THE ECONOMIC IMPACT OF IMPROVED DRAINAGE ON NORTHERN NEW YORK DAIRY FARMS

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June 1979 No. 79-12

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Nearly level terrain, heavy soils, and impermeable subsoil horizons commonly cause poor drainage in Northern New York. Forty-five percent of the cropland in this region is classified as poorly drained (Lucey). The soils in this area dry slowly, consequently restricting the effective length of the growing season. Production of corn is marginal and the establishment of legume seedings is prevented by poor drainage. Poor drainage is only a single characteristic of a farm's soil resource, but it has multiple effects. Farm managers have adjusted to poor drainage by using grass hay crops as a forage base and by adopting other management practices which utilize land more extensively.

Improving drainage has multiple effects on the farming system. Installing a tile drainage system is just the first step. Full adaptation includes changes in input use, field operations, crop enterprises, feeding systems, and herd size. Consequently, the procedure used to evaluate the drainage improvement must compare optimally organized systems before and after the installation of tile. Neither comparing the actual current, not necessarily optimal, situation with an optimally organized tiled situation nor simply introducing tile into the current operation correctly evaluates the drainage improvement. The evaluation of a new technology must compare optimally organized states of fully integrated systems with and without the new technology.

The objective of this study was to determine the impact of tiling on Northern New York dairy farms with different resource bases and management strategies by comparing optimal combinations of enterprises before and after tiling.

METHODOLOGY

It is important that the conceptual model used in this analysis be able to portray the farming system with and without the new technology, integrating the technology into the system and changing the input-output relationships. Integration can occur in the economic, technical, administrative, ecological, and social spheres. The latter two, although important, were not directly considered by the model.

The model consisted of two sets of enterprise budgets--before and after tiling--and a linear program to determine the most profitable enterprise combinations. The program maximized returns to a given set of fixed resources. The budgets showed the first stage integration, the effects of tiling on the individual enterprises. Input and output levels were changed as a result of the improved drainage.

At the second stage of integration, farm organization was adjusted. Optimal combinations of enterprises, subject to resource availability and technical relationships among resources, inputs, and products, were obtained, using the input-output relationships embodied in the enterprise budgets. The results show how overall farm organization and management income were affected by tiling. Since resource base and management strategy were expected to influence the level of benefit derived from tiling, alternative resource bases and management levels were analyzed.

MODELING THE TECHNOLOGICAL CHANGE: THE EFFECTS AND COST OF TILING

Tile drainage produces a series of beneficial physical effects on the soil, including faster drying, greater stability of structure, faster heating in the spring, better aeration, and improved availability of several plant nutrients. The agricultural benefits derived are higher and more stable yields of better quality crops, new crop enterprise capabilities of the land, lower machinery costs, less risky crop production, and improved timeliness of field operations (Wesseling; Neenan, Milligan, and Swader).

These benefits were captured in various ways; the basic assumption of the study was that the installation of tile raised the soil drainage class as follows: poorly drained to moderately well drained; somewhat poorly drained to an intermediate between moderately well and well drained; and moderately well drained to well drained. The shift to a better drainage class resulted in higher yields, rotations allowing more corn, and hay crops containing larger quantities of legumes.

An annual cost of tiling was derived from the initial installation charges and the maintenance expenses. The actual cost of a drainage system depends on a large number of factors: installation method; kind of tile used; size of job; soil texture, particularly stoniness; design of system; and auxiliary work required, especially ditching for outlets. For the conditions assumed, installation costs were $556.05 per acre, with annual costs of $34.21 (Table 1). The assumed 50-foot spacing was sufficient for relatively poor drainage conditions.

THE REPRESENTATIVE FARM MODEL

Enterprise budgets were based on a synthetic firm model that represented a typical Northern New York dairy farm. The model had an 80-cow freestall barn, 200 acres of crops, and 75 acres suited only for pasture. Livestock budgets were constructed for three forage bases (all hay crop silage, 2/3 hay crop silage and 1/3 corn silage, and 1/3 hay crop silage and 2/3 corn silage); two hay crops--grass (G) and mixed mainly legume (MML); and three milk production levels--10, 13, and 16,000 pounds per year. Rations for each forage base and production level were constructed using a least-cost balanced dairy ration program (Smith and LaDue) with corn grain, soybean meal, minerals,

Table 1. Investment and Annual Costs of Tiling in Northern New York, 1977.[a]

Item	Investment Costs		
	Ft./A.	Cost/ft.	Cost/A.
Trenching, tile placement, and backfilling	916	$ .35	$320.60
Tubing: 4"	870	.23	200.10
6"	23	.50	11.50
8"	23	.95	21.85
Corrugated metal outlet pipe[b]	0.4	4.34	1.75
Animal guard, $5/block[b]			0.25
Total			$556.05
	Annual Costs		
Repairs (1 blowout/block-5yrs.)			$ 0.50
Labor, 0.1 hr./A.-yr. @ $3.50/hr.			0.35
Amortized investment			
Depreciation, 40 yrs.			13.90
Interest, 7% of average value			19.46
Total			$ 34.21

[a] The conditions and design features assumed in preparing these budgets are: gently sloping, slowly permeable and generally stone-free soil; large job size (i.e. more than 20,000 feet of tile); plastic tube supplied by contractor; installation with a trencher; 50-foot spacing; half of collector lines 6" in diameter and half 8"; 200 acres tiled in ten equal blocks, each with a collector line.

[b] One for each 20 acre block, converted to a per acre basis.

and the specified forage bases. Nutrient contents of the forages were tailored to Northern New York conditions. The crop enterprise budgets were constructed using standard economic engineering methods and agronomic recommendations. The budgets covered a range of yields relating to different drainage conditions of the soil (Table 2). For additional details of the construction procedure, see Knoblauch, Milligan, and Woodell.

The linear programming model used was developed by Nott and Harsh and adapted for use in New York State by Milligan and Knoblauch. In addition to the budget data, the program uses a variety of information about resources available, prices, and management practices. The values used in this study represent the Northern New York dairy farm and its economic environment in 1977.

The analysis consisted of a base situation, depicting a typical Northern New York dairy farm, and several variations in which certain attributes of the farm likely to affect the value of tiling were altered: initial drainage characteristics of the land; milk production level; and strategy for utilizing added crop production capacity. The increased productivity could be used in three ways: surpluses sold; corn grain grown; and/or herd size increased.

The base farm had an 80-cow freestall barn, a 13,000 pound herd average, and 200 crop acres--150 acres of somewhat poorly drained and 50 acres of moderately well drained land. Before tiling, the hay crop was grass, afterwards, the mixed-mainly-legume. The maximum amount of corn in the rotation changed with tiling in accordance with the change in drainage class. Yields for the different drainage classes are shown in Table 2.

RESULTS

The investment in drainage was profitable on the base farm. Management income was obtained by subtracting all fixed costs including the tiling

Table 2. Summary of Dairy Livestock and Crop Enterprise Budgets for Northern New York, 1977.[a]

Enterprise	Production Level	Forage Base	Selected Variable Expenses[b]	Annual Labor Required
			$	Hrs./Yr.
Dairy Cow	10,000 Lb./Yr.	2G/1CS[c]	208.58	50
		1MML/2CS	210.21	50
	13,000 "	G	232.15	57
		2G/1CS	236.83	57
		1MML/2CS	238.59	57
	16,000 "	2G/1CS	268.65	66
		1MML/2CS	269.88	66
Heifer		2G/1CS	141.84[d]	25
		1MML/2CS	143.23	25
	Yield	Drainage Class		
Grass Hay Crop Silage	1.2 T,HEq/A[e]	PD[f]	29.00	6.7
	2.1 "	SPD	33.00	7.4
	2.9 "	MWD	42.00	7.9
Mixed Mainly Legume Hay Crop Silage	3.7 T,HEq/A	MWD	55.00	8.2
	4.2 "	MW-WD	60.00	8.4
	4.6 "	WD	65.00	8.5
Corn Silage	10.2 T/A	SPD	66.00	8.0
	13.5 "	MWD	76.00	8.3
	15.0 "	MW-WD	78.00	8.4
	16.2 "	WD	81.00	8.5
Corn Grain	55 Bu./A	SPD	75.00	5.4
	75 "	MWD	88.00	5.6
	83 "	MW-WD	89.00	5.7
	90 "	WD	93.00	5.8

[a] 1977 prices used.

[b] All variable expenses except labor, forages, corn grain, and soy meal.

[c] G=grass haylage; MML=mixed mainly legume haylage; 2G/1CS is a mixture of 2 parts grass and 1 part corn silage, on a dry matter basis, other mixtures are similarly defined.

[d] Birth to freshening (28 months). Heifers are always fed the ration with maximum corn silage.

[e] Tons, hay equivalent per acre.

[f] PD=poorly drained, SPD=somewhat poorly drained, MWD=moderately well drained, WD=well drained, MW-WD=an intermediate between MWD and WD.

from the return over variable expenses. Management income on the base farm rose from -$31,403 to -$17,406, an increase of $13,997 (Table 3). The negative management income resulted from several factors including valuing all resources and investments at their current prices new or opportunity costs; conservative budgeting procedures; and inclusion of all cash costs and all labor, including the operator's; and from leaving out speculative income. Although startling, this probably is not uncommon when procedures accounting all costs and returns at current new values are used.

In the base situation, herd size remained at the maximum of 80 cows before and after tiling. The rations contained the maximum amounts of corn silage allowed, 33 percent of the forage before and 67 percent after tiling. There was a shift of 24 acres from hay crop silage to corn silage. Only on the better drained land (type I) was the maximum permissible corn acreage in the rotation used. The changes in ration and cropping pattern resulted in a change from hay purchases of 58 tons to hay sales of 280 tons and a decline in corn grain purchases of 2,635 bushels. These adjustments increased labor use by 156 hours, or about 2 percent.

Shadow prices show the value of an additional cow or acre of land. The return to fixed factors of an additional cow increased by $138, from $128 to $266. The marginal value of additional land also increased, with the value of the more poorly drained land increasing relatively more.

A partial budget of the changes in income showed an increase in crop expenses of $5,380, due to the larger corn silage acreages and higher input usage in all crops, a slight increase in variable expenses for livestock, and a decline in feed expenses of $10,992 (Table 4). The feed expense decline was composed of $7,352 due to smaller corn grain purchases and $3,488

Table 3. Summaries of the Farm Organization Information from the Dairy Linear Program for the Base and Alternative Situations.

	Base			Poorer Drainage (PD)			Better Drainage (BD)		
	Before	After	Change	Before	After	Change	Before	After	Change
Management Income	-31,403	-17,406	13,997	-39,372	-20,211	19,161	-27,916	-15,997	11,919
Internal Rate of Return			18.6			23.2			16.7
Enterprises									
Dairy: herd size	80	80	0	80	80	0	80	80	0
% hay in ration	67	33	-34	93	33	-60	67	33	-34
Haylage, A: I	25	17	-8	31	19	-12	143	132	-11
II	128	112	-16	150	103	-47	0	0	0
Corn Silage, A: I	25	33	8	19	31	12	57	68	11
II	22	38	16	0	47	47	0	0	0
Feed Purchases									
Hay, T	58	0	-58	211	0	-211	0	0	0
Corn Grain, bu.	6,413	3,778	-2,635	7,555	3,778	-3,777	6,413	3,778	-2,635
Soy Oil Meal, T	50	49	-1	42	49	7	50	49	-1
Feed Sales									
Hay, T	0	280	280	0	209	209	0	326	326
Corn Silage, T	0	0	0	0	0	0	182	0	-182
Labor									
Annual, hrs.	6,734	6,890	156	6,590	6,859	269	6,806	6,904	98
Shadow Prices									
Cow	128	266	138	103	264	161	175	266	91
Type I land	75	108	33	78	97	19	51	108	57
Type II land	42	95	53	5	79	74	0	0	0

	Low Milk Production (LMP)			High Milk Production (HMP)			Corn Grain (CG)			Variable Herd Size (VHS)		
	Before	After	Change	Before	After	Change	Before	After	Change	Before	After	Change
Management Income	-42,441	-28,483	13,958	-20,616	-7,161	13,455	-32,147	-18,002	14,145	-28,568	-23,929	4,639
Internal Rate of Return			18.1			18.1			18.7			
Enterprises												
Dairy: herd size	66	80	14	80	80	0	80	80	0	69	135	66
% hay in ration	67	33	-34	67	33	-34	67	33	-34	67	33	-34
Haylage, A: I	25	17	-8	25	17	-8	25	17	-8	25	22	-3
II	136	110	-26	131	116	-15	94	63	-31	136	56	-80
Corn Silage, A: I	25	33	8	25	33	8	0	0	0	25	28	3
II	14	40	26	19	34	15	55	73	18	14	94	80
Corn Grain, A: I	0	0	0	0	0	0	25	33	8	0	0	0
II	0	0	0	0	0	0	1	14	13	0	0	0
Feed Purchases												
Hay, T	0	0	0	39	0	-39	116	0	-116	0	0	0
Corn Grain, bu.	3,940	2,180	-1,760	8,078	5,583	-2,495	4,642	0	-4,642	5,532	6,385	853
Soy Oil Meal, T	28	34	6	66	65	-1	50	49	-1	43	83	40
Feed Sales												
Hay, T	0	267	267	0	298	298	0	114	114	0	0	0
Labor												
Annual, hrs.	5,346	6,326	974	7,454	7,614	160	6,682	6,761	79	6,011	10,472	4,461
Shadow Prices												
Cow	0	120	120	263	394	131	125	270	145	0	0	0
Type I land	66	108	42	75	108	33	84	108	24	129	299	170
Type II land	36	95	59	42	95	53	47	95	48	82	272	190

Table 4. Disaggregation of Changes in Income After Tiling: The Base Farm.

Item	Cost
Added Costs:	
Labor: 156 hours @ $3.50	$ 546.00
Dairy Variable Expenses: 80 cows @ $1.76	140.80
Heifer Variable Expenses: 24 heifers @ $1.39	33.36
Haylage: I (17A @ $65) - (25A @ $42)	55.00
II (112.38A @ $60) - (128.16A @ $33)	2,513.52
Silage: I (33.0A @ $81) - (25A @ $76)	773.00
II (37.62A @ $78) - (21.84A @ $66)	1,492.92
	$ 5,554.60
Reduced Costs:	
Hay Purchases: 58.13T @ $60	$ 3,487.80
Corn Grain Purchases: 2635.03 bu. @ $2.79	7,351.73
Soy Oil Meal Purchases: 0.76T @ $200	152.00
	$10,991.53
Added Benefits:	
Hay Sales: 280.08T @ $55	$15,404.40
Change Income Due to:	
Change in Crop Expenses and Labor	$-5,380.44
Change in Livestock and Feed Costs	10,817.37
Increased Production	15,404.40
Total Change	$20,841.33[a]
Present Value of the Increase in Income Over 40 Years @ 7%	$276,517.00
Tile Installation Costs	111,210.00
Net Benefit from Drainage	165,307.00
Internal Rate of Return on Investment in Tiling	18.6%

[a] Figures do not agree exactly with those presented in other tables because of rounding.

due to elimination of hay purchases. The net reduction in livestock and feed costs was $10,817. An additional income source was hay sales of $15,404. The value of the increased output exceeded the value of the added inputs. The increase in income, without deducting tiling costs, was $20,841. The net present value of an annual stream of income of this size over 40 years at 7 percent interest is $276,517, which is the potential benefit of tiling. In this case, tiling the farm cost $111,210, leaving a net benefit of $165,307. The internal rate of return on tiling was 18.6 percent.

The Effects of Initial Drainage Characteristics

The effect of the severity of the drainage problem prior to tiling was investigated via three analyses. The base had 150 acres of somewhat poorly drained and 50 acres of moderately well drained soil. The poorer drainage situation was assumed to have 150 acres of poorly drained and 50 acres of somewhat poorly drained soil while the better drainage situation had 200 acres of moderately well drained soil. The drainage classes after tiling were as described earlier. Income increased $19,161 for poorer drainage, $13,997 in the base, and $11,919 with better drainage (Table 3). Yield improvements declined as the pre-tiling drainage class improved (Table 2); hay crop yields rose 2.5 tons when starting with poorly drained and 1.7 tons with moderately well drained land. With poorer drainage, greater adjustments in forage composition and corn grain content of the ration occurred because the area of corn land available before tiling was restricting. Also, the reduction in hay purchases was greater. At high production, no hay was purchased before tiling, eliminating one of the major sources of benefit. As can be seen in the budgets, the reduction in per ton cost of production due to tiling diminished as the initial drainage status of the land improved.

The effect of tiling on cow shadow prices also showed diminishing benefits with higher yield levels. With poorer drainage the increase was $161 while with the better initial drainage it was only $91. Tiling added more to the profitability of the marginal cow when the initial drainage condition was relatively worse.

Effect of Milk Production Levels

Since most of the crops were fed to dairy livestock, the level of milk production of the herd was hypothesized to influence the value of tiling. This hypothesis was rejected as the value of tiling was essentially unchanged when milk production was altered (Table 3). The only adjustment was that at low production 66 cows were included in the most profitable plan prior to tiling since gross returns would not have been sufficient to cover variable costs if roughage had been purchased.

Effect of Additional Management Options

In the base analysis, forage production exceeded the requirements of the herd after tiling, resulting in hay sales. This excess production capacity could be used to grow corn for grain or to support expansion of the dairy herd. Two analyses considered these options. In the first, a corn grain enterprise was added to the crop options and in the second, the maximum herd size was set at a level that utilizes all forage produced on the farm. At the price levels assumed, neither strategy was a good alternative to selling hay, due to the incurred fixed costs. However, the effects of alternative management strategies on farm organization were shown.

When a corn grain enterprise was added, returns over variable expenses increased by $384; however, this increase is much less than the $980 annual fixed cost of the snapper head needed for harvest. As was expected, hay acreage declined while corn acreage increased, compared to the base. Corn silage was grown only on the poorer land, which would increase risk, especially before tiling. Because of the larger corn area, hay purchases increased before tiling and hay sales decreased afterwards, compared to the base.

The primary objective of the variable herd size analysis was to determine how many more cows could be supported by on-farm forage production after tiling. The exogenous limit to herd size, 80 cows, was removed, but forage purchasing was not allowed. The herd size which maximized returns over variable costs increased by 66 cows from 69 to 135. Because of the allocation of all costs and the use of current prices of investments, total costs of additional cows exceeded total returns. Consequently, the expansion had a smaller change in management income than the base situation. The increase in cow numbers resulted in a large shift of land, 83 acres, out of hay into corn silage and large increases in labor and soybean meal purchases. In the variable herd size situation, additional land would have allowed for additional cows; consequently, the shadow price or added return to fixed factors of an additional acre was larger than in the base situation. On the better drained land it rose from \$129 to \$299 per acre compared to \$75 and \$108 per acre in the base situation. Feeding hay was more profitable than selling it, in terms of return to fixed factors.

The price relationships assumed made selling hay the economically preferable use of the increased crop productivity when fixed, as well as variable, costs were included. Nevertheless, substantial changes in the operations and organization of the farm became technically feasible. In different economic environments with different prices, these adjustments could become profitable. Tiling allowed the farm to become corn grain self-sufficient--a desirable feature in periods of high grain prices. Tiling also nearly doubled the forage-based carrying capacity of the land. The decision to increase herd size depends on the capital costs of expansion as well as the variable costs, however, the changes in technical feasibility are significant and do allow response to economic conditions which favor expansion.

CONCLUSIONS

Economic analysis of a technological change should be based on a comparison of optimally organized systems with and without the technological change. This procedure was utilized to evaluate the profitability of investments in tile drainage in Northern New York. The comparison was carried out by determining the most profitable combinations of enterprises on synthetic farms representative of dairy farms in Northern New York before and after tiling.

In all situations considered, the investment in tiling proved to be profitable. For the base scenario of 80 cows and 200 acres of fairly poorly drained land, management income increased $13,997 after all additional costs of the tile investment were paid, due to the increased productivity of the land. The profitability of the investment in tiling was greater when the initial drainage was poorer than the base and smaller when the initial drainage was better. With constant herd size, milk production per cow exhibited little effect on returns to tiling. Although neither was profitable under the specified circumstances, the investment in tiling increased the manager's flexibility to add cows or a corn grain enterprise.

The monetary benefits of the investment came from several interlocking changes in the farm organization. The two most important were the change in the hay crop from grass to mixed mainly legume (allowing an increased proportion of corn silage in the ration) and the shift from a deficit to a surplus in forage production. After tiling acreages of corn were nearly doubled, fertilizer, fuel, labor, and other input usage were reorganized and in general increased.

Although tiling was an expensive investment, it did have substantial returns when the management made the proper adjustments to take full advantage of the new opportunities. The increase in returns for the synthetic farms were roughly three times the annual costs of the investment in tile drainage.

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