Profits, Soil Erosion, and Risk

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The farmer faces on major question year after year. How do I make a profit? All other concerns are secondary, for if he fails to show a profit or at least breakeven, he will not coninue in the business of farming.

The competitive economic system in agriculture, which requires farm operators to try to maximize profits just to survive in farming, has been blamed for much of the soil erosion in United States. Many techniques used to reduce soil erosion have been investment items, such as grass waterways, terraces, tree lines, and contour strip cropping. These practices increase cost in the short run and frequently are of questionable economic value in the long run. It is not surprising that a relatively low percent of farmers have adopted these measures.

Technology and economics recently have been combined to make soil conservation profitable in many areas. The initial stimulus occurred during the mid 1970s when the energy crisis increased fuel prices. Rapidly rising tillage costs forced many farmers to seek ways to reduce their traditional level of tillage. Increased land prices and cash rents was another factor which changed the economic situation. It became more expensive to let land lay idle as summer fallow—the major cause of soil erosion in North Dakota.

While the economic system was providing some incentive for change, technological change was occurring in machinery, crops, weed control, and moisture management. The chemical industry introduced improved herbicides to substitute for tillage. Equipment manufacturers designed tillage and planting equipment to replace the traditional plow and drill. Universities and other research units expanded their knowledge on how to capture and conserve moisture. Winter wheat and sunflower were added to the crop rotation in western and central North Dakota and a number of additional crops expanded the options in eastern North Dakota.

The objective of this report is to present results of a study to analyze alternative crop management systems and their impacts on profitability, risk, and soil erosion.

Thè area chosen for the study is the Muskrat Lake Watershed in Mountrail County in northwestern North Dakota. It is a closed basin draining into Muskrat Lake, a shallow, small lake near the eastern boundary of the watershed.

The watershed contains 19,910 acres used primarily as cropland and rangeland (Table 1). Land capability class, also presented in Table 1, is a classification system based on limitations of a specific soil type for agricultural production. Class II land has the least number of limitations of any soil in the watershed, and Class VIII is the most limited with respect to potential use. Erosion potential generally increases in the higher numbered classes. One of the reasons for selecting this watershed as the study site was the relatively large acreage (1,418 acres) of highly erodible Class VI land used for crop production.

Characteristics were identified for each 2.5-acre unit in the watershed. The descriptors are land use, soil type, land capability class, slope gradient and length, crop and range productivity indices, and farm and field boundaries. Crop and livestock budgets were developed for several crop and tillage systems.

A computer simulation model, AGSIM, was used to analyze the profit and soil erosion impacts of alternative crop management systems (Figure 1). AGSIM consists of three main components: (1) a soil loss simulator based on the Universal Soil Loss Equation; (2) a profit simulator to estimate yields, revenues, and costs; and (3) a model which synthesizes and aggregates information generated by the other two components. Estimates of soil loss due to wind erosion were developed independently of the AGSIM model. A second computer model, RISKSIM, was used to estimate yield and net revenue for selected crop management systems under various precipitation and price conditions. RISKSIM consists of a random number generator, a set of precipitation data, a production function for durum and winter wheat, and budgets for each crop management system. A crop management system is defined as the crop rotation pattern, tillage system, chemical weed control alternative, level of inputs such as nitrogen and phosphate, and the machinery complement.

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Table 1. Summary of Land Use by Land Capability Class in Muskrat Lake Watershed, Mountrail County, North Dakota.

Land Capability Class	Cropland	Rangeland	Farmsteads	Tame Grassland	Wetland	Total[1]
			Acres			
II	8,505.50	1,318.15	75.00	128.25	16.05	10,042.95
III	1,704.00	482.50	6.00	33.25	0.00	2,225.75
IV	1,497.50	486.50	17.25	48.25	1.00	2,050.50
V	32.00	61.25	0.00	1.25	0.00	94.50
VI	1,418.00	2,850.50	36.75	117.75	0.00	4,423.00
VII	32.30	250.25	0.00	0.00	0.00	282.55
VIII	4.00	23.25	0.00	0.00	0.00	27.25
TOTAL	13,193.30	5,472.40	135.00	328.75	17.05	19,146.50

[1] Summary does not include 755 acres of lake and 8 acres of woodland.

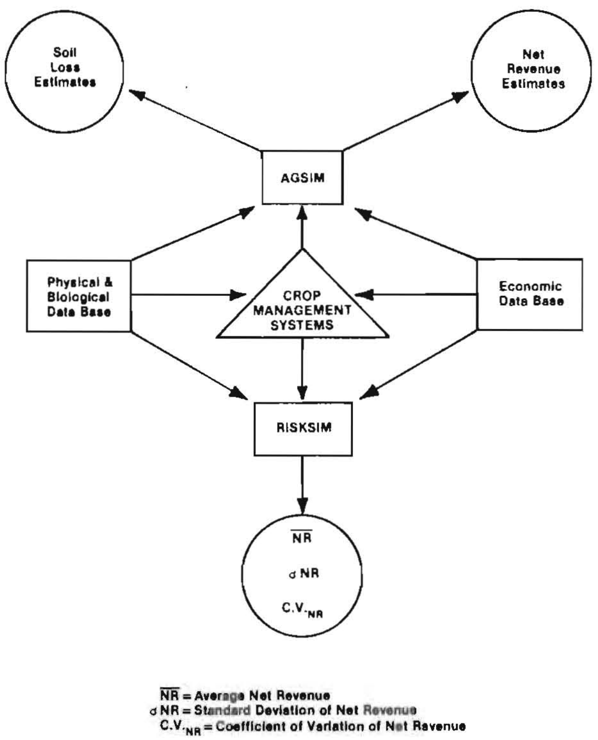

Figure 1. Structure of the Simulation Model Used to Estimate Net Revenue and Soil Loss.

Selected Results[1]

Analysis I

The first set of results is based on output from the deterministic AGSIM model which excludes risk (Table 2). Various combinations of three crops (durum, winter wheat, and sunflower) and summer fallow, two crop tillage systems (chisel plow and no-till), and four fallow weed control alternatives (chisel plow, stubble mulch, chemical plus one tillage, and chemical only) were considered in the analyses (Table 2).

[1] Results are reported for only a few of crop management alternatives analyzed due to space limitations.

Fallow-durum (F-D) with conventional (chisel plow) tillage and an uphill- and downhill cultivation pattern is the typical management system in the watershed. This system results in an average of 10.82 tons of soil loss due to water and wind erosion, varying from 6.34 tons on Class II to 32.59 tons on Class VI land. Generally, five tons per acre of soil loss is the maximum considered tolerable. Adoption of a chemical weed control alternative for the fallow portion of the rotation is estimated to reduce soil loss to about four tons per acre. Cost is reduced by approximately $5.00 per acre, and net revenue is thereby increased to $32.59.

The addition of winter wheat to the rotation not only has little effect on net revenue but also decreases soil loss only under the two mechanical tillage alternatives. Sunflower adds substantially to net revenue with less effect on soil loss. The crop management systems (CMS) which exclude fallow (#8 and 9) and the three no-till systems (#5, 6, and 7) exhibit a high potential for adoption. Chemical fallow followed by durum and no-till sunflower yields $39.96 in net revenue and less than five tons of soil loss.

The effect of these management systems on income variability was not analyzed in the first phase of the study. Crop diversification should assist in reducing risk; however, variability in soil moisture levels and higher cash costs may offset that advantage.

The concern about income variability became very apparent during a March 1983 meeting with a majority of the farmers in the watershed. They expressed substantial interest in the project results, particularly in the potential of increased profits. However, they also expressed an understandable reluctance to adopt the recommendations of the study without additional information. They wanted information on factors affecting the variability of yields and, in turn, net income. Factors mentioned at the meeting included the reliability of

Table 2. Annual Soil Erosion and Net Revenue on Cropland for Alternative Crop and Soil Management Systems in the Muskrat Lake Watershed, Mountrail County, North Dakota.

	Fallow Weed Control Alternatives							
	Chisel Plow		Stubble Mulch		Chemical + Tillage		Chemical Only	
Crop Management System[1]	S.L. (T/A)	NR ($/A)	S.L. (T/A)	NR ($/A)	S.L. (T/A)	NR ($/A)	S.L. (T/A)	NR ($/A)
1. F-D	10.82	27.49	6.40	29.16	4.55	30.09	3.99	32.59
2. F-D-WW	8.20	27.12	6.13	28.23	4.96	28.84	4.70	30.50
3. F-D-SFI	10.03	35.45	8.23	36.57	7.01	37.18	6.77	38.84
4. F-D-WW-SFI	8.08	33.59	6.89	34.43	5.97	34.90	5.78	36.15
5. F-D-WW(Z)	6.77	27.64	3.81	28.76	2.96	29.37	2.91	31.04
6. F-D-SFI(Z)	8.16	36.57	6.17	37.69	4.55	38.29	4.14	39.96
7. F-D-WW(Z)-SFI(Z)	6.63	34.83	5.06	35.68	3..85	36.15	3.53	37.40
8. D-WW-SFI	5.43	32.00						
9. D(Z)-WW(Z)-SFI(Z)							3.45	33.47

[1] F = fallow, D = durum, WW = winter wheat, SFI = sunflower, and Z = no-till.

NOTE: S.L. represents weighted average soil loss for all tilled land. NR represents net return to land, overhead, and management.

chemical weed controls, the performance of moisture-conserving techniques, problems associated with no-till farming, and the role of federal all-risk crop insurance. In response to these requests, the project was continued to investigate the effect of the alternative crop management systems on the variability in net farm income.

Analysis II

Only one local source of data on crop rotations which were continued for a reasonable length of time was discovered. This was a series of experiments performed by ARS-USDA at Sidney, Montana. Fifteen years of data were obtained and used to estimate annual net revenue for each CMS (Table 3). Revenues were estimated using actual prices for 1968 to 1982 and again using 1978 to 1982 average prices. Use of the average prices increased the average revenue and reduced variability.

Results were generally as expected. Rotations with fallow yielded lower average revenues but also lower income variability, as indicated by the standard deviation, range, and coefficient of variation. Crop Management Systems 11, 12, 14, and 15 define an E-V frontier where average revenue cannot be increased without an accompanying increase in risk (coefficient of variation). The other CMSs (10 and 13) are not efficient solutions.

A second approach used in the study to estimate yield and revenue variability required developing a production function for wheat.[2] The fertilizer levels were set at 90 pounds of nitrogen, 20 pounds of soil phosphate, and 20 pounds of fertilizer phosphate. A random-number generator, drawing from 412 values of soil moisture (SM) and 64 values of growing-season precipitation (GSP), was used to select 250 values each of SM and GSP. These values were then used to estimate yields. One inch of SM was added to the selected value if the crop followed a fallow year and one inch subtracted if it followed another crop. This two-inch differential in soil moisture is typical for the area.

No statistically significant correlation was obtained for sunflower due to lack of data. Therefore, sunflower yields were simply selected at random from yields in northwestern North Dakota during the seven years of available data (1976-1982).

The F-D-SFl (fallow-durum-sunflower) rotation was a clear winner from an economic viewpoint (Table 4). It achieved the highest net revenue, lowest standard deviation and coefficient of variability, and the highest minimum value. No other rotation is even close in terms of both high average net revenue and low risk. For example, the continuous rotation D-WW-SFl nearly matches the average net revenue but has a much higher coefficient of variation.

The three-year rotation of F-D-SFl may incur insect and plant disease problems on sunflower. If so, the second best rotation is the F-D-WW-SFl, which also achieves an average net revenue of over $40 per acre and the second lowest variability in revenue. This rotation reduces sunflower to only one year in four and will help decrease insect and disease problems.

Conclusions

The traditional crop management system in western North Dakota is a fallow-durum rotation with the chisel plow as the main tillage implement. This system yields a

[2] $Yw = -62.60 + 24.19 \log N + 11.95 \log SM + 27.04 \log GSP + 5.12 \log SP + 4.77 \log FP + 2.76 (D)$

where N = nitrogen, SM = soil moisture at seeding, GSP = growing season precipitation, SP = soil phosphate, FP = fertilizer phosphate, and D = durum.

($R^2 = .634$, C.V. = 22.71 with all parameters statistically significant at the .03 level or better.)

Table 3. Net Revenue in Dollars and Revenue Variability of Six Crop Management Systems, Sidney, Montana, 1968-1982.

	Average	Std. Dev.	Min. Value	Max. Value	C.V.[1]
	(Using Actual Prices from 1968 to 1982)				
#10 F-SW	36.20	25.32	5.94	86.34	69.95
11 F-WW	37.21	25.69	− 1.68	81.39	69.04
12 F-SW-WW	43.16	31.47	3.38	95.54	72.92
13 SW-B-WW-Saf.[2]	48.30	43.35	−22.63	110.35	89.74
14 SW-B-WW-Saf.[2]	56.09	51.91	−22.33	136.97	92.55
15 SW-B-WW-Saf.[2]	49.14	38.69	−24.16	105.84	78.73
	(Using a 1978 to 1982 Average Price)				
#10 F-SW	39.93	21.92	10.14	79.46	54.91
11 F-WW	43.58	22.26	− 1.75	84.91	51.07
12 F-SW-WW	49.56	28.08	− .09	91.49	56.65
13 SW-B-WW-Saf.[2]	53.46	42.52	−27.72	105.31	79.54
14 SW-B-WW-Saf.[2]	56.74	43.19	−27.94	121.51	76.12
15 SW-B-WW-Saf.[2]	56.70	35.97	−29.32	102.48	63.44

[1] The coefficient of variation is the standard deviation divided by the average and times 100.

[2] These rotations were an irregular sequences of spring wheat, barley, safflower, and winter wheat.

Table 4. Estimated Average Net Revenue and Revenue Variability for Five Crop Management Systems, Muskrat Lake Watershed, Mountrail County, North Dakota.

	Net Revenue				
Crop Management System	Average	Std. Dev.	Min. Value	Max. Value	C.V.
1. F-D	34.94	10.25	4.57	53.05	29.72
2. F-D-WW	33.70	13.421	− 4.66	58.72	39.82
3. F-D-SFI	44.90	8.19	20.62	62.62	18.25
4. F-D-WW-SFI	41.70	10.71	10.54	63.20	25.69
5. D-WW-SFI	44.46	14.96	− 2.05	74.54	33.64

net revenue of $27 per acre and over 10 tons of soil loss per acre (Table 5). A number of CMSs can yield about $10 more in net revenue per acre, reduce soil loss by 50 percent or more, and reduce the variability in income. A four-year rotation, F-D-WW(Z)-SFl(Z), using chemical fallow and no-till for winter wheat and sunflower appears to be the most practical and profitable. Results from Sidney, Montana, indicate that the fallow year could be replaced with barley or spring wheat and net revenue would be increased further. Safflower also appears to be a good substitute for sunflower in the rotation.

Existing crop management systems can improve profit and reduce soil loss with no increase in profit variability, so why haven't they been adopted? There are a number of reasons. The first is time. Changes in technology, no-till equipment, and herbicides have occurred recently and are still in a trial and error stage in many cases. Farmers do not want to invest in new technology until they are sure it is to their advantage. Second, some research on the new crop management systems is in progress, but little is completed or published for this geographic area. A third reason is increased risk, both physical and financial. The physical portion of risk involves occurrence and capture of nongrowing-season precipitation, effectiveness of the new herbicides, increased insect and disease problems, and the reliability and longevity of equipment, particularly no-till drills. On the financial side, the higher revenue CMSs also require higher cash operating costs and equipment investments, causing greater cash losses in case of a crop failure. In 1980, each of the three on the nonfallow rotations experienced a complete crop failure at Sidney, Montana, while two of three rotations involving fallow showed positive cash flows. Hail and all-risk crop insurance would help protect a farmer against those occurrences, but they also increase the cash costs per acre.

Research aimed at answering the farmer's concerns, translation of research into understandable information, dissemination of the information to farmers, and educational sessions to assist farmers in evaluating and

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Table 1. U.S. No. 1 Yield of NorKing Russet and Cultivars Grown at Grand Forks and Park River, ND (1981-1984).

	1981		1982		1983		1984		Average	
	Grand Forks	Park River	Grand Forks	Park River	Grand Forks	Park River	Grand Forks	Park River	Grand Forks	Park River
NorKing Russet	223	124	188	251	170	240	257	218	210	208
Norgold Russet	241	124	161	182	133	213	189	151	181	168
Russet Burbank	204	110	114	178	77	73	148	159	136	130
Lemhi	262	198								
Average	233	139	154	204	127	175	198	176		

Table 2. Percent Total Solids of NorKing Russet and Cultivars Grown at Grand Forks and Park River, ND (1981-1984).

	1981		1982		1983		1984		Average	
	Grand Forks	Park River	Grand Forks	Park River	Grand Forks	Park River	Grand Forks	Park River	Grand Forks	Park River
NorKing Russet	20.3	21.4	23.5	20.7	18.8	19.9	22.0	22.0	21.2	21.0
Norgold Russet	20.1	20.9	21.6	20.1	17.7	19.0	20.5	20.7	20.0	20.2
Russet Burbank	20.5	20.9	21.8	21.2	19.2	19.0	19.7	22.0	20.3	20.8
Lemhi	22.2	22.2								
Average	20.8	21.4	22.3	20.7	18.6	19.3	20.7	21.6		

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using the information are still needed to meet his needs. This requires more multidisiplinary cooperation than has occurred in the recent past. The "bottom line" is currently a popular term to describe an overall net effect. If we expect soil-conserving crop management systems to be adopted, we need to be able to provide farmers with information leading to and including the "bottom line."

Table 5. Summary of Selected Crop Management Systems.

	Analysis I		Analysis II	
Crop Management System	SL (T/A)	NR ($/A)	$\overline{NR}$ ($/A)	C.V.
F-D	10.82	27.49	34.94	29.72
F-D-SFI	6.77	38.84	44.90	18.25
F-D-SFI(Z)	4.14	39.96		
F-D-WW-SFI	5.78	36.15	41.70	25.69
F-D-WW-(Z)-SFI(Z)	3.53	37.40		
D-WW-SFI	5.43	32.00	44.46	33.64
D(Z)-WW(Z)-SFI(Z)	3.45	33.47		