditches are used both for draining of scattered wet areas and for main drains or county drains. Subsurface tile drains are used in both random and general field drainage.

Surface Ditches

Open ditches vary in depth and width depending on rainfall patterns, size of drainage area, soil type, types of crops grown and desired protection, the potential for flooding from natural watercourses, and the topographic setting of the area to be drained. Ditches can be constructed with equipment as simple as a moldboard plow to heavy equipment such as scrapers and draglines Required equipment depends on the slope and design of the channel, existing moisture conditions, soil type, volume of work, accuracy required, and financial considerations.

While surface ditches are usually much less costly to construct than subsurface drainage systems, they can result in a loss of cropland. When deep cuts are required it becomes more economical to install subsurface tile where conditions permit than surface ditches.

[6/] See also Advanced Drainage Systems (1976); Certain-Teed/Daymond Co. (undated); and Schwab et al. (1966) for a discussion of drainage practices.

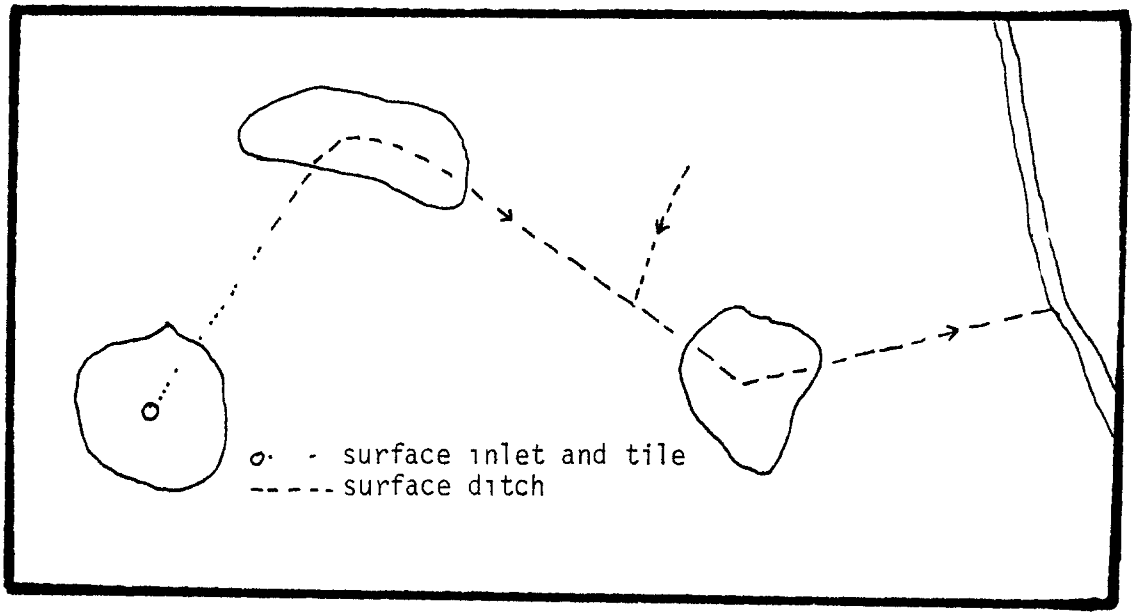

Figure 2. Random Field Drainage

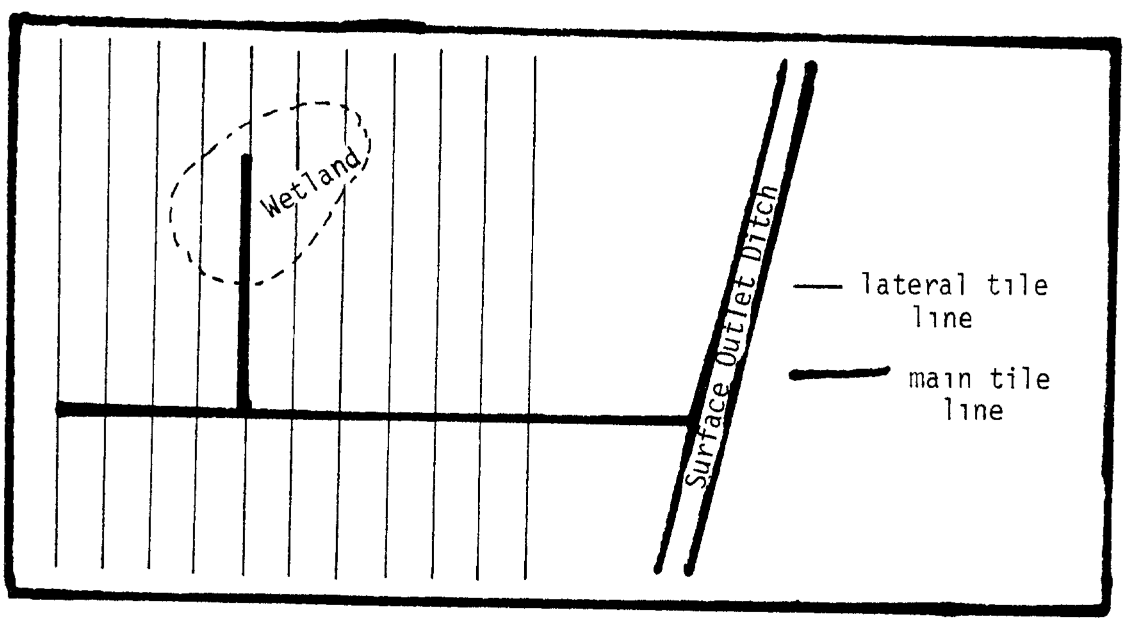

Figure 3. General Field Drainage

Subsurface Drains

Subsurface drains are used to drain random wet areas or entire fields in a systematic pattern. When entire fields are drained to eliminate excess soil moisture lateral tile lines are placed throughout the field connected to a main drain line. Random drainage with subsurface tile lines often requires a surface inlet or blind inlet at the wetland. Subsurface drains eventually lead to a surface outlet, emptying into a natural waterway or surface ditch.

Concrete was the most popular material for drain tile used in Minnesota until recently. Concrete tiles range in diameter from 5 inches to 24 inches. Tile up to 8 inches comes in 12-inch lengths, while larger tile is in 30-inch sections. Wall thickness for concrete tile is normally made about 1/12th of the diameter. On this basis, a 6-inch tile would have a 1/2-inch wall thickness, while a 12-inch tile would have walls 1 inch thick.

Concrete drain tile are laid end to end in a trench dug on grade. Cracks between adjoining tile allow water to enter. A slight to moderate grade on the line allows water to flow toward the outlet. A tile line draining a wetland or wet soil area is called a lateral. Laterals are connected to main lines which carry water to an outlet. The outlet could be a public ditch, a waterbody, or another wetland.

The depth of subsurface tile lines depends on the topography surrounding the wetland to be drained. Random wetland drainage could involve depths of 14 feet or more over short distances. In Minnesota general field drainage usually requires depths of from 2 to 5 feet and lateral spacings of 30 to 100 feet, depending on soil conditions and the location and elevation of the main line. Due to soil alkali problems, in irrigated areas of Western United States lateral line spacing may be 150 to 600 feet with depths up to 10 feet.

The high labor requirements of installing concrete tile along with the weight of the tile promoted the development of plastic tile. Plastic tile accounts for half of the tile installed in Minnesota today. It is extremely lightweight when compared to concrete tile. A 250-foot coil of 4-inch diameter plastic tubing weighs about 75 pounds and can be handled by one person. An equivalent length of concrete tile would be a small truck load. Plastic tile is installed in much less time than concrete and can be installed with a variety of equipment. Mole plow installation is less expensive, but caution must be taken in certain soils since the walls of the trench around the tile can become compacted by the plow so as to restrict water flow. Plastic is not affected by soil acids and alkali nor is it adversely affected by ground freezing. Advances in drain tile construction are being made frequently. A recent development has been the introduction of an arched plastic tile that is easier to handle and is claimed to outperform the conventional cylindrical tubing.

III. PROCEDURE

At least two conceptual approaches could be applied to estimate the costs and returns to wetlands drainage. Drainage costs could be estimated through an engineering approach or an empirical study of actual costs. Since prairie wetlands represent a heterogeneous resource, an engineering approach was ruled out. However, costs of general field drainage could be estimated fairly accurately in this way. A personal interview of farm operators who had drained in recent years was conducted to collect data on actual drainage costs. This was done for each study area and both random wetland drainage and general field drainage.

The dollar returns to drainage are measured by increases in crop production on drained lands. Drained wetlands become nearly indistinquishable parts of cropland. The crops grown on them are typically identical to crops grown on adjacent upland. Where productive soils are properly drained, yields will usually be significantly higher than yields from adjacent upland areas. Yields on drained wetlands may be higher than average due to better growing conditions or they may be lower if drainage is inadequate. The crop rotations on drained wetlands were assumed to be the same as county-wide rotations and were taken from a secondary source (Minnesota Crop and Livestock Reporting Service, 1980). Crop yields used for analysis were those reported by survey respondents, which were slightly above average county-wide yields.

The basic procedure was to use secondary data where it was appropriate and collect primary data when necessary. Specific sources of data are explained later in the paper.

Previous Investigations

Few empirical studies have been conducted on the costs and returns of wetlands drainage. Goldstein (1967) analyzed the feasibility of wetland drainage in two areas of Minnesota. He concluded that under most conditions, drainage of permanent wetlands and most temporary wetlands was not economically feasible under a free market situation. The presence of crop subsidies and drainage assistance made some temporary wetland drainage feasible to the farm operator, but, in general, drainage of random wetlands was not profitable from a strictly cash flow basis. Goldstein estimated the full cost of tile drainage to be $157.49 per acre and of ditch drainage to be $49.68 per acre, both in 1963 prices.

A survey of North Dakota farm operators resulted in an estimate of $14 per acre to drain all types of wetlands in the northeast central part of the state (Leitch and Scott, 1977). This figure represents an average

1974 cost in an area where much of the drainage is done by farm operators. Local relief is somewhat less than that in Minnesota and drainage in general is not as extensive as in Minnesota. As a result, the wetlands drained represent those at the lower end of the cost range.

The U.S. Soil Conservation Service until recently provided technical assistance to farmers wishing to drain. A 1978 SCS flat rate schedule (U.S. SCS, 1978) listed the cost of surface drainage systems at $150 for all of Minnesota except the Red River Valley where the cost was estimated to be $350 per acre. Subsurface drain installation was estimated to cost $350 in 1980. These figures are merely guides for estimating project costs and actual costs may vary considerably depending on local conditions.

Surface drainage costs in Manitoba were estimated to average $76 per acre in the early 1970's (Rigaux and Singh, 1977). Nine out of 15 projects evaluated were found to be infeasible given the benefit-cost ratios at that time. Average drainage costs for each of the 15 projects ranged from a low of $42 per acre to a high of $116 per acre.

The dearth of drainage cost estimates in the published literature prompted this study. Goldstein's estimates would be the most applicable if they were not antiquated. Therefore, much of the current analysis is patterned after the work of Goldstein.

Sample Selection and Summary Statistics

The west central Minnesota study area was sampled first. Preliminary investigations indicated that approximately 300 farm operators had drained wetlands in the period from 1978 to 1980. Identifying those who had drained turned out to be a difficult task.

Public agency personnel and others, who asked that their identity remain confidential, were able to provide names of approximately 75 individuals who they thought had drained. The Federal Freedom of Information Act prevented individuals from public agencies from identifying potential respondents in several instances. Drainage contractors were equally reluctant to talk about who they had drained for.

Letters explaining the need for drainage cost information were mailed to each potential respondent within two weeks prior to the time they were visited by the interviewer. In most cases this facilitated data collection by advance identification of the individual collecting data and providing lead time for potential respondents to think about their past drainage. One interviewer was used throughout the survey work to eliminate any variability in responses due to interviewer personalities.

Completed, usable surveys were obtained from 35 farm operators who had drained in the west central study area. However, not all of these had drained within the past three years.

Several explanations can be offered as to why the identified population and resulting sample were kept small. First, it was difficult to obtain names of people who had drained, as discussed above. Wetland issues have received increasing attention in the media in this area especially as they relate to the state Public Waters Law. This attention has heightened people's awareness of the public values of wetlands and the possible illegal nature of some drainage.

Several of the 75 individuals identified as drainers responded that they had only done maintenance work. Many refused to answer any questions regarding their drainage because they were currently involved in legal proceedings concerning drainage they had done. Others had drained during the 1960's and 1950's. Finally, there were those that refused to cooperate feeling it was not anyone's business but their own what they had done.

Cooperation in identifying a drainer population in the south central study area was much better than in the west central area. Public agency personnel were not able to provide any names of drainers, while drainage contractors were usually more than willing. Twenty-two drainage contractors were selected at random in the study area. Each was asked a few questions about their charges for drainage work and further asked to identify three or four individuals that they had drained for during the past three years. A total of 161 potential drainers were identified in this manner and by asking survey respondents if they knew of anyone else that had drained. Sixty-two usable surveys were obtained in the south central area. One possible explanation for better cooperation in the south central area relates to the level of government involvement in wetlands preservation. There is approximately seven times more wetland under FWS/DNR control in the west central area than in the south central area.

Summary data for respondents in the two study areas are presented in Table 1. Respondents were very similar in most respects with a few notable exceptions. No one surveyed in the south central area had participated in a wetlands preservation program. This is due primarily to the lack of availability of these programs in the area.

The average area drained was considerably larger in the south central area. Random wetland drainage predominates the west central area, while general field drainage is found in the south central area.

There were no problems farming drained areas in the south central study area, but half of the respondents in the west central area reported having problems. The source of most of the problems was inadequate drainage.

Less than half of the drainage done in the west central area was done with surface ditches, while 57 percent was done with subsurface tiles. All of the drainage was of random wetlands or wet areas. Only 5 percent of

TABLE 1. DRAINAGE SURVEY SUMMARY STATISTICS

	Study Area	
	West Central	South Central
Number of respondents	35	62
Primary occupation was farming	97%	94%
Operated their farms an average of	25 years	22 years
Were dairy farmers,	9%	6%
hog/beef operators,	6%	13%
cash grain farmers, or	57%	52%
diversified operators.	28%	29%
Average farm size was	779 acres	766 acres
Drained land was used for cropland or	92%	100%
pasture.	8%	0%
Would like to drain more wetlands, but	31%	47%
had not because too expensive,	58%	62%
had not gotten to it yet, or	33%	31%
had other reasons.	8%	7%
Participated in a wetland preservation program	23%	0%
Did not participate because of low payment,	18%	13%
did not want government involvement,	14%	2%
was not the right soil type, or	0%	44%
gave other reasons.	45%	41%
Average wetland or area drained was	16 acres	69 acres
Typical wetland drained was open water	35%	20%
Land surrounding drained area was cropland,	77%	84%
pasture,	17%	16%
or other.	6%	0%
Had problems farming drained wetlands	50%	0%
Problem was poor construction or design	66%	-
Did their own drainage work	4 respondents	1 respondent
Used surface ditches	43%	5%
Used subsurface tiles	57%	100%
Primary incentive to drain was to increase or improve cropland	(not asked)	100%

SOURCE: February/March 1981 survey of farm operators.

the respondents reported using ditch drainage in the south central area and these were in conjunction with tile drainage systems.

Returns to Drainage

Private landowner returns to drainage include increased agricultural production sales, decreased nuisance or avoidance costs, and a component for the net influence of intangibles. The monetary value of increased crop sales can be estimated by multiplying price by quantity and netting out costs: $V = p_i q_i - dC_i$; where p_i is the price of commodity i, q_i is the quantity of commodity$_i$ (or the change in output), and dC_i is the change in agricultural production expenses in production of commodity i. Assuming values are invariant with respect to time, the present value, V_p, of the flow of benefits in the form of increased crop production is estimated as follows: $V_p = (p_i q_i - dC_i)Z$; where Z is a present value multiplier [7/]

The value of nuisance or avoidance costs of wetlands in cropland is difficult to estimate. The cost of farming around power line structures has been studied by Hanus (1979) and Gronhovd et al. (1981) Decreased efficiency of field operations stemmed from reduced speed and overlapping operations. The main factors in increased cost of farming around obstacles

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[7/] Benefits associated with wetlands drainage generally occur over long periods of time (15 years in this study). Costs, however, are incurred at the start of the project. To account for this difference in time frame the stream of expected future benefits must be 'discounted' to reflect its present value. The value today of next year's net return is a fraction less than one of this year's net return; the value today of the net return two years from today is equal to a smaller fraction of today's net return; etc. Adding all the annual discounted values together gives the present value of the discounted benefit stream. A present value multiplier is merely the sum of the annual fractions. The multiplier is sensitive both to discount rate used and life of project assumed.

were the value of production lost, the value of extra time to farm around the obstacle, and the cost of weed control around the structure. While Hanus and Gronhovd et al. were able to estimate dollar values for losses due to farming around transmission line structures, it is extremely optimistic to expect to estimate such a value for farming around heterogeneous wetlands randomly located throughout a field.

Estimation of a value for the net influence of intangibles is well beyond the reach of economists at this time. Each individual farm operator has a unique set of values, with alternative uses of wetlands affecting their satisfaction uniquely. This analysis will concentrate on the monetary value of increased crop sales which will provide a floor upon which nuisance costs and intangible values can be added when they are known or can be estimated.

The returns to drainage depend upon a host of factors, some of which the farmer can control, others which he cannot. Prices for crops produced affect the profitability of drainage, but an individual farm operator has little influence over market price. The interest rate or opportunity cost of money invested in the drainage project also affects the return, which in turn is tied to the useful life of the project. Landowners can decide which crops to grow in what proportions, but cannot predetermine yields. They can influence yields through selection of input levels, but have no control over natural inputs such as the weather. Costs of a variety of productive inputs, both for drainage and for continuing production of crops, are subject to the vagaries of the marketplace.

Monetary returns to drainage of random wetlands in cropland, using either ditches or tiles, can be estimated as the vlaue of crop production from the drained area. Predrainage crop production is normally not significant. With general field drainage, however, predrainage crop production could range from negligible to full production during dry years. It becomes conceptually more difficult to estimate net returns to general field drainage because of the extreme variability in predrainage crop production.

Prices

Crop prices are perhaps the single most important tangible stimulus to drainage. Landowners weight their expected net returns against the estimated costs of drainage. Prices selected for this analysis are 5-year planning prices as developed by University of Minnesota Agricultural Economists for farm management planning.[8/] Each farm operator has a price in mind when making investment decisions. These supply inducing prices may be functions of past prices, futures prices, or current prices. It is assumed that prices used in this analysis (Table 2) are reasonable surrogates for farm operator expectations.

Discount Rate

The benefits associated with on-farm drainage occur over a period of years, while a majority of the costs are incurred in the initial year. Benefits must be discounted to account for this difference in time perspective. A dollar to be received next year has a much different present value than a dollar to be received 15 or 20 years from now. Discounting the benefit stream facilitates a comparison with costs incurred at the start of the project.

[8/] Five-year planning prices are from "Farm Planning Prices", a farm management guide distributed by University of Minnesota, Agricultural Extension Service. These prices can be expected to prevail in the near future and are assumed to be those used by farm operators when planning drainage investments.

TABLE 2. Five Year Planning Prices for Valuing Returns to Drainage

	Price	Unit
Corn (grain)	$2.50	bushel
Soybeans	6.40	bushel
All Wheat	3.50	bushel
Oats	1.35	bushel
Barley	2.10	bushel
All Hay	40.00	ton
Sunflowers	10.50	cwt.

SOURCE: "Farm Planning Prices," University of Minnesota, Agricultural Extension Service, 1980.

Selection of a discount rate when analyzing public investment projects has been a disputed issue for economists for some time. However, the rate for private projects is the market rate, the opportunity cost of using internal capital, whichever is lowest, or a weighted combination of these two. Individuals can either borrow project funds, or use their own capital and forgo interest on returns from alternative investments. In times of volatile interest rates, as presently being experienced, the market rate is difficult to establish for long term investments. It varies across lenders and borrowers. Some borrowers are able to acquire government subsidized rates for selected investments while others are not. Discount rates of 8 and 12 percent are used in this analysis, representing a realistic range when real annual returns are used for comparison.

Present value factors are shown in Table 3 for the discount rates selected. Higher discount rates reduce the value of the stream of future benefits, and vice versa. In other words, a higher discount rate would make preservation relatively more attractive than drainage, because it would reduce the present value of drainage benefits.

Project Life

On-farm drainage ditches lose their effectiveness after approximately 15 years[9/] (Rigaux and Singh, 1977). The effective life of ditches can be extended with maintenance, while preventive measures extend the life of tile lines. Using a planning horizon of 15 years is a period long enough to be realistic but not so long as to present questions on the propriety of distant

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[9/] The U.S. Soil Conservation Service (1978) suggests a project life for open channels of 25 years with a low level of maintenance; and tile systems to last from 10 to 25 years. Goldstein (1967) reported the useful life of a tile system was from 20 to 50 years. Increasing the project life to 25 years would increase benefits by 25 and 15 percent respectively at 8 and 12 percent discount rates.

TABLE 3. Discount Factors for 8 and 12 Percent

Year (n)	Present value of $1 received in year n		Present value of $1 received each year for n years	
	8%	12%	8%	12%
1	0.9259	0.8929	0.9259	0.8929
2	0.8573	0.7972	1.7833	1.6901
3	0.7938	0.7118	2.5771	2.4018
4	0.7350	0.6355	3.3121	3.0374
5	0.6806	0.5674	3.9927	3.6048
6	0.6303	0.5066	4.6229	4.1114
7	0.5835	0.4523	5.2064	4.5638
8	0.5403	0.4039	5.7466	4.9676
9	0.5002	0.3606	6.2469	5.3282
10	0.4632	0.3220	6.7101	5.6502
11	0.4289	0.2875	7.1390	5.9377
12	0.3971	0.2567	7.5361	6.1944
13	0.3677	0.2292	7.9038	6.4236
14	0.3405	0.2046	8.2442	6.6282
15	0.3152	0.1827	8.5595	6.8109
25	0.1460	0.0588	10.6748	7.8431
50	0.0213	0.0035	12.2355	8.3045

SOURCE: Richard D. Aplin and George L. Casler, Capital Investment Analysis, Grid, Inc., Columbus, Ohio, 1973.

benefits.

Crop Rotations and Yields

The returns to drainage are sensitive to the mix of crops grown on drained lands. Drained land is assumed to be allocated among the various crops in the same proportions as cropland currently in production in the study areas. Current crop rotations were estimated using published annual statistics (Minnesota Crop and Livestock Reporting Service, 1980).

Two crop rotation schemes were developed for the west central study area due to significant differences in yields and rotations. A northern (N) composite acre represents the situation in Otter Tail, Becker, Douglas, and that portion of Clay County outside of the Red River Valley. The southern (S) composite acre represents the situation in Stevens, Grant, and Pope counties. One composite acre was sufficient to represent the agricultural patterns in the south central study area. The composite acres are shown both in Table 4 and on Figure 4. They represent what could be expected to be grown on drained lands.[10/] Specialty crops or crops that make up only a small portion of total planted acreage are not included. In the case of specialty crops, such as sugar beets or potatoes, the expected return may be considerably greater than for county-wide crop patterns.

Yields were selected on the basis of what farm operators could expect to obtain. The crop years used for estimating average yields were 1977, 1978, and 1979. Weather data for the study area indicate that 1979 was a year of average precipitation, while 1977 was slightly wetter than normal, and 1978

[10/] A composite acre is a representation of agricultural land use in a region. It shows what proportion of the cropland is seeded to the various crops. A composite acre can also be used to represent the mix of crops grown over time, and may be used to represent the mix of crops that would be planted during a specific period in the planting period.

TABLE 4. Crop Rotations and Yields

Crop	West Central Area						South Central Area		
	Sub-Area N			Sub-Area S					
	Percent of Cropland[a]	Average Yield[b]	Survey Yield[c]	Percent of Cropland[d]	Average Yield[e]	Survey Yield[f]	Percent of Cropland[g]	Average Yield[h]	Survey Yield[j]
Corn (grain)	20	68.0	83.0	26.0	92.0	99.0	47	119.0	128
Soybeans	5	27.0	32.0	16.0	27.0	31.0	45	40.0	42
Wheat	15	33.0	41.0	24.0	40.0	49.0	--	--	--
Oats	22	57.0	47.0	10.0	65.0	60.0	3	73.0	100
Barley	8	50.0	55.0	7	51.0	62.0	--	--	--
Sunflowers	5	15.5	13.0	9	16.0	13.5	--	--	--
Tame Hay	25	2.5	k	8	3.2	k	5	4.0	k
	100			100			100		

SOURCE: Minnesota Crop and Livestock Reporting Service, Minnesota Agricultural Statistics 1980 (and 1978), St. Paul; and farm operator survey.

[a]Percent of cropland is the average of 1978 and 1979 acres planted in Becker, Douglas, and Otter Tail counties.

[b]Yield is the average of the highest two out of the last three years (1977, 1978, 1979) weighted by acres planted per county for Becker, Douglas, and Otter Tail counties.

[c]Yield is the average expected or actual yield survey respondents reported on drained wetland in Becker, Douglas, and Otter Tail counties.

[d]Percent of cropland is the average of 1978 and 1979 acres planted in Grant, Pope, and Stevens counties.

[e]Yield is the average of the highest two out of the last three years (1977, 1978, 1979) weighted by acres planted per county for Grant, Pope, and Stevens counties.

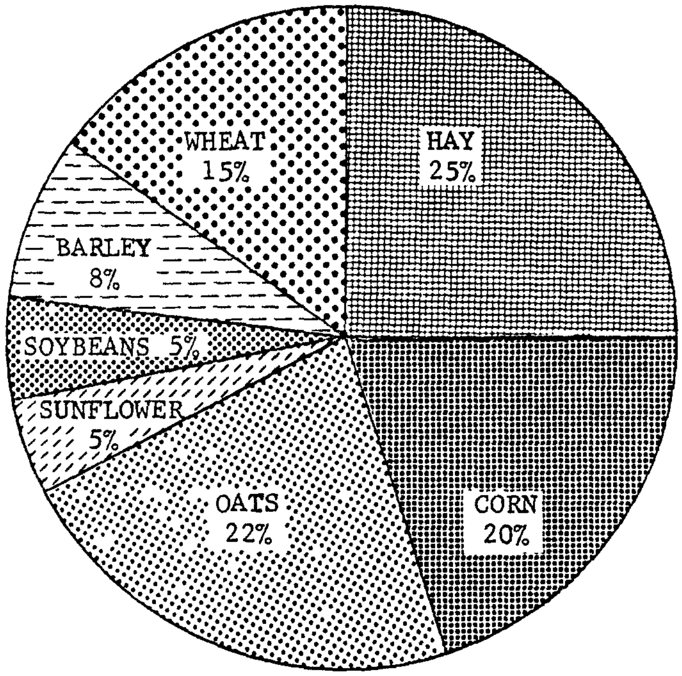
[f]Yield is the average expected or actual yield survey respondents reported on drained wetland in Grant, Pope, and Stevens counties.

[g]Percent of cropland is the average of 1978 and 1979 acres planted in Fairbault, Freeborn, Martin, Nicollet, LeSueur, Waseca, and Watonwan counties.

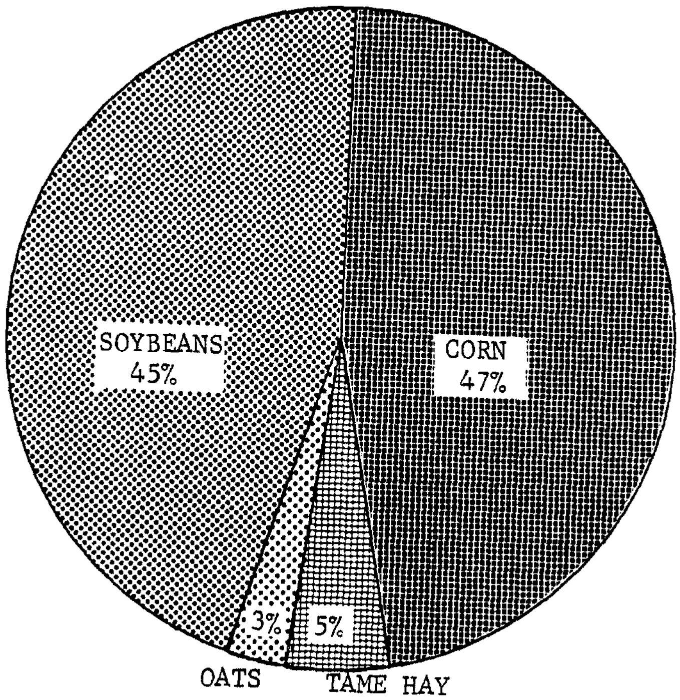
[h]Yield is the average of the highest two out of the last three years (1977, 1978, 1979) weighted by acres planted per county for south central area counties.

[j]Yield is the average expected or actual yield survey respondents reported on drained land in south central area counties.

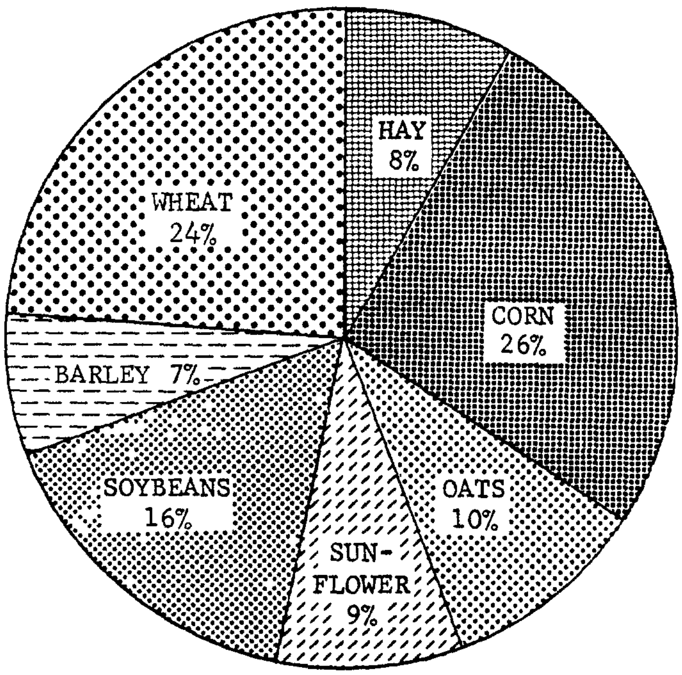
[k]Yields were not given by respondents, average yields were used in analysis.



West Central Sub-Area N



South Central Area



West Central Sub-Area S

Figure 4. Composite Acres Used in Drainage Analysis

was slightly drier than normal. Most landowners indicated they expected to get better than average yields from their drained lands, however, cases of inadequate drainage and poorly installed systems may reduce actual yields. Yields as reported by survey respondents (Table 4) are used in the analysis which follows.

Production Expenses

Crop production on adequately drained wetlands requires the same set of inputs as on upland cropland. The majority of wetlands drained by respondents were semi-permanent or permanent. Therefore, the assumption is made that crop production from wetlands was infrequent and insignificant prior to drainage.

Three classes of production costs involved in producing agricultural crops are cash expenses, land and other overhead costs, and crop insurance. Cash expenses are variable costs incurred only with crop production and include money spent for fuel, oil, repairs, fertilizer, seed, chemicals, and hired labor. These costs must be considered in either short- or long-run analyses.

Land charges are not included in this anlaysis, even though they represent a substantial opportunity cost, because they represent a sunk cost and do not affect the drainage decision. The land charge is the same if the wetland is drained or undrained. The agricultural market value of the land can change which changes the land tax paid. If purchasing wetland expressly to drain and farm was being considered, the land charge would play a key role in the investment analysis. In addition, the ownership cost for land varies considerably among farm operators depending on their debt-equity balance and the initial cost and financing arrangements.

Other costs that vary among farm operators are labor and machinery costs.

A labor charge is included as a cost in the profitability analysis. It includes the value of the farm operator's labor. Net returns were initially computed both with and without cost for owning machinery, but it is assumed that a marginal addition to cropland will not change the machinery complement. In addition, wear and tear on farm machinery may be reduced by removing wetland obstacles to farming. Considerable time may be spent farming around wetlands, so no increased machinery charge is added for a marginal addition to cropland. The possibility of getting mired down in a wetland is also lessened, thus reducing the chances of machinery damage.

Crop insurance can be included either as an insurance premium or as a discount on expected returns. This cost accounts for the risk element in agricultural production and is accounted for as a production outlay.

There are three feasible scenarios relative to inclusion or exclusion of selected production expenses:

1) Land and machinery included: Farmer buys land for expansion, enough acreage that he has to consider expanding his machinery line.

2) Machinery included: Farmer drains land already owned. Large enough plot that he has to expand his machinery line.

3) Land and machinery excluded: Farmer drains owned land to ease his operation. Farms with existing macinery, because of time savings he can cover more acres than before.

The third scenario is assumed to be most likely for contemporary drainage decisions in Minnesota. Table 5 shows production expenses for study areas N and S under scenarios 2) and 3).

Net Returns

The annual income stream a landowner can expect from an acre of drained wetland is the amount of production times product price. The return over production expenses is the profit or net return. Expected net annual

TABLE 5. Composite Acre Production Costs[a] on Drained Wetland in 1980

Costs Excluded	West Central Minnesota		South Central Minnesota
	Sub-Area N	Sub-Area S	
Land	$111.97	$116.72	$163.93
Land and Machinery	86.53	89.82	$135.99

[a]Production costs are from Anthony *et al.* (1980) and are computed on the basis of composite acres presented in Table 4.

returns are shown in Table 6 under the two cost and two yield scenarios. These values are sensitive to crop rotations, yields, prices, input costs, and farm management skills. The potential range of annual net benefits could go from a loss of all cash expenses to a substantial profit in a year of high crop prices and high local yields.

The present value of the stream of annual benefits is compared with the current cost of drainage to determine profitability. Present values were calculated using a project life of 15 years without maintenance. A project life of 25 years with maintenance is introduced later in the paper. Present values of net returns range from $284 to $464 in sub-area N, $597 to $974 in sub-area S, and $1,004 to $1,639 in the south central area (Table 7).

To facilitate comparison of returns with costs over a number of years the present values of annual net returns were indexed using 1980 as the base year. This resulted in a series of estimated present values for the years 1972 through 1979 (Table 7). The present values reported in Table 7 can be compared with the cost as reported by year by respondent to estimate the profitability of past drainage decisions.

Drainage Costs

Survey respondents reported drainage costs for years from 1970 through 1980. These year-specific costs were inflated to 1980 dollars (Table 8) using a composite price index (Table 9). Use of this index assumes drainage technology and industry structure have been constant during the time period.

A small-sample test of differences in means showed there were no significant differences at the 5 percent level in either tile or ditch drainage costs between west central sub-areas N and S. In addition, there were no differences in drainage costs due to farm size or type of farm. The source of variation

TABLE 6. Net Annual Crop Production Returns Per Acre of Drained Wetland[a], 1980

Costs Excluded	West Central Minnesota		South Central Minnesota
	Sub-Area N	Sub-Area S	
	Average Yield		
Land	$9.48	$46.91	$103.01
Land and Machinery	$34.92	$73.81	$130.95
	Survey Yield		
Land	$16.32	$60.74	$119.48
Land and Machinery	$41.76	$87.64	$147.42

[a]Before netting out the cost of drainage.

TABLE 7. Present Values of Net Returns Per Acre on Drained Land, 1980 Dollars[a]

Year	Index[b]	West Central Minnesota				South Central Minnesota	
		Sub-Area N		Sub-Area S			
		8%	12%	8%	12%	8%	12%
1980	100	$357	$284	$750	$597	$1,262	$1,004
1979	112	400	319	840	669	1,413	1,124
1978	120	429	341	900	716	1,514	1,205
1977	124	443	353	930	740	1,565	1,245
1976	148	529	421	1,110	883	1,868	1,486
1975	172	615	488	1,290	1,027	2,171	1,727
1974	236	844	671	1,770	1,409	2,978	2,369
1973	128	458	364	962	764	1,615	1,285
1972	76	272	216	571	454	959	763

a/ Drainage costs have not been deducted from present values. A 15-year project life is assumed, survey yields were used, and values were rounded to the nearest dollar.

b/ Developed from U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Current Business (Annual).

TABLE 8. Wetland Drainage Costs, 1980 Dollars

Sample Size	Cost Per Acre		
	Mean	Coefficient of Variation[a]	Confidence Interval[b]
West Central Minnesota Ditch Drainage[c]			
8[d]	$145	0.63	$ 99 - $ 191
9[e]	$143	0.60	$103 - $ 183
15[f]	$279	1.18	$165 - $ 383
West Central Minnesota Tile Drainage[c]			
6[d]	$626	0.39	$480 - $ 772
12[e]	$514	0.57	$400 - $ 628
18[f]	$622	0.86	$455 - $ 789
19[g]	$781	1.11	$516 - $1,046
South Central General Field Drainage			
11[d]	$373	0.52	$292 - $ 454
31[h]	$374	0.57	$325 - $ 423
62[i]	$477	0.66	$425 - $ 529

SOURCE: Survey of farm operators, winter 1981.

[a]The coefficient of variation is an indicator of variability around the mean. It is the standard deviation (s) divided by the mean ($\bar{X}$). Values close to zero represent very little variability among responses, while values near or greater than 1.0 indicate considerable variability.

[b]There is an eighty percent probability that any additional observation would fall in this interval.

[c]Although there was not a statistically significant difference between mean values of ditch and tile drainage costs, they are treated separately.

[d]Costs as reported by respondents for 1980.

[e]Includes costs for 1978 and 1979 indexed to 1980 and 1980 costs.

[f]Includes costs for 1972 through 1979, except one extreme value, and 1980 costs.

[g]Includes costs for 1972 through 1979, except one extreme value, and 1980 costs.

[h]Includes costs for 1978, 1979, and 1981 indexed to 1980 and 1980 costs

[i]Includes costs for 1970 - 1979 and 1981 indexed to 1980 and 1980 costs.

TABLE 9. Drainage Cost Index

Year	Ditch[a/]	Tile[b/]
1980	100	100
1979	83	85
1978	71	73
1977	65	66
1976	60	62
1975	57	58
1974	47	49
1973	37	40
1972	35	38

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Current Business.

[a/] Ditch index is weighted average of construction machinery (67%) and fuels (33%) indexes.

[b/] Tile index is weighted average of construction machinery (50%), fuels (25%), and concrete products (25%).

in drainage costs may be due solely to differences in selected wetland characteristics and topographic setting.

The coefficients of variation for drainage (Table 8) indicate there was little consistency in reported wetland drainage cost in the west central study area where random wetland drainage is most common. It may be possible to drain large ditches or tile lines. On the other hand, small wetlands in areas of high local relief may require long, deep open channels or subsurface tile lines. An attempt to estimate statistically equations for west central ditch and tile drainage costs showed constructed outlet length, cut depth, and percent open water to be influential variables.

Drainage cost data can be used to test the profitability of past drainage decisions. In other words, an ex post benefit/cost analysis can be made of past drainage investments by comparing costs as reported by year and benefits as shown in Table 7. Estimates of drainage costs can also be used to predict the profitability of potential drainage, given expected benefit levels.

Income Tax Considerations

Income taxes can have a significant impact on the relative cost and returns of drainage investments. The exact impact of tax implications is dependent on the income and tax situation of each farm operator. The fact that ditch construction and maintenance costs are deductible would have little impact on a farm operator with no taxable income. However, tax deductions could reduce the real cost of drainage considerably for a farm operator in an upper income bracket. But, while the cost of drainage may be reduced, so are the net returns to crop production.

For purposes of this analysis two tax situations are depicted: (1) no tax liability, and (2) 40 percent combined federal and state tax liability

Extension farm management specialists suggest many Minnesota farmers would fall in the 40 percent bracket (Farmer, 1981). Leitch and Danielson (1979) have shown it is the young, expansion-minded farmers that are the most likely to drain. These farmers may also be in the lowest tax brackets due to high debt and interest obligations coincident with getting established. On the other hand, the respondents to the drainage costs survey reported they had been farming an average of 25 years--definitely not beginning farmers. These higher income farmers may drain in good years when capital is available and tax incentives are greater.

Tile drainage costs qualify for a 10 percent investment credit and a 20 percent first year depreciation in the year they are incurred. The remaining 80 percent of cost can be deducted over a period of years and under various depreciation schedules. Eight years at 10 percent per year straight-line depreciation was assumed to be a representative schedule.

Ditch drainage costs qualify as deductible expenses, initial expenses as first year deductions and annual maintenance as a business expense.

Drainage System Maintenance

Periodic maintenance of drainage ditches is required to maintain their function and to extend their useful life. This is especially true when they are regularly crossed with farm machinery during normal crop production operations. Annual maintenance requirements depend on soil erodability, frequency of crossing with farm machinery, rainfall, wind, vegetation, and a number of ditch characteristics such as slope, side slope, and how straight or crooked it is.

Estimates of the cost of ditch maintenance range from 3 percent of initial cost per year (U.S. SCS, 1978) assuming a 15-year life to one-third of the original cost every 7 years (Goldstein, 1967). These two maintenance cost estimates have an approximately equal impact on the present value of drainage costs.

Preventative maintenance of subsurface tile drains can extend their useful life. Ways of maintaining the effectiveness of tile drains include ensuring outlet ditches and surface inlets are kept clean, installing sediment traps, controlling rodents and plant roots, and keeping livestock and heavy equipment away from shallow lines.

Cropland Loss to Ditches

Surface drains may or may not be farmable.[11/] Some are maintained as grassed waterways while others are barely noticeable in cropland. The land lost from production may equal or exceed land area gained if a long, deep ditch is required. However, it is assumed in this analysis that all ditches are able to be farmed the same as adjacent cropland. In many cases this assumption will not appreciably affect the results. Subsurface drains are assumed to be used where ditches would take a disproportionate amount of land.

Landowner Benefits of Natural Wetlands

Wetlands in their natural condition may provide some benefits to their owners. Crop production prior to drainage is included in equation (3), but was found to be almost insignificant.[12/] The values of stock water, recreation,

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[11/] We failed to ask survey respondents the amount of land lost due to surface drainage ditches. This variable should be considered in future drainage cost analyses.

[12/] Over two-thirds of the respondents to the drainage cost survey never harvested a crop from wetlands before they were drained. Those who reported getting a crop on undrained wetland said it occurred approximately every third year, but yields were considerably below average.

furbearer harvest, hunting leases,[13] erosion control, and other possible owner benefits may be important to some farm operators and not to others. In most instances these benefits are relatively insignificant (dollarwise) when compared to drainage benefits. Their exclusion from the analysis should not bias the results.

III. RESULTS

The returns to drainage vary considerably across Minnesota. Estimated annual net returns to crop production range from $42 in the west central study area to $147 in the south central region (Table 6). If landowners want to recover their drainage costs with increases in production they can spend no more than the present values of these annual returns to drain land. Present values were shown to range from $284 to $1,639 (Table 7) depending on assumptions regarding discount rate and study area.

Net returns will be presented in two ways in this section: 1) by individual drainage projects, and 2) comparing average costs with average returns. The first scenario gives a feel for why past drainage decisions were made, while the latter offers suggestions as to the general profitability of on-farm drainage.

Net Returns to Drainage

The present values of the stream of annual agricultural production benefits of drainage were presented above in Table 7. These net returns, indexed to the appropriate years, will be compared with actual drainage costs as reported by respondents. Results are reported by individual for each of three study areas as well as averages.

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[13] Dorf (1981) has argued that the values of hunting leases may exceed the benefits of drainage in at least parts of Minnesota's Region 6W.

Monetary Benefits

Dollar returns are the most important tangible incentive for drainage for many farm operators. Others drain to remove nuisances or square up fields. Whatever the reason, a balance between cost to drain and dollar returns to drainage can be made.

Ditch Drainage

Fifteen respondents had drained random wetlands with ditches since 1972. With only one exception (before taxes at 12 percent discount rate) all ditch drainage projects yielded positive net benefits--the return was greater than the cost (Appendix Tables A1, A2). The effect of taxes was to lower both net gains and losses. An individual who appeared to have a loss before taxes, had a small gain after taxes were considered.

Ditch drainage construction costs can be expected to be between $103 and $183 per acre drained (Table 8). Ditch drainage costs are highly variable due to the nature of random wetland drainage, but they are also low relative to crop returns.

Average net returns to drainage in Sub-Area N are $214 before taxes and $128 after taxes (Table 10, 8 percent). All drainage costs are recovered in 5 years. With the same cost to drain and higher returns, the net returns in Sub-Area S average $607 before taxes and $450 after taxes (Table 10). Ditch drainage costs are recovered in only 2 years in Sub-Area S.

If we include ditch maintenance in the analysis, the returns are even more rewarding. Assuming annual maintenance expenditures of 3 percent of initial construction costs would extend the useful ditch life to 25 years, net benefits would rise approximately 17 percent at 8 percent discount rate and 10 percent at 12 percent discount rate (Table 11).

TABLE 10. West Central Minnesota Ditch Drainage Costs and Benefits Per Acre, Without Maintenance, 1980[a]

	Sub-Area N		Sub-Area S	
	BEFORE TAXES			
Cost[b]	$143 (103 - 183)[c]		$143 (103 - 183)	
	Discount Rate		Discount Rate	
	8%	12%	8%	12%
Gross Benefit[d]	$ 357	$ 284	$ 750	$ 597
Net Benefit (= G)[e]	214	141	607	454
B/C Ratios	2.5	2.0	5.2	4.2
Years to Payback	5	5	2	2
	AFTER TAXES[f]			
Cost[b]	$86 (62 - 110)		$86 (62 - 110)	
Gross Benefit[d]	$ 214	$ 170	$ 450	$ 358
Net Benefit (= G)[e]	128	84	364	272
B/C Ratios	2.5	2.0	5.2	4.2
Years to Payback	5	5	2	2

[a]A 15-year useful project life is assumed.

[b]From Table 9.

[c]Numbers in parentheses represent 80 percent confidence interval.

[d]From Table 8. Returns over agricultural production expenses.

[e]Returns over agricultural production expenses and drainage costs.

[f]All farm operators are assumed to be in a 40 percent combined (federal and state) tax bracket. Ditch costs are deducted from taxable income in the year they are incurred.

TABLE 11. West Central Minnesota Ditch Drainage Costs and Benefits Per Acre, With Maintenance, 1980[a]

	Sub-Area N		Sub-Area S	
	BEFORE TAXES			
Cost[b]	$143 (103 - 183)[c]		$143 (103 - 183)	
	Discount Rate		Discount Rate	
	8%	12%	8%	12%
Gross Benefit[d,e]	$ 400	$ 294	$ 890	$ 654
Net Benefit (= G)[f]	257	151	747	511
B/C Ratios	2.8	2.1	6.2	4.6
Years to Payback	5	6	2	2
	AFTER TAXES[g]			
Cost	$86 (62 - 110)		$ 86 (62 - 110)	
Gross Benefit	$ 240	176	$ 534	$ 392
Net Benefit (= G)	154	90	448	306
B/C Ratios	2.8	2.0	6.2	4.6
Years to Payback	5	6	2	2

[a]Annual maintenance expenses of 3 percent of initial construction cost are assumed to extend the useful life of the project to 25 years.

[b]From Table 9.

[c]Numbers in parentheses represent 80 percent confidence interval.

[d]From Table 8 after netting out present value of annual maintenance cost.

[e]Returns over agricultural production expenses.

[f]Returns over agricultural production expenses and drainage costs.

[g]All farm operators are assumed to be in a 40 percent combined (federal and state) tax bracket. Ditch costs are deducted from taxable income in the year they are incurred.

Random Subsurface Drainage

Nineteen respondents had used subsurface drains to drain random wetlands since 1972. Nine respondents from Sub-Area N drained with subsurface tiles, with five of those having an apparent net loss at both discount rate and tax situations (Appendix Table A3). Roughly two-thirds of the subsurface drainage by respondents in Sub-Area S resulted in a positive net benefit. The effect of taxes on tile drainage was to reduce gains and losses (Appendix Table A4).

Tile drainage costs can be expected to range from $400 to $628 per acre drained (Table 8). Tile drainage costs for random wetlands are no less variable than random ditch drainage. Average net returns to tile drainage in Sub-Area N are negative (Table 12). In other words, the costs of drainage can never be recovered given the low gains in agricultural productivity. There may be overriding non-monetary or unquantified returns to drainage, however.

Average net returns in Sub-Area S are $236 before taxes and $103 after taxes using an 8 percent discount rate (Table 12). It would take 9 years to pay back drainage costs before taxes and 10 years after. Average net returns are considerably lower when a 12 percent discount rate is used, but they are still positive.

General Field Drainage

General field drainage is popular in southern Minnesota. Our interest is primarily wetland drainage, but unfortunately (from an analytical standpoint) wetlands are drained along with the rest of the field. As described above, entire fields are latticed with subsurface drain tile. Only a fraction of the total area may be wetland, while the remaining area is cropland. The

TABLE 12. West Central Minnesota Subsurface Tile Drainage Costs and Benefits Per Acre, 1980[a]

	Sub-Area N		Sub-Area S	
	BEFORE TAXES			
Cost[b]	$514 (400 - 628)[c]		$514 (400 - 628)	
	Discount Rate		Discount Rate	
	8%	12%	8%	12%
Gross Benefit[d,e]	$ 357	$ 284	$ 750	$ 597
Net Benefit (= G)[f]	-157	-230	236	83
B/C Ratios	0.7	0.6	1.5	1.2
Years to Payback	> 50	> 50	9	12
	AFTER TAXES[g]			
Cost	$421 (328 - 515)		$421 (328 - 515)	
	Discount Rate		Discount Rate	
	8%	12%	8%	12%
Gross Benefit	$ 301	$ 265	$ 524	$ 455
Net Benefit (= G)	-120	-156	103	34
B/C Ratios	0.7	0.6	1.2	1.1
Year to Payback	> 50	> 50	10	15

[a]A 15-year useful project life is assumed.

[b]From Table 8.

[c]Numbers in parentheses represent 80 percent confidence interval.

[d]From Table 7.

[e]Returns over agricultural production expenses.

[f]Returns over agricultural production expenses and drainage costs.

[g]All farm operators are assumed to be in a 40 percent combined (federal and state) tax bracket Tile costs are deducted from taxable income 20 percent in year 1 and 10 percent in each of years 2 through 9, assuming annual depreciation on a straight-line basis. Tile costs also qualify for a 10 percent investment credit in the year they are incurred.

primary reason for general field drainage in southern Minnesota is to remove excess soil moisture, wetlands are drained as a secondary motive.

The cost to drain the wetland area is difficult to separate from the cost to drain the entire field. However, it is at least as costly to drain areas with standing water or depressions that accumulate runoff than it is to drain soils with a wetness problem.

Two alternatives are feasible for ferreting out the cost to drain wetlands when their drainage is a part of general field drainage. First, the cost could be assumed equal to the average per acre cost for the entire area drained. Second, the cost to add wetland drainage to the system could be calculated for each of the systems respondents reported. This second technique is no less subject to bias than the first and much more tedious.

Wetlands were defined in the survey as nontillable areas with temporary or permanent standing water and possibly wetland vegetation present. Therefore, reported pre-drainage crop production was negligable on these areas. The improvement brought about by drainage could go from zero percent of potential production to 100 percent. Drainage of wet soils brought cropland from a lower productivity to 100 percent of potential (based on the composite acres developed earlier). As a basis for analysis, we will assume that prior to drainage production on tillable land, although with excess soil moisture, was equal to 50 percent of potential. Since estimating profitability of general field drainage was not included in our objectives, we did not explicitly collect information on before and after drainage performance.

Appendix Table A5 presents data on 58 on-farm drainage projects in south central Minnesota. In most all cases the net benefit to drainage of wetlands is positive. In only one instance at 8 percent discount rate, and two at 12 percent discount rate was drainage of wetlands not feasible on a strictly cash flow basis.

Alternatively, general field drainage was feasible 52 out of 58 times at 8 percent discount rate and 47 out of 58 times at 12 percent discount rate. However, in those instances where prima facie indications are general field drainage was not economically feasible there may have been individual circumstances that made it viable.

Looking at average wetlands drainage cost and returns figures, it appears to be a profitable venture in south central Minnesota. Drainage costs before taxes run between $325 and $423, while the present value of the stream of returns averages $1,262 at 8 percent discount rate (Table 13). It would take an up front payment of $888 to make the farm operator indifferent to drainage on a strictly cash basis.

The situation changes slightly if taxes are considered. Costs average $266 to $346, because of the influence of the investment credit and deductable expenses. Benefits are reduced by taxes and increased by cost deductions in years 2 through 9. The payment required to make the farm operator as well off financially after taxes are considered would be $688 at 8 percent discount rate.

In general, it is profitable to drain to remove excess soil moisture if predrainage production is 50 percent or less of postdrainage production, when postdrainage production is equivalent to the composite acre developed above. Average costs of general field drainage are from $325 to $423, while average benefits are $631 at 8 percent discount rate and $502 at 12 percent discount rate.

TABLE 13. South Central Minnesota Subsurface Tile Drainage Costs and Benefits Per Acre, 1980[a]

	Wetlands Drainage[b]		Drainage to Remove Excess Soil Moisture[c]	
	BEFORE TAXES			
Cost[d]	$374 ($325 - $423)[e]		$374 ($325 - $423)	
	Discount Rate		Discount Rate	
	8%	12%	8%	12%
Gross Benefit[f]	$1,262	$1,004	$ 631	$ 502
Net Benefit[g]	888	630	257	128
B/C Ratios	3.4	2.7	1.7	1.3
Years to Payback	3	3	7	7
	AFTER TAXES[h]			
Cost	$306 ($266 - $346)		$306 ($266 - $346)	
	Discount Rate		Discount Rate	
	8%	12%	8%	12%
Gross Benefit	994	810	497	405
Net Benefit	688	504	191	99
B/C Ratios	3.2	2.6	1.6	1.3
Years to Payback	3	3	7	7

[a]A 15-year useful project life is assumed.

[b]Wetlands drainage is drainage of land that was not cropped prior to drainage, therefore the change in crop production was from zero to 100 percent of the composite acre described in the text.

[c]Drainage to remove excess soil moisture is drainage of land that was previously cropped. Crop production is assumed to go from 50 percent before draining to 100 percent of the composite acre after drainage.

[d]From Table 8.

[e]Numbers in parentheses represent 80 percent confidence interval.

[f]From Table 7, returns over agricultural production expense.

[g]Returns over agricultural production expenses and drainage costs.

[h]All farm operators are assumed to be in a 40 percent combined (federal and state) tax bracket. Tile costs are deducted from taxable income 20 percent in year 1 and 10 percent in each of years 2 through 9, assuming annual depreciation on a straight-line basis. Tile costs also qualify for a 10 percent investment credit in the year they are incurred.

Nonmonetary Benefits of Drainage

While the obvious measure of the feasibility of drainage is dollars and cents, there are other incentives and benefits to drainage. Land drainage in general promotes root growth so plants can sustain dry periods; makes fertilizer application more effective; aerates the soil; expands cropping possibilities; saves time and labor; extends the growing and harvesting season; increases yields; reduces runoff and erosion; increases land value; reduces soil damage; and reduces nuisance weed and wildlife problems. Many of these benefits of drainage translate back to increased crop production, or reduced costs of production. Others have less obvious benefits in dollar terms, such as reducing runoff or erosion.

The social and nonmonetary benefits of wetland drainage should not be overlooked, neither from the individual drainer's perspective nor from society's perspective. Wetland drainage permits farm operators to shift row crops and small grains from areas subject to erosion to drained lands, while putting these former cropland acres in a permanent cover, such as hay. Good soil conservation practices on cropland are conducive to rainfall and snow-melt infiltration, leading to groundwater recharge and reducing problems with runoff. While wetlands can serve as firebreaks when they are wet, they may be prone to fires in the fall and spring of the year when the vegetation is dry.

The problems involved with estimating a nuisance factor for wetlands in cropland were discussed above. One can infer from the fact that in several instances there was a net dollar loss associated with drainage, that farm operators were willing to pay this amount to be rid of a real or imagined nuisance or simply underestimated costs or overestimated returns. They felt it was worth the money spent to save time and reduce the chance of getting mired down in a wetland. With modern, large farm machinery any obstacle in an otherwise open field can cause delays and bothersome avoidance costs.

Conclusions

Agricultural land drainage has been nearly synonymous with increased agricultural production since early settlement in Minnesota. Surface ditch and subsurface tile drainage of scattered prairie wetlands in west central Minnesota and general field drainage in south central Minnesota represent the majority of contemporary drainage. All were shown to be profitable in most situations. Where they were not profitable in a dollars and cents context, they may have been feasible in terms of overall efficient field operations.

Decision makers concerned with preservation of prairie wetlands are seeking means to halt the continual decline in wetland acreage. Outright regulation is not politically feasible and difficult to enact due to a variety of unknowns, especially related to social values of wetlands. Ongoing preservation programs offer payments to farm operators willing to not drain their wetlands. The level of these payments and their adequacy has been discussed by Farmer (1981). This paper went one step further by looking at 92 individual on-farm drainage projects installed since 1972.

The present value of net benefits per acre ranged from over \$2,000 to a loss of over \$1,600, depending on drainage area, tax assumptions, and discount rates used. Losses imply, assuming the farm operator had complete information on the project, a willingness to pay to be rid of wetlands. This further implies that the required preservation incentive payment not only equals potential net benefits but exceeds the present value of the stream of future expected returns to drainage. It is worth more to the farm operator to drain a wetland than just the dollar return he can expect to gain. Most existing preservation programs base payments on net returns to drainage or cash rent for similar cropland. This ignores the nuisance factor and may be a prime reason for lack of participation in existing programs. There are other social and political reasons for nonparticipation as discussed by others (Leitch and Danielson, 1979).

The basic point is that it may be feasible to pay a landowner the present value of his expected returns for a standard block of land (i.e. rent a quarter section or a section). Alternatively, it is not logical to assume farm operators would be willing to accept the per acre present value of expected returns for scattered areas throughout their fields.

Social values of wetland benefits may be large compared to individual agricultural returns on drained wetlands. This has been the supposition of preservation agencies. However, until social values are known or can be estimated with reliability we have no yardstick to determine what to pay to preserve wetlands. We have shown an average minimum level needed, but have also argued this is frequently not sufficient. Social values must be estimated so that preservation program payments can be sufficient to induce landowners not to drain. If marginal social values of perservation turn out to be less than marginal drainage benefits, the optimal allocation at the margin suggests drainage.

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APPENDIX TABLE A1. Costs, Benefits, and Benefit/Cost Ratios of 15 West Central Minnesota On-Farm Ditch Drainage Projects, 1980 Dollars, 12 Percent Discount Rate[a]

Year	Cost	Benefit	Benefit/Cost Ratio	Net Return to Drainage
		Sub-Area N[b]		
1980	$ 100	$ 284	2.8	$ 184
1980	200	284	1.4	84
1980	100	284	2.8	184
1980	160	284	1.8	124
1980	50	284	5.7	234
1980	344	284	0.8	-60
1976	50	421	8.4	371
1974	200	671	3.4	471
1973	75	364	4.9	289
		Sub-Area S[b]		
1980	110	597	5.4	487
1980	100	597	6.0	497
1979	104	669	6.4	565
1975	606	1,027	1.7	421
1975	50	1,027	20.5	977
1974	487	1,409	2.9	922

[a]15-year project life, before taxes.

[b]See Figure 1.

APPENDIX TABLE A2. Costs, Benefits, and Benefit/Cost Ratios of 15 West Central Minnesota On-Farm Ditch Drainage Projects, 1980 Dollars, 8 Percent Discount Rate[a]

Year	Cost	Benefit	Benefit/Cost Ratio	Net Return to Drainage
BEFORE TAXES				
		Sub-Area N[b]		
1980	100	357	3.6	257
1980	200	357	1.8	157
1980	100	357	3.6	257
1980	160	357	2.2	197
1980	50	357	7.1	307
1980	344	357	1.1	13
1976	50	529	10.6	479
1974	200	844	4.2	644
1973	75	458	6.1	383
		Sub-Area S[b]		
1980	110	750	6.8	640
1980	100	750	7.5	650
1979	104	840	8.1	736
1975	606	1,290	2.1	684
1974	50	1,770	35.4	1,720
1973	487	962	2.0	475
AFTER TAXES				
		Sub-Area N		
1980	60	214	3.6	154
1980	120	214	1.8	94
1980	60	214	3.6	154
1980	96	214	2.2	118
1980	30	214	7.1	184
1980	206	214	1.1	8
1976	30	317	10.6	287
1974	120	506	4.2	386
1973	45	274	6.1	229
		Sub-Area S		
1980	66	450	6.8	384
1980	60	450	7.5	390
1979	62	504	8.1	442
1975	364	774	2.1	410
1974	30	1,062	35.4	1,032
1973	292	577	2.0	285

[a]15-year project life.

[b]See Figure 1.

[c]All farm operators are assumed to be in a 40 percent combined (federal and state) tax bracket. Ditch costs are deducted from taxable income in the year they are incurred.

APPENDIX TABLE A3. Costs, Benefits, and Benefit/Cost Ratios of 19 West Central Minnesota On-Farm Subsurface Tile Drainage Projects, 1980 Dollars, 12 Percent Discount Rate[a]

Year	Cost	Benefit	Benefit/Cost Ratio	Net Return to Drainage
		Sub-Area N[b]		
1980	$ 200	$ 284	1.4	$ 84
1980	686	284	0.4	-402
1979	833	319	0.4	-514
1979	500	319	0.6	-181
1978	267	341	1.3	74
1976	140	421	3.0	281
1972	800	216	0.2	-684
1972	400	216	0.5	-184
1972	57	216	3.8	159
		Sub-Area S[b]		
1980	733	597	0.8	-136
1980	520	597	1.1	77
1980	700	597	0.9	-103
1980	917	597	0.7	-320
1979	290	669	2.3	379
1979	115	669	5.8	554
1978	60	716	11.9	656
1977	2,400	740	0.3	-1,660
1974	175	1,409	8.1	1,234
1972	333	454	1.4	121

[a]15 year project life, before taxes.

[b]See Figure 1.

APPENDIX TABLE A4. Costs, Benefits, and Benefit/Cost Ratios of 19 West Central Minnesota On-Farm Subsurface Tile Drainage Projects, 1980 Dollars, 8 Percent Discount Rate[a]

Year	Cost	Benefit	Benefit/Cost Ratio	Net Return to Drainage
BEFORE TAXES				
		Sub-Area N[b]		
1980	200	357	1.8	157
1980	686	357	0.5	-329
1979	833	400	0.5	-433
1979	500	400	0.8	-100
1978	267	429	1.6	162
1976	140	529	3.8	389
1972	900	272	0.3	-628
1972	400	272	0.7	-128
1972	57	272	4.8	215
		Sub-Area S		
1980	733	750	1.0	17
1980	520	750	1.4	230
1980	700	750	1.1	50
1980	917	750	0.8	-167
1979	290	840	2.9	550
1979	115	840	7.3	725
1978	60	900	15.0	840
1977	2,400	930	0.4	-1,470
1974	175	1,770	10.1	1,595
1972	333	571	1.7	238
AFTER TAXES[c]				
		Sub-Area N		
1980	164	241	1.5	77
1980	563	335	0.6	-228
1979	683	387	0.6	-296
1979	410	366	0.9	-44
1978	219	295	1.3	76
1976	115	327	2.8	212
1972	738	327	0.4	-411
1972	328	260	0.8	-68
1972	47	165	3.5	118
		Sub-Area S		
1980	601	440	0.7	-161
1980	426	526	1.2	100
1980	574	560	1.0	-14
1980	752	602	0.8	-150
1979	238	533	2.2	295
1979	94	499	5.3	405
1978	49	523	10.7	474
1977	1,968	988	0.5	-980
1974	143	1,037	7.3	894
1972	273	388	1.4	115

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APPENDIX TABLE A4. Costs, Benefits, and Benefit/Cost Ratios of 19 West Central Minnesota On-Farm Subsurface Tile Drainage Projects, 1980 Dollars, 8 Percent Discount Rate[a] (continued)

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[a] 15 year project life.

[b] See Figure 1.

[c] All farm operators are assumed to be in a 40 percent combined (federal and state) tax bracket. Tile costs are deducted 20 percent in year 1 and 10 percent in each of years 2 through 9, assuming annual depreciation on a straight-line basis. Tile costs also qualify for a 10 percent investment tax credit in the year they are incurred (IRS, 1980).

APPENDIX TABLE A5. Before Tax Costs, Benefits, and Benefit/Cost Ratios of 58 South Central Minnesota On-Farm Drainage Projects, 15 Year Project Life, Per Acre

		8 Percent Discount Rate				12 Percent Discount Rate			
Year	Cost	Benefit[a]	B/C	Net B[b]	Threshold Benefit[c]	Benefit[a]	B/C	Net B[b]	Threshold Benefit[c]
1981	90	1,262	14.0	1,172	.93	1,004	11.2	914	.91
"	450	"	2.8	812	.64	"	2.2	554	.55
1980	81	1,262	15.6	1,181	.94	1,004	12.4	923	.92
"	104	"	12.1	1,158	.92	"	9.7	900	.90
"	250	"	5.0	1,012	.80	"	4.0	754	.75
"	300	"	4.2	962	.76	"	3.3	704	.70
"	347	"	3.6	915	.73	"	2.9	657	.66
"	360	"	3.5	902	.71	"	2.8	644	.64
"	416	"	3.0	846	.67	"	2.4	588	.58
"	438	"	2.9	824	.65	"	2.3	566	.57
"	486	"	2.6	776	.61	"	2.1	518	.52
"	571	"	2.2	691	.55	"	1.8	433	.44
"	753	1,262	1.7	509	.40	1,004	1.3	251	.23
1979	98	1,413	14.4	1,315	.93	1,124	11.5	1,026	.91
"	137	"	10.3	1,276	.90	"	8.2	987	.88
"	327	"	4.3	1,086	.77	"	3.4	797	.71
"	340	"	4.2	1,073	.76	"	3.3	784	.70
"	417	"	3.4	996	.70	"	2.7	707	.63
"	476	"	3.0	937	.66	"	2.4	648	.58
"	714	"	2.0	699	.49	"	1.6	410	.38
"	1,041	1,413	1.4	372	.26	1,124	1.1	83	.09
1978	167	1,514	9.1	1,347	.89	1,205	7.2	1,038	.86
"	209	"	7.2	1,305	.86	"	5.8	996	.83
"	261	"	5.8	1,253	.83	"	4.6	944	.78
"	305	"	5.0	1,209	.80	"	4.0	900	.75
"	313	"	4.8	1,201	.79	"	3.8	892	.74
"	389	"	3.9	1,125	.74	"	3.1	816	.68
"	417	"	3.6	1,097	.72	"	2.9	788	.65
"	556	"	2.7	958	.63	"	2.2	649	.54
"	573	1,514	2.6	941	.62	1,205	2.1	632	.52
1977	66	1,565	23.7	1,499	.96	1,245	18.9	1,179	.95
"	190	"	8.2	1,375	.88	"	6.6	1,055	.85
"	203	"	7.7	1,362	.87	"	6.1	1,042	.84
"	304	"	5.1	1,261	.81	"	4.1	941	.75
"	608	1,565	2.6	957	.61	1,245	2.0	637	.51
1976	390	1,868	4.8	1,478	.79	1,486	3.8	1,096	.74
"	579	"	3.2	1,289	.69	"	2.6	907	.61
"	820	"	2.3	1,048	.56	"	1.8	666	.45
"	937	"	2.0	931	.50	"	1.6	549	.37
"	1,640	1,868	1.1	228	.12	1,486	0.9	-154	**
1975	138	2,171	15.7	2,033	.94	1,727	12.5	1,589	.92
"	143	"	15.2	2,028	.93	"	12.1	1,584	.92
"	589	"	3.7	1,582	.73	"	2.9	1,138	.66
"	680	"	3.2	1,491	.69	"	2.5	1,047	.60
"	710	"	3.1	1,461	.67	"	2.4	1,017	.58
"	1,433	2,171	1.5	738	.34	1,727	1.2	294	.17

APPENDIX TABLE A5. Before Tax Costs, Benefits, and Benefit/Cost Ratios of 58 South Central Minnesota On-Farm Drainage Projects, 15 Year Project Life, Per Acre (CONTINUED)

		8 Percent Discount Rate				12 Percent Discount Rate			
Year	Cost	Benefit[a]	B/C	Net B[b]	Threshold Benefit[c]	Benefit[a]	B/C	Net B[b]	Threshold Benefit[c]
(CONTINUED)									
1974	173	2,978	17.2	2,805	.94	2,369	13.7	2,196	.93
"	468	"	6.4	2,510	.84	"	5.1	1,901	.80
"	667	"	4.5	2,311	.78	"	3.6	1,702	.72
"	699	"	4.3	2,279	.77	"	3.4	1,670	.71
"	728	"	4.1	2,250	.76	"	3.3	1,641	.70
"	780	2,978	3.8	2,198	.74	2,369	3.0	1,589	.67
1973	368	1,615	4.4	1,247	.77	1,285	3.5	917	.71
1972	108	959	8.8	851	.89	763	7.1	655	.86
"	297	"	3.2	662	.69	"	2.6	466	.62
"	742	"	1.3	217	.23	"	1.0	21	0
"	750	"	1.3	209	.22	"	1.0	13	0
"	1,080	959	0.9	-121	**	763	0.7	-317	**

[a] The benefit shown is the net return after production is netted out. It assumes pre-drainage production was negligible.

[b] The net benefit is the net return to crop production less the per acre cost of drainage.

[c] Most of the drainage done in south central Minnesota is general field drainage and the land drained was productive prior to drainage. However, production was only a fraction of potential (or drainage would not have been necessary) as expressed by composite acres developed in the text. The decimals in this column represent the maximum percentage of potential production that could have been produced prior to drainage and still have drainage be feasible. For example, .93 indicates that if pre-drainage production was 93 percent of the composite acre production or less, then the drainage project would be feasible if the cost per acre to drain were $90 as in the case of the first row of the table. If, in general, pre-drainage harvest was approximately 50 percent of potential, then every entry in this column above .50 indicates general field drainage was feasible. Alternatively, all entries above 0.0 indicate wetlands drainage was feasible.

APPENDIX B

A Comparison of This Report With The Economics of Wetland Drainage in Agricultural Minnesota (Farmer, 1981)

Farmer's 1981 report, The Economics of Wetland Drainage in Agricultural Minnesota, was a precursor to this report. The conclusions reached in both reports are quite similar, while the methods were somewhat different. No attempt will be made to reconcile the subtle differences in assumptions between the two studies, nor will the advantages of one over the other be argued. Rather, some of the differences will be pointed out to help the interested reader bridge the gap between the two studies.

Farmer relied primarily on secondary data to develop estimates of drainage costs and returns. We have relied as much as possible on primary data collected from farm operators during February and March 1981.

Both studies used the same source for estimating agricultural production costs. We included all costs of production except land and machinery depreciation. Farmer reduced these by 20 percent to account for savings realized by not having to farm around wetlands.

Gross returns to crop production were estimated using crop budgets in each study. We used farm operator survey data for expected yields on drained wetlands, while Farmer used 5-year average yields from published sources. Crop rotations were nearly identical in both cases, but our estimated yields were approximately 20 percent higher than Farmer's.

Estimated drainage costs were surprisingly close in the two studies. Our cost estimates followed from responses to the farm operator survey. Farmer's cost estimates were based on estimated ditch construction and tile installation expenses collected from contractors and others knowledgeable of drainage costs. An example of cost similarity is the south central tile cost estimate. We estimated per acre cost to be $325 to $423, compared to Farmer's estimate of $350 to $440.

A significant difference between the two studies (other than the data bases used) is that we did our analyses based on capitalized values, while Farmer worked with annual values. This, along with the numerous scenarios depicted in each study, makes comparison of numerical estimates somewhat taxing.

Finally, where Farmer finds government program payments to be inadequate, we too would concur in that finding based on cash flows alone. However, where he finds payments are adequate to compensate for foregone incomes, we would conclude that compensation may still be inadequate when other costs -- namely the nuisance cost -- are considered. Farmer, however, does point out the necessary caveats to consider when conducting analyses such as these. The two studies complement one another quite well, their common conclusions indicating we are closer to understanding wetlands drainage from the farm operators' perspective than before the studies.