Economics of a Wetland-Reservoir Subirrigation System in Northwestern Ohio

Steven T. Richards, Marvin T. Batte, Larry C. Brown, Bernie J. Czartoski, Norman R. Fausey, and H.W. Belcher[1]

Department of Agricultural, Environmental and Development Economics
The Ohio State University

May 6, 1999

Corresponding Author: Marvin T. Batte
2120 Fyffe Rd.
Columbus, OH 43210-1067
Phone: 614-292-6406
e-mail: batte.1@osu.edu

Paper presented at the American Agricultural Economics Association annual meeting, August 8-11, 1999 in Nashville, Tennessee.

Keywords: Economic Analysis, Wetlands, Subirrigation, Net Present Value Model

[1]Farm Business Management Specialist, Wyoming and Erie Counties, Cornell University and former Graduate Research Associate, Department Agricultural, Environmental, and Development Economics, The Ohio State University; Fred N. VanBuren Professor of Farm Management, Department Agricultural, Environmental, and Development Economics, The Ohio State University; Associate Professor, Extension Agricultural Engineer, Dept. Food, Agriculture, and Biological Engineering, The Ohio State University; Program Coordinator, USDA-NRCS, Maumee Valley RC&D; Research Leader, USDA-ARS, Soil Drainage Research Unit, The Ohio State University; Associate Professor, Dept. Agricultural Engineering, Michigan State University. Salaries and research support by provided State and Federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University. The authors wish to thank Dr. Warren Lee, and John Gutrich, for their comments on an earlier draft of this paper.

Farmers are continually searching for new ways to increase farm outputs or reduce average production costs, and thereby increase profits. Concomitantly, society is seeking ways to diminish the adverse effects of agricultural production on the environment. Both of these goals may be addressed with an emerging technology: The combined wetland-reservoir-subirrigation system (WRSIS). In a WRSIS, a wetland is constructed to receive subsurface drainage and runoff from adjacent cropland. The cropland is subirrigated with water provided from a supply reservoir that stores water received from a constructed wetland. The wetland, reservoir and subirrigated cropland are integrated to recycle runoff and drainage waters. The objective of this study is to determine whether the WRSIS system is an economically sound capital investment for farmers. This paper reports estimates of private farm-level economic impacts for the adoption of WRSIS technology based on demonstration sites in Northwest Ohio.

Data and Methods

The data for this study were collected from three demonstration sites in Northwest Ohio. The test sites were chosen for this research by considering factors such as soil physical properties, land conformation, and geographic location. The sites chosen were in the Ohio Counties of Defiance, Van Wert, and Fulton. The data collected from each site include capital costs, variable input costs, management costs, maintenance costs, yield benefits, and land allocation.

The Fulton County site will be used as the basis for the profitability analyses reported in this paper. This site is privately owned and is managed by the owner with the intention to maximize net returns. This site includes 20 acres of subirrigated cropland, a 1.5 acre wetland, a 2.0 acre reservoir, and a 41 acre watershed. Subirrigation pipes are 16 feet apart. A Hoytville silty-clay soil predominates the site. Total WRSIS investment costs at the Fulton County site was $60,091 or $3,005 per acre (table 1). Nearly half of this expenditure ($28,161) was incurred retrofitting the existing tile drainage for subirrigation. New tile lines were installed to accomplish a 16-foot subirrigation spacing from the original 32-foot subsurface drainage spacing. Infrastructure for pumping and water control represented the next largest investment at $17,254. The remainder of the capital investment ($14,316) was the artificial wetland construction and existing reservoir modification. Because the 2.0 acre reservoir existed prior to the project, the total investment for this site is understated to the extent of reservoir construction cost

Table 1: Description of the Fulton County WRSIS site..

Project Variables:	**Fulton**
Total Site Acreage	23.5
Wetland acreage	1.5
Reservoir acreage	2.0
Reservoir existing prior to project?	Yes
Subirrigated acreage	20
Was the subirrigation a retrofit of drainage tile?	Yes
Project Costs:	
Subirrigation Construction	$28,161
Wetlands Construction	$11,158
Reservoir Construction/Modification	$3,158
Pumping Facility Construction	$17,254
WRSIS construction (*Total Capital Costs*)	$60,091
Project Costs *Per Subirrigated Acre*	$3,005

Net Present Value (NPV) Analysis

The WRSIS investment is characterized by a sizable initial investment followed by a lengthy stream of annual returns over the life of the investment. When analyzing investments with substantial time duration and significant differences in the timing of expenditures and receipts over time, net present value analysis (NPV) is recommended.

NPV analysis employs discounting techniques to explicitly recognize the opportunity cost associated with the timing of a receipt or expenditure flow.

The net present value of the WRSIS investment will recognize all sources of private costs and benefits to the farmer. These costs and benefits will vary with size of the required capital investment, opportunity cost of capital, terms of financing, marginal improvement in commodity yields, change in acreage under production due to wetlands and reservoir construction, marginal change in production input costs, additional WRSIS management and maintenance costs, change in the market value of the land asset resulting from the WRSIS improvement, and change in federal and state income tax liabilities resulting from additional commodity sales and changes in tax deductible expenses.

The after-tax net present value of the WRSIS investment is:

$$\mathrm{NPV} = -\mathrm{I}_0 + \sum_{t=1}^{T} \left\{ \frac{(\Delta \mathrm{R}_t - \Delta \mathrm{EC}_t) - [(\Delta \mathrm{R}_t - \Delta \mathrm{CC}_t - \Delta \mathrm{D}_t) \times \mathrm{MTR}] + \mathrm{S}_t + \mathrm{ESV}_t}{(1+\mathrm{k})^t} \right\} + \frac{\Delta \mathrm{LV} \times (1 - \mathrm{CGR})}{(1+\mathrm{k})^T}$$

Where,

NPV	=	The after-tax net present value for the WRSIS
I_0	=	The amount of investment ($) required to construct the WRSIS
t	=	year index
T	=	The length of the planning horizon (30 years)
ΔR	=	Change in gross revenue resulting from the WRSIS investment. This is the product of changed crop yield, changed cropped acreage, and market price for the commodity.
ΔEC	=	Change in the economic costs of production resulting from the WRSIS investment. Economic costs include all cash and noncash (e.g., unpaid family labor and management) costs of production excluding financing costs and depreciation.
ΔCC	=	Change in cash costs of production resulting from the WRSIS investment. These costs are included in the calculation of federal and state tax liabilities.
ΔD	=	Change in depreciation expenses resulting from the WRSIS investment. Depreciation is calculated using the provisions of current (1997) federal income tax codes.
MTR	=	The individual's marginal tax rate (combined federal and state rate).

ΔLV	=	Difference in terminal value of land (at the end of the planning horizon) with and without the WRSIS investment.
CGR	=	The individual's capital gains tax rate.
k	=	The after-tax opportunity cost of capital (weighted cost of debt and equity): $k = (P_e * k_e) + (P_d * k_d)$, where k_e (k_d) is the cost of equity (debt) and P_e (P_d) is the proportion of equity (debt) financing the investment.
S	=	Subsidy (positive) or Tax (negative) amount due to government or third party payments such as mitigation payments.
ESV	=	Economic Social Value. Environmental benefits such as: improving downstream water quality, reducing agricultural runoff, providing wildlife habitat, and increasing wetland acreage.

The value for ΔR varies positively with the yield improvements from subirrigation and negatively with the diversion of cropped land to wetlands and reservoir uses. Zucker and Brown (1998) have explored the impact of subirrigation on corn and soybean yields in Ohio. Long term average yield increases for corn and soybeans have averaged 30% and 43%, respectively. These average yield increases are assumed for the base model. Sensitivity analyses are performed on this assumption. It is also assumed that all land required for wetland and reservoir was previously in crop production. Hence, land in production is reduced with the addition of the WRSIS project. Construction guidelines typically suggest that the wetland and reservoir be sized at 3% and 7% of the total WRSIS acreage, respectively.

The change in production costs with and without the WRSIS investment, ΔEC, is influenced by several factors as well. The number of acres under production decreases with WRSIS, thereby decreasing the acres treated with inputs. Fertility costs were modeled based on the cost of replacing nutrients removed by the crop. The higher yields resulting from subirrigation will remove more fertilizer nutrients, thereby increasing fertility costs. Also associated with the higher yields are higher fuel and labor requirements. Utility costs associated with the pumping plant and other direct costs of operating the WRSIS system were included. Costs of seed, tillage, pest control, and other variable inputs were thought to be invariant with subirrigation and were held constant for the with and without WRSIS scenarios. Of course, crop inputs and receipts were reduced to zero for the land diverted from crop production to wetlands or reservoir use.

The NPV analysis is conducted on an after-tax basis. The numerator terms enclosed in square brackets estimates the net addition of federal and state income taxes. If this term is positive, it decreases NPV. However, if this term is negative (that is, the value of tax deductions exceed the tax value of additional income), then the tax provisions serve to increase project NPV. Note that this last statement can only hold true if the individual has other taxable income against which these excess deductions can be applied. This assumption is reasonable if the business is profitable and the size of the WRSIS project is small relative to the farming business.

The value of tax offsets will be influenced by a number of factors. Clearly, the individual's marginal tax rate is of paramount importance.[2] Also, because only debt capital costs are deductible, the proportion of the investment that is financed with debt is important. For the base model, a 34% marginal tax rate (combined state and federal) is used in conjunction with a 25% down payment. Depreciation provisions of current tax law are used to calculate tax liabilities.[3] Current capital gains tax provisions also were modeled.

The ΔLV term in the NPV model reflects the change in land values attributable to the addition of the WRSIS. Because the productive life of the WRSIS is expected to

---

[2] Self-employment tax obligations also may be reduced with a reduction in the individual's taxable income. The impacts of self-employment taxes are not modeled here.

[3] All subirrigation improvements are assumed depreciable over 20 years. Pump equipment (Section 179 of federal tax code) and wetland/reservoir construction (conservation deduction) is expensed within 6 years.

substantially exceed the 30-year investment horizon modeled, terminal land values with and without WRSIS are expected to differ. A maximum land bid price model (Lee and Rask, 1976) was used to evaluate the differences in land values generated by a WRSIS investment. This model recognizes differences in land productivity with and without the WRSIS investment. An economically rational maximum bid price is established for both the WRSIS and non-WRSIS land at the beginning of the investment period. These land values are assumed to rise over the investment horizon at the land inflation rate (4%). The difference in these land values, net of capital gains tax obligations, is discounted and included as a single value at the end of the analysis period.

The Subsidy (S) and ESV terms are included in the model to reflect the external value this technology may have to society, and the potential that the farmer-investor may receive transfer payments or subsidies from governmental organizations in exchange for wetland creation. Unless such transfers of external costs or benefits occurs, the profit maximizing producer will not include the value of external costs and benefits into the profitability analysis. The S and ESV variables will be included with zero values in the base analysis: That is, external costs and benefits will be excluded entirely. Later, sensitivity analyses will be conducted with positive values for S and ESV to recognize the impact of transfer payments and subsidies from society to encourage environmental stewardship by the profit maximizing farmer.

Base-Case Model

In the section that follows, results will be presented for a *base-case* model. The Fulton County site is the basis for these analyses. This site was chosen because it is privately owned and is managed by the owner with the intention to maximize net returns.

The site also included a more-complete cost accounting for capital costs and more years of data concerning operational costs. As noted earlier, an existing reservoir was used at this site. Thus, total investment is understated somewhat due to the lower costs of retrofitting the reservoir. Sensitivity analyses will be conducted to explore the impact of changing individual assumptions of the base case with all other assumptions unchanged. Table 2 lists the assumptions of the base-case model.

Table 2. Variables and Assumptions of the Base-Case Model.

Variable	Value
Capital Investment costs	$60,091
Planning horizon (loan term)	30 Years
WRSIS acreage	Total acreage 23.5 acres. 20 acres are subirrigated.
Crop Mix	50% each of corn and soybeans.
Commodity prices	Corn: $2.50/bu. Soybeans: $6.00/bu
Marginal tax rate	34% (federal + state combined)
Down payment percent	25%
Financing interest rate	8% (after tax rate is 5.28%)
Before-tax Opportunity Cost of Capital	12%
Base Crop Yield (control)	150 bu/ac corn, 47 bu/ac soybeans
Subirrigation Yield Improvements	30% for corn, 43% for soybeans
Long term yield growth/yr	1% for both subirrigated and non-subirrigated crops
Inflation rate	3%
Farm land value inflation	4%
Dredging Interval and Cost	Dredging every 15 years at a cost of $5000
Net Income/acre	$141/ac non-subirrigated and $178 subirrigated
Capital Gains Tax Rate	20%
Price of recent land sales per acre	$2000/ac
Subsidy/Third Party Payments (S)	$0
Economic Social Value (ESV)	$0

Results

Under the assumptions of the base-case model, the after-tax net present value is -$11,241 (table 3). The combined effect (30-year discounted value) of subirrigation-increased yields but diminished cropped acreage was $35,598. Additional production inputs associated with these higher yields were valued at -$8,031. The discounted value of periodic dredging of the wetlands and reservoir was -$2,487.

Table 3: Net Present Value Analysis of the Fulton County Demonstration Site Under the Base-Case Scenario.

Source of Cost or Return	**Discounted Value**
Investment	$ -60,091
Value of Yield Improvements	35598
Additional variable inputs	-8031
Additional labor inputs (system management)	-342
Utilities and other operating costs for the SI/Wet system	-342
Periodic dredging of wetlands and upland reservoirs	-2487
Changed federal and state income tax liabilities	20340
Value of land sales after 30 years	4114
Total Net Present Value	**$ -11241**

The importance of federal and state income tax provisions are very evident. The changed income tax liabilities of the farm resulting from the addition of the WRSIS is $20,340. The positive sign indicates that tax provisions add to profitability. This result occurs because the value of tax offsets (deductions for depreciation and debt finance charges) exceed the tax liabilities created by the additional value of yield improvements. Again, it is important to note that this result can occur only if the farmer has sufficient other farm income against which these tax deductions can be applied.

Finally, the addition of the WRSIS investment also is expected to increase the market value of the land. Because yields are increased, the rational farmer-investor will be willing to pay more for the WRSIS land. The increased land value, net of capital gains tax liabilities, were recognized at the end of the 30 year investment horizon and totaled $4,114 in present value terms.

Sensitivity Analyses

A number of the parameters included in the NPV model can be expected to vary among farmers. In the following sections, sensitivity analyses will be conducted for several of these variables. All parameters that are not subject to the sensitivity analysis are held constant at their base-case levels.

Capital Investment

The initial capital investment assumed in the base-case model was $60,091. Table 4 summarizes the changes that would result if the initial investment were smaller or larger. Clearly, the higher the initial capital investment, the lower the net present value of the investment. Notice, however, that a reduction in initial investment of $10,000 (say, a reduction from $50,000 to $40,000 in the above table) does not increase NPV by $10,000. This result occurs because income tax liabilities are a function of depreciation and finance charges, both of which are diminished with the reduction of the WRSIS investment. The break-even investment is $38,618; maintaining all other assumptions of the base case, the WRSIS investment will be profitable only if the initial investment can be limited to $38,618 or less. This translates into a per acre WRSIS investment of nearly $1,930/acre for a site similar to that of Fulton County.

Table 4: Sensitivity Analyses for the Base Case Model With Alternative Levels of Initial Investment.

Initial Capital Investment	NPV
$20,000.00	$9,746.00
$30,000.00	$4,511.00
$40,000.00	($724.00)
$50,000.00	($5,959.00)
$60,000.00	($11,194.00)
$70,000.00	($16,428.00)
$80,000.00	($21,663.00)

Marginal Tax Rate and Down Payment Percentage: The magnitude of federal and state income tax liabilities is determined predominantly by the individual's marginal tax rate and the proportion of the investment that is debt financed. Federal and Ohio marginal tax rates for alternative levels of adjusted gross income are reported in Table 5. In this model, the NPV is calculated for the WRSIS investment using these combined marginal tax rates.

Table 5. Federal and Ohio Marginal Tax Rates.

	Marginal Tax Rate (%)		
Adjusted Gross Income	Federal	Ohio	Combined
Less than $41,200	15.00%	6.00%	21.00%
$41,200 - 99,600	28.00%	6.00%	34.00%
$99,600 - 151,750	31.00%	6.00%	37.00%
$151,750 - 271,050	36.00%	6.62%	42.62%
More than $271,050	39.60%	7.20%	46.80%

Presented in table 6 are net present values for the WRSIS investment for alternative levels of marginal tax rate and percent of debt employed. Variation of NPV with changed tax parameters occurs because NPV is calculated on an after-tax basis. Not only does gross income rise with the increased yields due to subirrigation, but tax deductible expenses also increase with the WRSIS investment. Thus, tax obligations can either rise or fall with addition of the WRSIS. As the percent of debt employed rises, ceteris paribus, the magnitude of tax deductible interest expense also rises, decreasing taxable income and tax liability, and increasing after-tax annual net cash flow. Similarly, an increase in marginal tax rate increases the value of tax offsets such as depreciation and cash interest expense. The results summarized in table 6 suggest that, for our base case, the tax offsets provided by the WRSIS were larger than the increased taxes from the increased gross receipts. An important assumption of this model was that the individual undertaking the WRSIS project would be able to take advantage of all the tax benefits arising from the WRSIS investment. That is, there was sufficient other farm income against which depreciation, cash interest and other deductions could be applied.

Table 6. Combined Effect of Down Payment Percentage and Marginal Tax Rate on WRSIS Net Present Value -- Base Case

	Percent Down Payment (Equity Financed)			
Combined MTR	25%	50%	75%	100%
21.00%	($21,668)	($29,157)	($34,892)	($39,342)
34.00%	($11,241)	($22,036)	($29,985)	($35,971)
37.00%	($8,653)	($20,322)	($28,824)	($35,176)
42.62%	($3,767)	($17,096)	($26,651)	($33,687)
46.80%	$24.56	($14,687)	($25,037)	($32,579)

Financing Terms: Similar to the results of MTR and percent down payment, the term of the loan also has an effect on the net present value of the WRSIS system. As the term of the loan increases, with interest rate and all other parameters unchanged, net present value increases (table 7). As the loan length increases, the total value of interest paid over the loan term will increase. As deductible interest payments rise, tax deductions rise, taxable income and tax liabilities decline, and after tax net cash flows increase.

Table 7. Sensitivity Analyses of Loan Term on Base-Case Model NPV.

Term of Loan	NPV
5Years	($20,516.00)
10 Years	($18,083.00)
15 Years	($15,949.00)
20 Years	($14,108.00)
25 Years	($12,546.00)
30 Years	($11,241.27)

Yield Improvement: Presented in table 8 are sensitivity analyses for subirrigation-induced yield improvements. Yield increase scenarios range from 110% of base to 170%

of base yields. The base yields used for the Fulton County site were 150bu/ac for corn and 47bu/ac for soybeans. As yield increases, the NPV of the WRSIS project increases.[4]

Table 8: Sensitivity Analyses of Crop Yields on Base-Case Model NPV.

	Bean Yield (Bu/Ac)						
Corn (Bu/Ac)	52	56	61	66	71	75	80
165	(39078)	(34254)	(29430)	(24605)	(19781)	(14957)	(10133)
180	(33119)	(28295)	(23471)	(18647)	(13823)	(8999)	(4175)
195	(27161)	(22337)	(17513)	(12689)	(7864)	(3040)	**1784**
210	(21203)	(16378)	(11554)	(6730)	(1906)	**2918**	**7742**
225	(15244)	(10420)	(5596)	(772)	**4053**	**8877**	**13701**
240	(9286)	(4462)	**363**	**5187**	**10011**	**14835**	**19659**
255	(3327)	**1497**	**6321**	**11145**	**15970**	**20794**	**25618**

<u>Crop Mix</u>: Sensitivity analyses reported in table 9 gives some indication of how different mixes of crops would affect the NPV for the WRSIS system. Because soybeans have shown a relatively greater response to subirrigation than has corn, as the relative amount of soybeans in the rotation increases, so to does the NPV for the WRSIS system. Although not demonstrated here, the market value of a commodity also will impact system profitability. Thus, the WRSIS system is expected to be more profitable for applications with higher-valued commodities relative to lower-valued commodities assuming yield response and all other parameters are unchanged.

Table 9. Sensitivity Analyses for Crop Mix Variation on Base-Case NPV.

Crop Mix	NPV
100% Corn	($14129)
75% Corn, 25% Soybean	($12685)
50% Corn, 50% Soybean	($11241)
25% Corn, 75% Soybean	($9798)
100% Soybean	($8354)

[4] The sensitivity analyses reported above represent increases in expected (average) yields. To the extent that the investor is risk averse, there may also be value created by reducing the variation in net revenues over time. Although this would represent an important extension of this model, it also adds tremendous data needs concerning serial correlation of yields across time for a specific site, joint distributions for yield and price, and information regarding individual farmer utility functions (willingness to tradeoff return for risk reduction).

The Effects of Transfer Payments and Externalities

There are many factors that interact to determine the value of a wetland. A wetland creates environmental value by increasing wildlife diversity and helping to filter soil sediments, nutrients, and agricultural chemicals from effluents (Sibbing, 1995). In addition, wetlands decrease erosion by trapping sediment, abating storm water runoff, and producing amenity value. Although environmental and social values attributed to wetlands may be significant, only those values that can be internalized (transferred back to the owner of the wetland) will influence the market value of the wetland or serve as an incentive for an individual to create an artificial wetland.

Environmental policy can create a demand for artificial wetlands. Ohio mandates that before a wetland can be destroyed, a new wetland site must be created elsewhere (mitigation). A wetland will be approved for mitigation only if it meets certain environmental criteria. To insure that the wetland is not converted to cropland later, an easement is granted for the new wetland. Wetland market value is influenced by the number of parties on each side of the market, by the value created from developing the existing wetland, and by the costs and lost values associated with converting land into a new wetland. Ohio Department of Natural Resources personnel (Marshall, Evans, and Rennick) provided an estimate the current market value for an acre of wetlands at $20,000. In areas of high demand, this price could be substantially higher than $20,000.

It is assumed that the base case model qualifies for a wetland mitigation payment and that the current market price is $20,000 per acre of wetland ($30,000 for the 1.5 acre wetland) can be negotiated. These payments are assumed to be available immediately, and thus are not discounted. The adjusted NPV for the WRSIS project is $8,933.

Summary

Results for the demonstration site in Northwest Ohio suggest that, in the absence of subsidies or transfer payments, this investment will not be profitable under the assumptions of the base case. The system may become profitable (on an after-tax basis) under conditions of high leverage and high marginal tax rates due to tax off-sets produced by the investment. This will have full value only if the farmer has other farm taxable income in excess of these deductions. Tax laws also are subject to change. This introduces an element of risk to the producer who may be counting on the continued deductibility of cash interest and depreciation as a source of benefit from this investment.

Capital costs for the project are by far the largest expense. Reducing required investment greatly increases the likelihood that the WRSIS will be profitable. It is encouraging to note that the break-even level of WRSIS investment (base case) is about $1,930 per acre. This is substantially higher than estimates given in previous studies (which ignored tax implications), and is a level of investment that may be achievable in the future.

Additional inputs are necessary to grow and harvest a larger yield. Research is currently underway to study variable input usage under subirrigation. Preliminary results suggest that input utilization efficiency may increase with subirrigation technology. Also, land set aside for construction of reservoirs and wetlands lessens the impact of positive yield effects. If the WRSIS project were built on a larger scale, the proportion of land removed from production may be lessened. Furthermore, it is expected that the cost of creating larger reservoirs and wetlands is a nonlinear function of their capacity.

References

Lee, Warren and Norman Rask. 1976. Inflation and crop profitability: how much can farmers pay for land? American Journal of Agricultural Economics. Vol. 58 No. 5: 984-990.

Marshall J., J. Evans, and K. Rennick. 1998. Division of Wildlife, Division of Soil and Water Conservation, and Deputy Director of the Ohio Department of Natural Resources. Information obtained through discussions held during the month of July, 1998.

Sibbing, Julie M. 1995. "Ohio wetlands". National Audubon Society. Ohio Environmental Education Fund, August, 1995.

Zucker, L.A. and L.C. Brown (Eds.). 1998. Agricultural drainage: Water quality impacts and subsurface drainage studies in the Midwest. Ohio State University Extension, Bulletin 871. The Ohio State University (In press).