Agribusiness & Applied Economics Report No. 685 **August 2011**

Managing the Economics of Soil Salinity

Joleen C. Hadrich

Department of Agribusiness and Applied Economics
Agricultural Experiment Station
North Dakota State University
Fargo, North Dakota 58108

Acknowledgements

The author would like to thank Dr. Frayne Olson and Dr. Ryan Larsen for their constructive comments regarding earlier versions of this paper and Dr. Tom Desutter for his guidance regarding the technicalities of salinity in the Red River Valley.

Please address your inquiries regarding this publication to: Department of Agribusiness & Applied Economics, P.O. Box 6050, Fargo, ND, 58108-6050, Phone: 701-231-7441, Fax: 701-231-7400, Email: ndsu.agribusiness@ndsu.edu. This publication is also available electronically at this web site: http://agecon.lib.umn.edu/.

TABLE OF CONTENTS

LIST OF TABLES

Abstract

Saline soils result in decreased crop growth and yield with the potential for losing productive farm land. Enterprise budget analysis was extended to include the fixed costs of installing tile drainage to manage soil salinity in the Red River Valley of North Dakota for corn, soybeans, wheat, sugar beets, and barley. Installing tile drainage to manage soil salinity decreased per acre crop profitability from 19-49% due to the large upfront capital investment of tile drainage. These losses can be decreased to zero with more consistent and predictable yields from tile drainage in the intermediate to long run. With no salinity management lost revenues were estimated to be $150 million due to 1.2 million acres of slightly saline soils and 275,000 acres of moderate soil salinity.

Managing the Economics of Soil Salinity

Soil salinity is a serious environmental and resource management problem for crop producers in the Northern Great Plains. Saline soils result in decreased crop growth and yield with the potential for loss of productive crop land. These issues are further magnified with increased rainfall and more persistent wet cycles, which is the case in the Red River Valley (RRV) of North Dakota. The political profile of salinity in the Northern Great Plains is not at the level of Australia where salinity continues to worsen even with the intense use of major government programs (Pannell). Farmers in the Northern Great Plains and the RRV, have the opportunity to manage soil salinity through tile drainage or crop rotation schedules incorporating more saline tolerant crops. However, there is limited research analyzing the economics of soil salinity management techniques. This analysis estimates investment costs of tile drainage and incorporates it in an enterprise budget framework to determine the effects on per acre profitability across common crop enterprises in the RRV. The analysis is further extended to evaluate the economic cost of soil salinity due to lost crop production in the RRV.

Soil Salinity Management

Soil salinity results in lower crop growth and yields since the excess salts in the soil interfere with the uptake of nutrients needed by the plant in the crop root zone. Yield reductions have been reported up to 50% in moderate to high saline soils (Kandel). In the most severe cases, crop production is no longer feasible. However, these yield losses can be reduced to zero with proper saline soil management. Saline soils are typically predominant in areas with shallow ground water tables (less than six feet below the surface) and salt redistribution, which is common in the RRV (Franzen). Other factors causing saline soils include land use practices and rainfall patterns (USDA-ARS). Adding to the shallow ground water of the RRV is the fact that RRV has experienced a wet cycle since the late 1990s with record flooding in 1997 and 2009. The Red River has also experienced near record river levels in 2010 and 2011, with record rainfall in 2011. This translates to even higher water tables, delays in planting, and increased focus on salinity management.

Crop managers must manage the flow of saline water in the crop root zone to limit crop growth and yield decreases. Three options exist: investing in tile drainage, crop selection based on saline tolerance levels, or do nothing and have less productive land. The simplest solution for saline soil management is installing tile drainage. Tile drainage allows the salt to be carried away from the field through tile lines and into natural waterways or drainage canals. By removing the salt, crop managers have more consistent and higher crop yields than without tile drainage. Wiersma et al. evaluated yield response to tile drainage on wheat, soybeans, and sugar beets in Northwest Minnesota. The results showed that adopting tile drainage resulted in yield increases for wheat (5-10 bu/acre), soybeans (1-6 bu/acre), and sugar beets (0.7-3.8 T/acre). Additional yield benefits include earlier planting, better utilization of water for stand establishment and growth as well as reduced plant stress. Cost benefits include reduced wear and tear on equipment due to limited operation in mud and wet conditions and more predictable and consistent yields to allow for more efficient use of limited resources. However, tile drainage requires a large upfront capital investment which depends on regional soil type, depth and spacing of tile, and land characteristics.

If tile drainage is not economically feasible, crop rotations may be a more likely solution since each crop has a maximum tolerance for salts before a yield loss is recognized. A study completed in Australia found that enterprise substitution in saline soils changed the enterprise combination and economic surplus within non-saline soil acres (Marshall and Jones). In the RRV, barley is a saline tolerant crop with minimal to non-existent yield losses when planted in saline soil. On the other spectrum, corn is a saline sensitive crop with yield losses ranging up to 50% on moderate to highly saline soils (Kandel). A feasible management option would be planting barley rather than corn, but in the last 10 years, corn acreage has increased by 73.1% in the RRV (USDA-NASS, 2000; 2010). Crop rotations to more saline tolerant crops are of increasing management importance due to the increased acreage of lower salt tolerant crops (ie. corn) in the RRV and two decades of higher than average precipitation (Anderson, Zimmerman, and Ulmer).

The third option for saline soil management is to do nothing and have less productive land. This is not a long-term feasible option since failure to manage saline soil will result in loss of crop production land, and with land as a limited resource this would not be advised.

Enterprise Budget Model

Crop producers maximize profit subject to their budget constraint, land quality, and environmental sustainability. Profit is typically estimated on a per acre basis using crop enterprise budgets. The per acre profit function is calculated as:

$$(1)\quad \pi_i = p_i y_i - vc_i - fc_i ,$$

where p_i is the commodity selling price for crop i, y_i is the per acre yield for crop i, vc_i is the variable cost of producing crop i, and fc_i is the fixed cost of producing crop i. Variable costs of crop production include: seed, herbicides, fungicides, insecticides, fertilizer, crop insurance, fuel and lubrication, repairs, drying expenses, miscellaneous expenses, and operating interest. Fixed costs include miscellaneous overhead, machinery deprecation, machinery investment, and a land charge[1].

Whole farm profit is maximized by summing individual profit from each cropping enterprise. Total whole farm profit is calculated as:

$$(2)\quad \Pi = \sum_{i=1}^{n} \pi_i A_i ,$$

where π_i is the per acre profit for crop i and A_i is the number of acres planted in crop i.

Model Assumptions and Parameters

An enterprise budget analysis was used to evaluate the profitability of adopting tile drainage to manage soil salinity on crop farms in the RRV of North Dakota. The RRV consists of nine counties, Cass, Grand Forks, Pembina, Ransom, Richland, Sargent, Steel, Traill, and

Walsh which cover 6.2 million acres of farmland[2]. The top four crops grown in this region include corn, soybeans, sugar beets, and wheat on 3.9 million acres. Soybeans, sugar beets, and wheat are moderately tolerant to saline whereas corn is a saline sensitive crop. It is estimated that 1.2 million acres in the RRV are classified as slightly saline and 275,000 acres are moderately saline. In both of these scenarios crop yield is diminished.

Projected crop enterprise budgets are compiled on an annual basis by the NDSU Extension Service based on nine production regions (Swenson and Haugen, 2010a, 2010b). The projected budgets consider full economic opportunity costs for land and machinery investment regardless of the farm operator equity position. The estimated profit is the return to unpaid labor and management on a per acre basis[3]. The primary cost assumptions used by Swenson and Haugen are included in Appendix 1. Production costs and yield vary by production region. This is especially important for the RRV since yields can vary greatly from northern North Dakota to southern North Dakota. For example, corn in the Northern RRV (NRRV) has a return to labor and management of $81.26/acre compared to the Southern RRV (SRRV) with $107.87/acre. Much of this difference is due to the growing season difference between the two regions and its effects on planting and subsequently yield.

As stated previously, tile drainage is a significant financial investment. A custom rate survey distributed by North Dakota State University (NDSU) extension found tile drainage costs ranged from $400-800/acre with and average charge of $576/acre (Aakre). The NDSU projected crop budgets use full economic costs—which include investment costs for machinery. This analysis extended the NDSU projected budgets to incorporate tile drainage investment costs in the NRRV and SRRV. It was assumed that the investment cost was $576/acre with a useful life of 25 years. The salvage value at the end of the useful life was assumed to be zero.

Results

The return to unpaid labor and management with tile drainage (Table 1) is reported for corn, soybeans, wheat, sugar beets, and barley. Barley was included in this analysis to determine the amount of acreage in the RRV devoted to a saline tolerant crop. Spreading the cost of the tile drainage investment over its useful life of 25 years allowed us to incorporate it into annual crop enterprise budgets. Tile drainage depreciation[4] was calculated at $23.04/acre. The tile drainage investment cost captures the cost of borrowing by accounting for the interest on the investment. The average investment[5] for tile drainage was calculated as $288/acre. This was converted to an annual basis by dividing the $288/acre by the useful life of the drainage tile (25 years) and multiplied by the nominal interest rate (6.5%) to result in an annual investment cost of $0.75/acre. The additional fixed cost for tile drainage was $23.79/acre. This value does not change as a function of the crop grown. Tile drainage was approximately 20% of total fixed costs for corn, wheat, soybeans, and barley. It was only 10% of total fixed costs for sugar beets due to high machinery depreciation associated with sugar beet production.

Table 1. Crop Budgets with Drainage Tile

	Corn		Wheat		Barley		Soybeans		Sugar Beets
Crop	NRRV	SVV	NRRV	SVV	NRRV	SVV	NRRV	SVV	RRV
Market Yield	113	130	49	50	63	68	30	33	19.88
Market Price	4.33	4.42	7.18	7.25	4.83	4.87	11.52	11.62	39.6
Total Revenue	***489.29***	***574.6***	***351.82***	***362.5***	***304.29***	***331.16***	***345.6***	***383.46***	***787.24***
Variable Costs									
Seed	71.63	82.77	22.00	22.00	15.00	15.00	51.63	51.63	136.61
Herbicides	14.50	18.00	19.00	19.00	16.00	16.00	14.50	18.00	49.86
Fungicides	0.00	0.00	5.50	5.50	1.50	1.50	0.00	0.00	0.00
Insecticides	0.00	0.00	0.00	0.00	0.00	0.00	7.00	7.00	0.00
Fertilizer	87.98	107.55	73.95	78.20	55.35	63.36	0.22	3.6	98.49
Crop Insurance	31.60	27.10	15.70	13.50	10.50	9.10	13.70	13.70	20.86
Fuel and Lubrication	28.31	29.40	19.69	19.75	22.03	22.37	16.45	16.65	54.92
Repairs	19.75	20.14	16.40	16.43	17.58	17.7	15.78	15.85	92.37
Drying	22.60	26.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miscellaneous	6.50	6.50	6.50	6.50	6.50	6.50	3.50	3.50	2.89
Operating Interest	7.08	7.94	4.47	4.52	3.61	3.79	3.07	3.25	9.42
Total Variable Costs	289.95	325.4	183.21	185.4	148.07	155.32	125.85	133.18	465.42
Fixed Costs									
Misc. Overhead	8.85	9.11	6.76	6.77	7.22	7.30	6.40	6.45	5.80
Machinery Depreciation	27.73	28.44	18.64	18.69	20.27	20.49	17.71	17.84	86.55
Machinery Investment	16.30	16.68	11.04	11.07	12.14	12.26	10.42	10.49	6.97
Tile Drainage Depreciation	23.04	23.04	23.04	23.04	23.04	23.04	23.04	23.04	23.04
Tile Drainage Investment	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Land Charge	65.20	87.10	65.20	87.10	65.20	87.10	65.20	87.10	115.00
Total Fixed Costs	141.87	165.12	125.43	147.42	128.62	150.94	123.52	145.67	238.11
Total Costs	***431.82***	***490.52***	***308.64***	***332.82***	***276.69***	***306.26***	***249.37***	***278.85***	***703.53***
Return to Unpaid Labor & Mgmt	**57.47**	**84.08**	**43.18**	**29.68**	**27.6**	**24.9**	**96.23**	**104.61**	**83.72**
Payback Period (years)	10.02	6.85	13.34	19.41	20.87	23.13	5.99	5.51	6.88

Investing in tile drainage decreased the return to unpaid labor and management (profit) for all crops. Profit decreases ranged from 20% for soybeans up to 36-44% for wheat. Barley, a saline tolerant crop, had the largest profit loss (49%). This is due to the low per acre profit of barley compared to other commodities in the RRV. This low profit level is likely the reason why barley acreage is low in the RRV. Even with a 10% yield loss, corn has a similar profit level as barley. The interaction between price and yield plays an important role in crop enterprise combinations. With recent high commodity prices, it may be difficult to rationalize switching more profitable acreage with potential yield losses due to salinity to barley.

The payback period[6] was calculated for each crop to determine the amount of time it would take for the return on the investment in tile drainage to "repay" the sum of the original investment. The payback period is a function of the investment of tile drainage and return to unpaid labor and management. Therefore, in years when there are a high commodity prices, the return to unpaid labor and management will be higher, resulting in a quicker payback period, as is the case for soybeans and sugar beets. The opposite holds for wheat and corn. In the past few years, commodity prices have been volatile. For example, wheat in this model has been valued between $7.18-7.25/bu, but recently has been selling at above $8/bu. This small change would make the payback period for wheat around eight years, which would make tile drainage a more attractive investment compared to $7.00/bu wheat. The difficulty in making this decision is tile drainage is a 25 year investment, and the probability commodity prices will continue to be high over that time period is not likely. Therefore, producers must critically evaluate this trade-off between commodity prices and the life of the investment when using the payback period.

Similarly with prices, small yield fluctuations directly influence the economic feasibility of adopting tile drainage. Since the payback period varies by commodity, a producer may choose to install tile drainage in certain fields for a specific crop rotation. Corn is the most saline sensitive crop in the RRV, and corn acreage continues to increase each year. Delayed planting due to wet conditions decreases corn yield potential, and in some cases results in crop producers harvesting corn grain as corn silage at a sizable loss. At the current prices, corn yield would need to increase by approximately 5.5 bu/acre to capture the additional fixed costs of tile drainage. Similarly, wheat yield would need to increase by 3.3 bu/ace and soybean by 2 bu/acre. If a producer can recognize yield benefits with tile drainage up to these levels on an annual basis, holding all else constant, they would be able to justify the adoption of tile drainage. Due to price and yield variations, tile drainage investment will always be a site specific decision based on economic profits, which is why enterprise budgets are an ideal analytical tool.

The crop enterprise budgets presented in Table 1. do not consider potential crop yield losses due to salinity. It is estimated that 1.2 million acres in the RRV are classified as slightly saline soils and 275,000 acres are moderately saline. It is assumed that slightly saline soils result in a 15% yield loss, and moderately saline soils have a 50% yield loss. The saline acreage was allocated in the nine RRV counties as a percentage of the total acreage in the nine county region (Table 2). Once the saline acreage was allocated at a county level, it was distributed within the county as a weighted average of the four crops grown (corn, soybeans, wheat, and sugar beets) in the county (Table 3). Selling prices, variable costs, and fixed costs were held constant from the previous analysis (Table 1). Production losses (yield) are presented in Table 4. Overall, there is an 8.15% loss in production across the four crops. Using the projected commodity prices presented in Table 1, the lost revenue due to the two yield losses is $48,076,578 for corn, $33,580,614 for wheat, $57,991,677 for soybeans, and $10,682,871 for sugar beets. The total lost crop revenue in the RRV is approximately $150 million. Installing tile drainage could decrease these lost revenues to zero within six years of adoption due to yield increases (Fore, Kandel). This loss only considers lost revenue, but the lost production levels will directly affect the food supply indicating the importance of managing saline soil before land has to be taken out of the production cycle.

Table 2. County Level Saline Soil Distribution

County	Total Crop Acres	Acres in top 5 Crops	% Acres in County	Slightly Saline Acres[1]	Moderately Saline[2]
Pembina	649,281	396,000	10	121,956	27,948
Walsh	795,415	341,600	9	105,202	24,109
Grand Forks	825,552	428,000	11	131,811	30,207
Steel	401,959	297,200	8	91,528	20,975
Traill	543,650	405,500	10	124,881	28,619
Cass	1,038,930	898,800	23	276,802	63,434
Richland	905,922	639,600	16	196,977	45,141
Ransom	527,276	213,000	5	65,597	15,033
Sargent	505,015	276,800	7	85,246	19,535
Total	**6,193,000**	**3,896,500**	**100**	**1,200,000**	**275,000**

[1] Slightly Saline Acres = Acres in top 5 crops * % acres in county
[2] Moderately Saline Acres = Acres in top 5 crops * % acres in county

Table 3. Saline Soil Distribution Across Crops at the RRV of ND County Level

County	Slightly Saline	Moderately Saline	Corn	Wheat	Barley	Soybeans	Sugar beets
	Acres				%		
Pembina	121,956	27,948	5	55	0	25	16
Walsh	105,202	24,109	9	63	3	21	4
Grand Forks	131,811	30,207	21	45	2	32	0
Steel	91,528	20,975	26	25	0	49	0
Traill	124,881	28,619	24	22	0	47	7
Cass	276,802	63,434	26	13	1	58	2
Richland	196,977	45,141	36	11	0	49	5
Ransom	65,597	15,033	31	19	0	50	0
Sargent	85,246	19,535	34	13	0	53	0
Total	1,200,000	275,000	24	27	7	44	4

Table 4. Production Losses Due to Slightly and Moderate Saline Soils in the RRV of ND

Soil Type	Corn (bu)	Wheat (bu)	Soybeans (bu)	Sugar Beets (T)
No Saline	82,956,805	35,325,748	38,062,761	2,057,470
Slightly Saline	34,943,606	14,880,142	16,033,044	866,661
Moderately Saline	4,710,535	2,005,901	2,161,317	116,829
Total Production	122,610,946	52,211,791	56,257,122	3,040,961
Previous Production	133,488,000	56,843,600	61,247,800	3,310,730

Conclusion

Farm managers must efficiently manage land resources to be economically sustainable while jointly maximizing profit. As corn acreage continues to expand into the Northern Great Plains, salinity management will continue to become a top priority for crop producers. The simplest solution to manage soil salinity is installing tile drainage, which requires a large capital investment. Many times cost-share programs exist to provide an economic incentive to adopt capital intensive investments to promote environmental sustainability. Salinity management would fit in this category, but such programs currently do not exist. Australia is an example where soil salinity continues to be a major issue, even though numerous government programs exist (Pannell). Learning from Australia's experience with salinity it is important to be proactive before the problem becomes too severe. This is especially important in the RRV which has some of the most fertile land in the U.S. Losing this land due to improper salinity management could cause a potential issue with food supply in the future as well as future economic losses to farmers and the state.

Extensions of this analysis can be used to begin evaluating the economic trade-off of crop rotations as a function of soil salinity at a field level using linear programming. Secondly, a linear programming model can be used to evaluate the trade-off between enterprise combinations with and without tile drainage adoption in various saline soils.

Footnotes

[1] It is important to note that the profit estimated in equation (1) is the return to unpaid labor and management for the purposes of this research.
[2]The Red River Valley is also in Minnesota. This analysis is only applied to the Red River Valley of North Dakota.
[3] The terms “profit” and “return to unpaid labor and management” will be used synonymously throughout the paper.
[4] Depreciation = ((Purchase price-salvage value)/Useful life
[5] Average Investment = ((Purchase Price + Salvage Value)/2
[6] Payback Period = Investment/Return to Labor and Management

References

Aakre, D. 2011. "Custom Farm Work Rates, on North Dakota Farms, 2010, by North Dakota Farming Regions." *North Dakota State University Extension Service.* EC-499(revised).

Anderson, K., D. Zimmerman, and M. Ulmer. "Development and Application of Salinity Risk Index for Soils of the Red River Valley of the North (MLRA 56)." Paper presented at *ASA, CSSA, and SSA International Meetings*, Oct. 31-Nov. 4, Long Beach, CA, 2010. Available at: http://a-c-s.confex.com/crops/2010am/webprogram/Session7241.html

Fore, Z. 2003. "Tile Drainage: Research Results, Economics, and Where do we go from Here?" *University of Minnesota Extension Service.* Available at: http://www.soybeans.umn.edu/pdfs/regional/nw/Tile%20Drainage%20Research%20Results%20and%20Economics.pdf

Franzen, D. 2007. "Managing Saline Soils in North Dakota." *North Dakota State University Extension Service*, SF-1087. Available at: http://www.ag.ndsu.edu/pubs/plantsci/soilfert/sf1087.pdf

Kandel, H. 2011. Personal Communication, Extension Agronomist Broadleaf Crops, North Dakota State University.

Pannell, D.J. 2001. "Dryland salinity: economic, scientific, social, and policy dimensions." *The Australian Journal of Agricultural and Resource Economics*. 45(4):517-546.

Marshall, G.R., and R.E. Jones. 1997. "Significance of Supply Response for Estimating Agricultural Costs of Soil Salinity." *Agricultural Systems.* 53:231-252.

Swenson, A., and R. Haugen. 2010a."Projected 2011 Crop Budgets South Valley North Dakota." *Farm Management Planning Guide. North Dakota State University Extension Service.* . Available at: http://www.ag.ndsu.edu/farmmanagement/documents/sv2011redo.pdf

Swenson, A., and R. Haugen. 2010b."Projected 2011 Crop Budgets North Valley North Dakota." *Farm Management Planning Guide. North Dakota State University Extension Service.* . Available at: http://www.ag.ndsu.edu/farmmanagement/documents/nv2011redo.pdf

United States Department of Agriculture-Agricultural Research Services (USDA-ARS). "Frequently asked questions about salinity." Accessed May 1, 2011. Available at: http://www.ars.usda.gov/Aboutus/docs.htm?docid=10201&page=6.

United States Department of Agriculture-National Agricultural Statistics Services (USDA-NASS), 2000, "North Dakota Agricultural Statistics 2000", *Agricultural Statistics Report No 69.*

United States Department of Agriculture-National Agricultural Statistics Services (USDA-NASS), 2010, “North Dakota Agricultural Statistics 2010”, *Agricultural Statistics Report No 79.*

Wiersma, J.J., G. R. Sands, H. J. Kandel, A. K. Rendahl, C. X. Jin, and B. J. Hansen. 2010. Responses of Spring Wheat and Soybean to Subsurface Drainage in Northwest Minnesota. *Agron. J.* 102:1399-1406.

Appendix 1. Projected Budget Assumptions

Enterprise Budget Item	Assumption
Market Price	Best estimates of NDSU Extension Economists.
Market Yields	• 7 year average (2003-2009) after the low and high yield years are removed.
Fertilizer	• Cost of fertilizer applied based on soil test to meet yield goal of 130% market yield.
Soil test	• Nitrogen = 30 lb, Phosphorus = 10 ppm, Potassium = 278 ppm
Fertilizer prices	• Nitrogen = $0.48/lb., Phosphorus = $0.56/lb, Potassium = $0.46/lb
Seed Prices	• Spring Wheat = $11.00/bu, Barley = $7.50/bu, Corn grain = $2.15/thou.kernel, Soybean = $0.29/thou.kernel
Fuel Prices	• Diesel = $3.00/gal, Fuel = $3.00/gal
Lubrication charge	• 15% of fuel cost
Crop Insurance	• Coverage levels are 70% on all insurable crops. Yield protection or APH insurance estimates are used, except for Revenue Protection on wheat, corn, and soybeans.
Miscellaneous	• Soil testing, machinery rent and custom work.
Operating insurance	• Direct costs charged 5.0% interest for a 6 month period.
Misc. Overhead	• Machinery housing and insurance at 0.5% and 0.85%, respectively, of average machinery investments. General farm utilities, farm publications, meetings, dues, income tax preparation, and legal fees are estimated at $3/acre.
Land charge	• Average cash rent.
Machinery investment	• 6.5% nominal interest rate is charged on average machinery investment, where Average machinery investment = (Purchase price + disposal price)/2
Depreciation	• Depreciation = (Purchase price – disposal cost)/years of ownership

**Assumptions taken directly from Farm Management Planning Guides –Projected Crop Budgets*