The Impact of Irrigation Erosion Damage on Farm Profitability

by

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Introduction

Irrigation-induced erosion causes onsite damage in the form of reduced crop yields and offsite damage from sediment and nutrients in return flows. Soil losses are high and the impact on water quality is great. Recent reports from many regions of the US report that cumulative erosion has reduced crop yields from about 20% to 50% (White et al., 1985; McDaniel and Hajek, 1985; Frye et al., 1985; Krauss and Allmaras, 1982). Under furrow irrigation, Carter et al. (1985) reported crop yield potential reduced 25% by 80 seasons of irrigation. Erosion and runoff also contribute to nonpoint source pollution and impose costs for downstream water users. Nationally, about 46% of the sediment, 47% of the total phosphorous, and 52% of the total nitrogen discharged into U.S. Waterways comes from agricultural sources (Gianessi et al. , 1986). Approximately 85% of Idaho's water quality problems have been attributed to nonpoint source pollution (Moore, 1987). The onsite damage is a cost to the grower in the form of reduced future income and sometimes higher per unit production cost from erosion. Erosion rates and the cost of erosion damage are variable across crop rotations and across tillage systems. If growers had better information on the dollar value of erosion damage they might voluntarily reduce erosion (and sediment) to avoid this cost.

This paper examines the cost of erosion damage in an irrigated tract near Twin Falls, Idaho. Erosion damage cost is calculated for alternative rotations and alternative tillage systems. Erosion and water quality impairment from irrigated agriculture may be more controllable than from dryland agriculture. Erosion and runoff from dryland agriculture are influenced heavily by rainfall and other stochastic weather factors whereas in irrigated agriculture the eroding force, irrigation water, is applied and controllable by man. Armed with this information on erosion damage cost, growers can make better decisions about managing their soil and water resources for sustained profitability and at the same time provide environmental benefits from improved water quality.

Study Area

The study area near Twin Falls, Idaho, produces dry beans, sugarbeets, alfalfa, corn, cereal, peas, potatoes and smaller acreages of other crops. These crops are primarily furrow irrigated on land ranging from about 0.3 to 3.5% slope, with most fields having a slope of 1 to 1.5%. Soils are highly erodible silt loams. Irrigation water is delivered through a canal system on a continuous basis of 1 cfs per 80 acres, requiring farmers to irrigate essentially every day during the growing season. Hence, farmers generally set water in the early morning and late evening and let it run for 12 or 24 hours. Other farming activities require their attention at other times. Stream sizes are generally set large enough to assure that the water reaches the lower ends of the furrows in a few hours for adequate infiltration time to provide the needed water for the growing crop. These stream sizes are erosive, particularly during the first half of the season.

Traditionally, fields were all moldboard plowed between every crop. When beans follow alfalfa, the average number of tillage operations used to get to the point of seeding beans is 10 (Carter and Berg, 1991). New conservation tillage technology is being accepted now, and some farmers no longer moldboard plow.

Nature and Extent of Erosion and Crop Yield Decline

Irrigation-induced erosion began when water was first applied to the soil surface where the land slope was sufficient that moving water had enough shear force energy to detach soil particles from the soil mass and transport them. This erosion causes serious problems. As topsoil depth decreases, the crop production potential of the soil decreases. Sediment entering streams and rivers covers fish spawning gravels. Sediment clogs waterways and fills storage reservoirs. Sediment reduces the recreation potential of water, and it increases wear on pumps used to pump water for various purposes.

Irrigation-induced erosion generally increases with increased land slope and with furrow stream size. It varies with crop. The most severe erosion occurs when row crops such as dry beans, sugarbeets and corn are grown, and the least erosion occurs on pastures, alfalfa and solid stand cereal crops (Carter, 1990). Excessive tillage, a common practice on irrigated land, dramatically increase soil erosion. Conversely, reducing the number of tillage operations reduces erosion and sediment loss. Carter and Berg (1991) and Carter et al. (1991) have demonstrated that no-tillage farming is feasible for some crops on irrigated land. For example, corn can be grown without tillage following alfalfa, cereal or corn. Cereal can be grown successfully without tillage following alfalfa or corn. These studies demonstrated that changing the sequence of crops in typical rotations to permit the fewest tillage operations not only reduces erosion and sediment loss by 80 to 100%, but also increases farmer net income by reducing tillage cost. No yield or crop quality is sacrificed by these cropping sequence changes. These studies demonstrate that much of the irrigation-induced erosion can be prevented by applying presently available erosion and sediment loss control technology. There is, however, a big challenge to effectively transfer this technology to growers.

Approximately 75% of the fields in the study area have lost enough soil from irrigation induced erosion that they exhibit white upslope ends, usually extending about one-third of the field length. Originally the topsoil was about 15 inches deep above a white subsoil. As irrigation induced erosion removed soil from the upper ends of fields the topsoil became thinner until tillage, mainly moldboard plowing, turned up the white subsoil. This changed the color of a portion of the fields (Carter, 1993; Carter et al., 1985). As this erosion and sediment process continues, more subsoils are exposed.

Subsoils are much less productive than topsoils in the study area. Therefore, when subsoils are exposed the crop producing potential of the soil is decreased. Results of extensive field studies have shown that as topsoil depth decreases below about 15 inches, yields of all crops decrease. These yield reductions can be as high as 70% for some crops as topsoil depth decreases from 15 inches to 4 inches (Carter, 1993; Carter et al., 1985). Results from extensive field studies indicate that the crop production potential in the study area was decreased 25% over the first 80 years of furrow irrigation. In other words the area has the potential to produce only 75% as much crop as if there had been no erosion (Carter, 1993; Carter et al., 1985).

Unfortunately, we do not have the technology to restore the production of this lost topsoil except to replace it with topsoil. Once soil is lost into a river or stream the cost of recapturing it and replacing it on exposed subsoil areas is prohibitive. Farmers can haul topsoil from deposition areas on downslope positions to the upper ends of fields and restore the production potential. They can also trap sediment in catchment basins, and later place it on portions of fields where erosion and sediment loss has reduced the production potential.

Measuring Cost of Erosion Damage

The cost of erosion damage is the value of the lost crop yield and income in the future from current erosion. Technical progress in crop yields masks erosion damage. To correctly measure erosion damage we must compare potential yield with technology on conserved soil versus realized yield with technology on eroded soil. The computer model employed in this study to measure erosion damage correctly incorporates technology and uses a dynamic soil erosion damage function (Walker, 1982 AJAE). The damage function incorporates multiplicative technology impacts (Walker and Young, 1986a) and employs nonlinear topsoil-yield relationships (See Figure 1) (Carter, 1990).

The cost of erosion damage is the present value of the lost income over a future damage horizon caused by erosion this year that reduces future crop yields. This study uses a 75 year damage horizon for calculating erosion damage, a period roughly equal to the present farmer's tenure and that of his son and grandson. A real private rate of discount of 4% was used to calculate present value, based on the real rate of return to farm assets. This discount rate and damage horizon for counting lost income capture 96% of the lost income into perpetuity. It is important to understand that the cost of erosion damage is an annual figure and that the damage model measures the present value of lost income in the future from current year erosion.

The damage function is dynamic; it does not measure damage simply as the product of an annual income loss multiplied by the number of years in the damage horizon. It is dynamic because it correctly captures the effect of crop yield technology on erosion damage cost over the damage horizon. Technical progress magnifies lost income in subsequent years of the damage horizon because technology increases yields more on deeper soils where the genetic potential of the crop can be realized (Walker and Young, 1986b). Thus the difference between potential yield without current year erosion and realized yield with current erosion increases slightly in each year of the damage horizon with technical progress.

Another dynamic aspect of the damage function reflects declining topsoil during the damage horizon and thus an accelerating impact of current year erosion on future yields. Because erosion continues during the damage horizon and topsoil decreases reaching steeper portions of the yield-topsoil function over the damage horizon, the impact of a given decline in topsoil depth from current year erosion on future yield increases over the damage horizon.

Results

We estimated the cost of erosion damage for three alternative cropping systems combining a typical cash crop rotation and a soil-conserving rotation along with conventional tillage and reduced or conservation tillage. The three cropping systems studied were:

System 1. Winter wheat/Dry beans/Dry beans with conventional tillage.

System 2. Winter wheat/Dry beans/Dry beans with conservation tillage.

System 3. Peas with alfalfa/Corn/Winter wheat/Dry beans/Dry beans with conservation tillage.

System 1 reflects a popular rotation intensive in a high value crop and a common conventional tillage system that produces high erosion. Systems 2 and 3 allow us to study the effect of tillage alone and the combined effect of tillage and rotation on reducing erosion damage.

Typical Field Configuration

A typical field for the region representing topsoil depths after 80 years of erosion was used to estimate field average cost of erosion damage. The typical field had a depth of 4 inches in the upper 33% of the field, 10 inches for the next 15% of field area, 15 inches for the next 27% and 24 inches for the lowest 25% of the field.

The cost of erosion damage was estimated for four areas of the field because that cost differs with the existing topsoil depth and then the four costs were averaged for an estimate of annual erosion damage for the field.

Cost of Erosion Damage

The estimates of the cost of erosion damage by field segment and field average are shown in Table 1 for each system. The cost of erosion damage is greatest with System 1, the high value rotation with conventional tillage, with an annual cost of $38.82 per acre. Erosion damage was next highest with System 2, the same rotation but conservation tillage, at $16.58 per acre annually. The lowest cost of erosion damage occurred with System 3, the soil conserving rotation with conservation tillage, at $10.56 per are per year. Growers using conventional tillage with the typical crop rotation could reduce annual erosion damage cost from $38.82 per acre to $10.56 per acre by adopting a soil conserving crop rotation and reduced tillage.

Table 1. Cost of Erosion Damage at Twin Falls, Idaho

Topsoil Depth by Field Area

	Erosion (T/A)	4" ($)	10" ($)	15" ($)	24" ($)	Field Avg. ($)
System 1	13.3	63.08	40.80	28.93	16.29	38.82
System 2	5.6	26.98	17.46	12.38	6.85	16.58
System 3	4.2	17.96	10.99	7.45	3.89	10.56
Field Percent		33%	15%	27%	25%	

A comparison of erosion damage cost between irrigated and non-irrigated agriculture is interesting and has important policy implications. The Palouse region of north Idaho, a dryland grain producing area noted for its high wheat yields, provides a meaningful comparison because wheat is also an important crop in the irrigated area studied here. An earlier study reported the cost of erosion damage in the Palouse near Moscow, Idaho (Walker et al., 1991). That study evaluated the common wheat-pea rotation with conventional tillage on a typical slope (16% and 200 foot length) with annual soil loss of 12.6 tons per acre. The cost of one year of erosion damage was $7.82 per acre.

Even though the erosion rate in the irrigated area was nearly the same as in the dryland area, the cost of erosion damage was nearly five times as great. The greater erosion damage cost in the irrigated area was due to the severe yield decline on eroded soil possibly due to toxic subsoil. Also, with the higher rates of technical progress in irrigated yields the damage is greater because the yield potential over time that is lost with erosion is greater. The higher cost of erosion damage in the irrigated area suggests that it might be a high priority for targeting soil and water conservation efforts.

Conclusions and Policy Implications

Without conservation efforts the cost of erosion damage in the irrigated area is great, $38.82 per acre annually. In addition to this onsite damage there is offsite damage from degraded water quality associated with erosion and the resulting sediment and nutrients in runoff. Growers do not incur the cost of offsite damage but they directly bear the cost of onsite damage in the form of reduced future income due to this year's erosion. They bear this onsite damage even though they may not know exactly what the amount is. Knowing the magnitude of this damage cost might be an incentive to voluntarily adopt soil conserving rotations and tillage systems in order to reduce this cost. Growers can reduce their damage cost $22.24 an acre by adopting conservation tillage. Damage can be reduced an additional $6.02 per acre by combining a soil conserving rotation with conservation tillage. To the extent that these potential savings in onsite damage cost serve as an incentive for growers to reduce erosion voluntarily, society at large will also benefit from improved water quality.

Because of the significant potential onsite saving in erosion damage and the additional concurrent benefit of reducing offsite damage, there is incentive to develop cost-effective soil and water conserving practices for irrigated agriculture. Finally, the high cost of erosion damage in the irrigated area in this study suggests that irrigated agriculture could be a high priority for targeting soil and water conservation efforts.

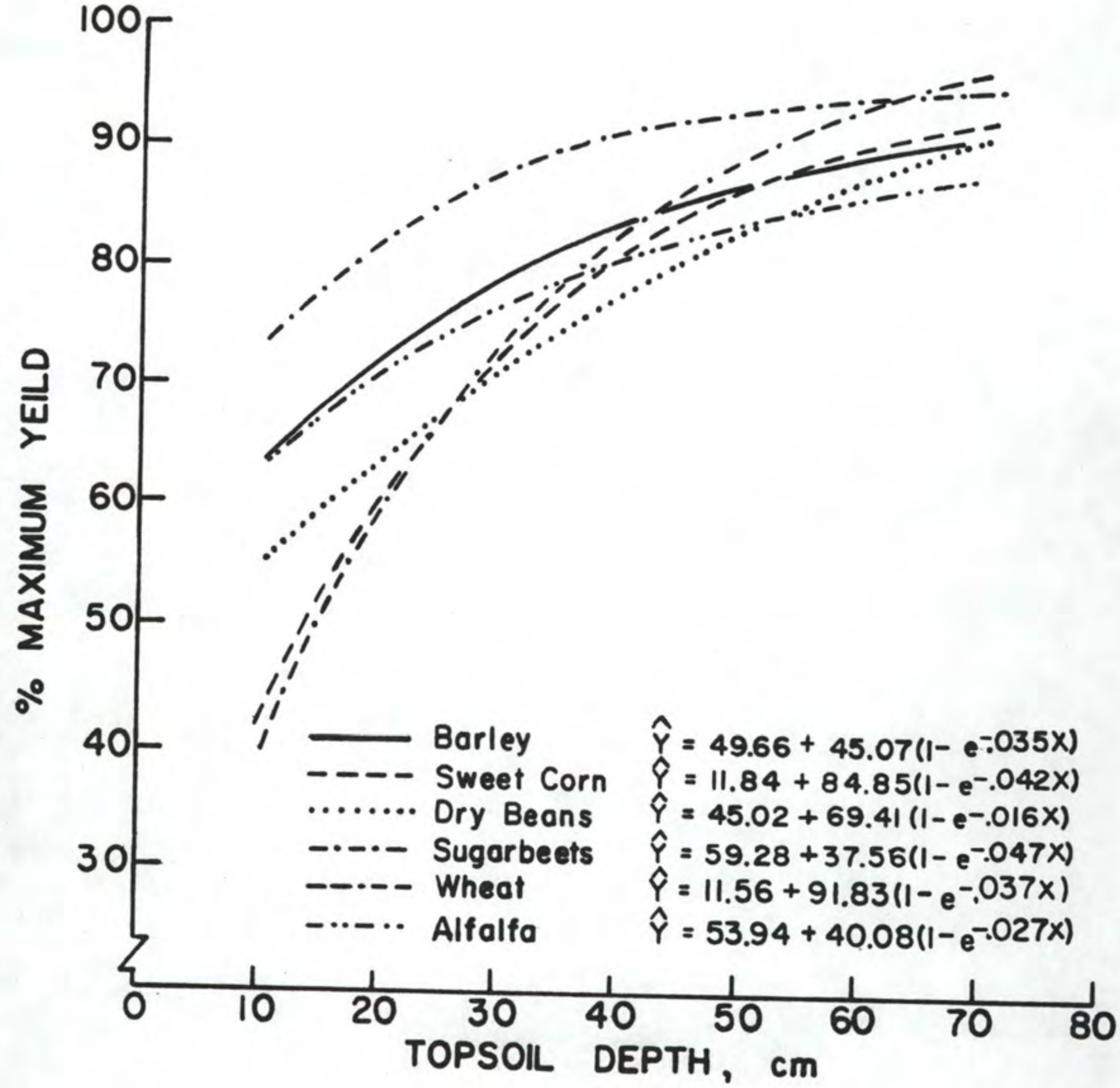

Figure 1. Effect of Topsoil Depth on Relative Crop Yield

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