Controlling erosion and sediment loss on furrow-irrigated land

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Erosion and sediment loss from irrigated land has been recognized as a serious problem for about 40 years. Only during the past 10 years has significant progress been made toward controlling such erosion. Carter (*5*) reviewed and evaluated information available before 1976 and proposed a set of guidelines for controlling erosion and sediment loss on furrow-irrigated land. Brown and associates (*4*) measured sediment inflows and outflows for two large irrigated tracts and provided information on sediment and phosphorus (P) concentrations in surface drainage waters or irrigation return flows (*6*). Sediment concentrations in return flows from these two large tracts ranged from 20 to 15,000 mg/l. Total P concentrations were proportional to sediment concentrations. Therefore, conserving sediment also conserves P.

Berg and Carter (*2*) conducted detailed investigations of water and sediment inflows and outflows from 50 furrow-irrigated fields. They concluded that an average of 50 percent of the water applied ran off the surface. Their data have been used to develop estimated sediment losses for different crops on various slopes along the furrow (*7*). Additional data have been collected and several computer models are being developed to provide better estimates of erosion and sediment loss.

During the past five years, considerable research has been directed toward evaluating present practices for reducing erosion and sediment loss on furrow-irrigated land. Initially, most of this research was directed at reducing the sediment concentration in irrigation return flows. Presently, greater emphasis is being placed on reducing erosion and sediment loss on individual fields. Along with the evaluation of known practices came the development and evaluation of new management alternatives for erosion and sediment loss control.

Here, we report the erosion control and sediment removal efficiencies for five practices and provide information on the advantages and disadvantages of each. We also present a brief summary of the application of these practices, along with some water management practices on a 1,600-ha irrigated basin and the resulting decrease in sediment loss. Third, we present the initial results of some research on the relationship of topsoil loss from erosion to crop yield decreases, work that is just beginning.

Procedures

The sediment removal efficiencies of sediment basins, minibasins, vegetative filters, straw in furrows, and a buried-pipe runoff control system were determined by measuring water and sediment inflows and outflows at specific frequencies throughout one or more irrigation seasons. We summarized data over each irrigation season; thus, results presented generally are seasonal averages. Continuous sampling and recording devices were used at some sites, but most of the measurements were made on grab samples and flow measurements taken weekly or biweekly. Detailed sampling to determine time of day or diurnal fluctuations indicated that time of day had little influence on results from drainage streams transporting runoff from several fields or farms. Measurements made on specific fields were made at regular intervals during each irrigation so that results could be summed and averaged over the entire irrigation.

We determined sediment concentrations by filtering known volume samples, collecting the sediment on a weighted filter paper, drying at 105 °C, and weighing the dried material. Water flow volumes were measured with wiers, flumes, or, in a few instances, with a current meter.

Some of the results have been published, and some are from recently completed investigations. Therefore, this paper is a current status report on erosion and sediment control technology for furrow-irrigated land.

The integrated impacts of applying the practices studied to a drainage basin are summarized for one 1,600-ha, furrow-irrigated basin. Results of this study are based on the net sediment outflow from the basin.

We determined the effects of erosion on sediment yields by comparing crop yields where topsoil depth was 30 to 38 cm, or about the same as when the land was first brought under cultivation, with yields where subsoils had been exposed. Subsoils were exposed because erosion had reduced topsoil depth sufficiently that plowing brought subsoil to the surface. The actual amount of topsoil mixed with subsoils at the upper ends

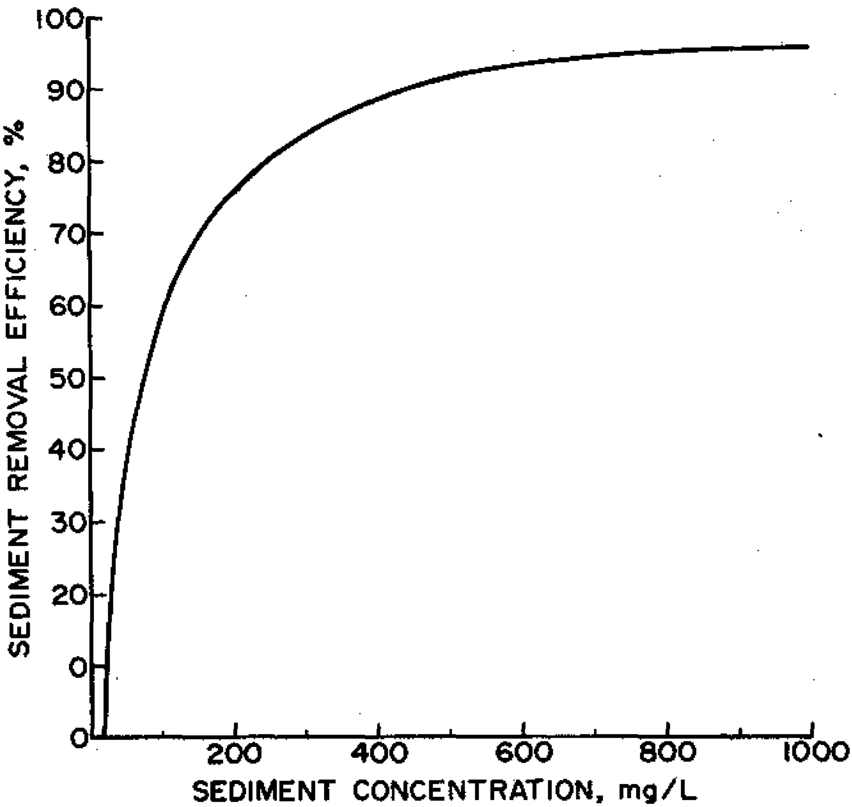

Figure 1. Efficiency of sediment removal basins in relation to sediment concentration in the inflow water, retention time greater than 2 hours.

of fields was not known. Therefore, results are tentative. Detailed investigations of erosion's effect on crop yields are underway.

Results and discussion

Sediment basins. Figure 1 shows a generalized relationship of results from detailed studies on the sediment removal efficiencies of many sediment basins. This relationship holds for silt loam soils and when the retention time is 2 hours or longer. Retention time is the time required for the inflow stream to fill the basin. The relationship shows that sediment basins remove more than 80 percent of the inflow sediment when the inflow sediment concentration is 250 mg/l or higher. The highest efficiency expected is about 95 percent, although we found some basins with efficiencies up to 98 percent when the inflow sediment concentrations were extremely high (Table 1).

Several parameters may alter the sediment removal efficiency of a basin. One is retention time. If the retention time is less than 2 hours for part of a season because the basin has partially filled with sediment or the stream size is unusually high part of the time, the seasonal efficiency may be a little lower than indicated by the generalized relationship (3). Inflow sediment concentration also affects the sediment removal efficiency. If these inflow concentrations are extremely high all season, the seasonal efficiency may be very high. Conversely, if concentrations are unusually low, seasonal efficiencies may be rather low. Thus, the second and subsequent sediment basins placed in series have low efficiencies until the first basin fills sufficiently so that the retention time drops below 2 hours and effluent sediment concentrations increase. A third parameter is the salt concentration of the water entering the basin (8). Efficiencies are significantly lower for water with very low salt concentrations. Finally, a fourth important parameter is soil texture. Efficiencies tend to be lower for finer textured soils, particularly where dispersion is extensive. Generally, eroded soil particles remain as small aggregates on silt loam soils.

Minibasins. Small sediment basins along the lower ends of fields that catch runoff water from 5 to 15 furrows are called minibasins (Figure 2). The sediment removal efficiency of minibasins follows the same general relationship presented for larger sediment basins. Usually, however, minibasin efficiencies are high early in the season because sediment inflow concentrations are high and retention time is often several hours.

Minibasins not only remove sediment from runoff water but also reduce erosion along the lower 5 to 15 m of furrow length. Many irrigated fields have increasing slopes along the lower ends of furrows because the drainage ditch has been maintained deeper than the furrow ends. Much of the sediment lost from fields is eroded from that portion of the fields. This property is called convex ends. As furrow stream velocity increases

Table 1. Seasonal sediment removal efficiencies of selected sediment basins.

Basin Identification	*Drainage Type*	*Sediment Removal Efficiency (%)*
M-1	Main drain	85
M-2	Main drain	92
F-1	Several fields	87
F-2	Several fields	87
S-1	One field	85
S-2	One field	76

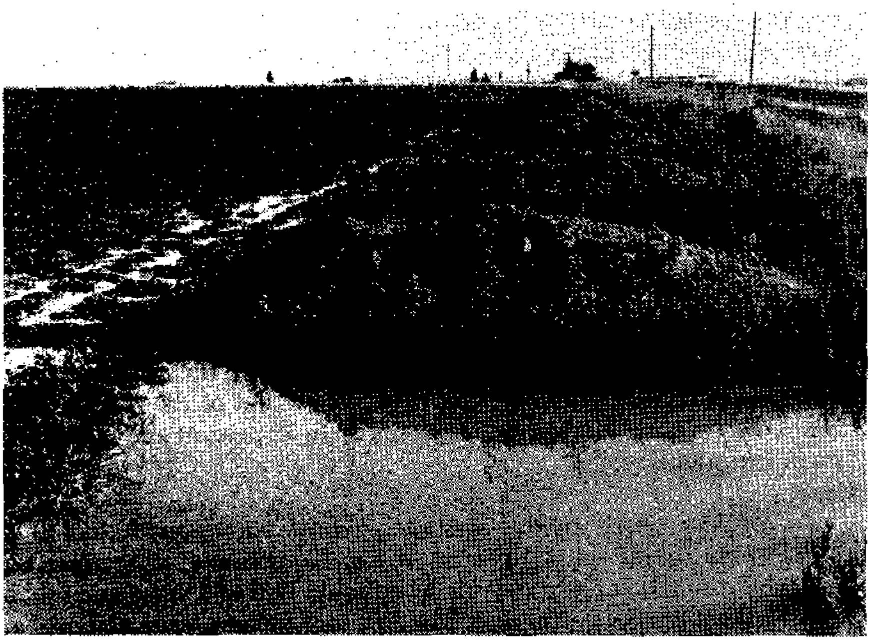

Figure 2. Minibasins along the lower end of a bean field. Each basin has a separate outlet into a ditch to the right.

along an increasing slope, its energy increases, causing erosion. Minibasins can correct the convex end problem and decrease erosion.

There are management requirements associated with the use of minibasins. One is that each minibasin needs a separate outlet into a drainage ditch. If water is allowed to flow sequentially from one minibasin to the next, the stream size soon becomes too large and efficiency decreases. Usually, when this is the case, basins wash out. Because of this requirement, minibasins occupy land that would otherwise be in crops. Thus, minibasins can reduce crop production on the field until they are filled with sediment and farmed in place. Also, minibasins often fill with sediment before the season ends, and heavy weed populations grow in the sediment. This requires some additional weed control the first season.

Vegetative filters. Most vegetative filters were cereal grains seeded along the lower ends of fields (Figure 3). Sediment removal efficiency varied widely, ranging from 0 to 70 percent. Fall-seeded cereals or perennial plants, such as grass or alfalfa left along the lower end of the field when alfalfa was plowed out in the normal rotation were most effective. Management is an important factor controlling efficiency. When furrows are pulled all the way through the filters, efficiencies are low. When furrows are pulled to the upper edge of the filter or only slightly into it, sediment settles at the upper end of the filter and runoff water erodes a new channel just upslope from the filter. Those filters with the highest efficiencies are on convex ends with furrows pulled about 2 m into them. Properly installed vegetative filters will remove 40 to 60 percent of the sediment from runoff water. They can reduce erosion along the lower ends of fields and correct convex ends.

Straw in furrows. Small quantities of straw placed in furrows along steep slope segments significantly reduce erosion. Arstad and Miller (*1*) demonstrated that straw placed in furrows reduced erosion to an acceptable level and increased water infiltration. Applying their method to only steep slope segments representing 10 to 20 percent of the furrow length can reduce erosion along these segments up to 90 percent and reduce sediment loss significantly.

Buried-pipe runoff control system. A new management tool is the buried-pipe runoff control system. It has the potential to increase crop production sufficiently to pay for installation in 6 to 8 years and add net income from the field after that. The first such systems were designed and

Figure 3. A vegetative filter comprised of spring wheat along the lower end of a bean field.

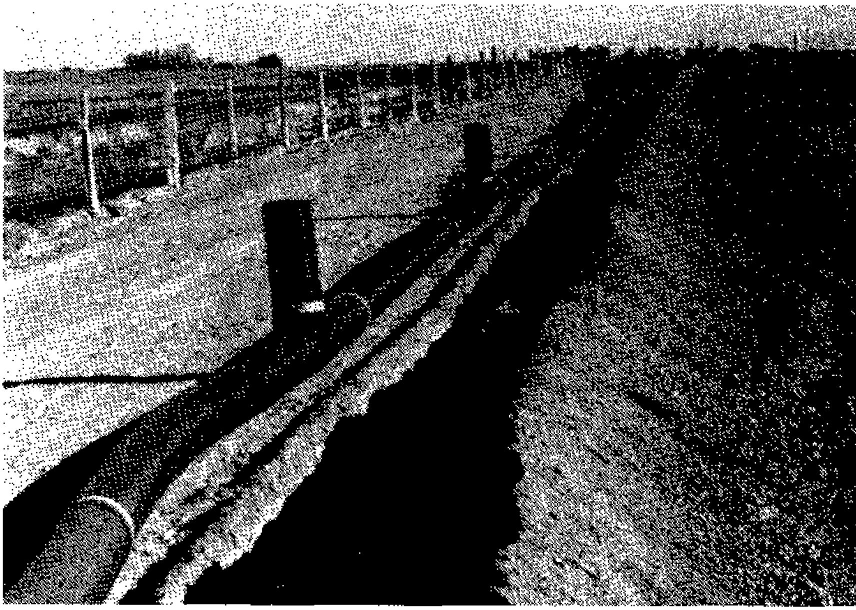

Figure 4. An assembled buried-pipe runoff control system ready for installation.

installed in 1978. Since then 18 additional experimental systems have been evaluated and numerous systems have been installed by farmers and contractors.

The system is comprised of a buried pipe that replaces the tailwater ditch. At intervals along the pipe, T-connectors are installed and a piece of pipe is placed vertically into the T-connector. These risers serve as outlets for minibasins and inlets into the buried line (Figures 4 and 5). Small earthen dams are installed immediately downslope from the riser-inlets to form the minibasins. Any kind of pipe can be used, but flexible polyethylene pipe is easy to install and usually among the lowest in cost.

Sediment removal efficiencies for these systems range from 80 to 95 percent, with a few exceptions, until the minibasins are filled with sediment. After that, the efficiency drops to the 70 to 90 percent range, but the sediment concentration in runoff water is much lower than before because convex ends have been corrected.

Buried-pipe runoff control systems are installed at the extreme lower ends of fields. Usually, they require only a little more area the first season than is used for the tailwater ditch. And after the convex end is corrected, crops can be seeded to the extreme end of the field and more area can be harvested than before the system was installed. Production from this increased area will increase net income sufficiently to pay for the system in 6 to 8 years with crops in Idaho.

Figure 5. Buried-pipe runoff control system after the first irrigation following installation.

Results from a 1,600-ha basin. The Snake River Soil Conservation District, the Soil Conservation Service, University of Idaho, Idaho Department of Health and Welfare's Division of Environment, and the Agricultural Research Service cooperated in installing the practices discussed here on a 1,600-ha furrow-irrigated basin. Sediment outflow was measured for a season before practices were installed. Then, practices were installed on farms and fields where applicable throughout the basin. Some practices were in place before the next irrigation season; some were installed before the second, subsequent season; and a few more were put in place between the second and third seasons.

Table 2. Sediment loss decreases with progressive application of erosion and sediment loss control technology on a 1,600-ha basin.

Season	*Water Outflow (million m³)*	*Sediment Loss (t)*	*Percent of 1977 Sediment Loss*
1977	10.02	8,709	-
1978	12.30	3,447	40
1979	11.59	1,769	20
1980	13.97	2,087	24

Table 3. Yield decreases resulting from topsoil loss along the upper ends of fields.

Crop	*Yield* Original Topsoil Depth	Exposed Subsoils	Percent Loss
	kg/ha		
Dry beans	2,140	1,557	27
Dry peas	2,430	1,945	23
	t/ha		
Sugarbeets	74	63	15
Alfalfa, 1st	9	6.5	28

Sediment loss from the basin decreased 80 percent in two seasons. Sediment concentration in the runoff water was lowest in the third season (Table 2). The larger volume of runoff in the last season accounted for a little greater sediment loss than the previous season.

Erosion-crop productivity relationships. Preliminary results show that significant crop yield decreases are associated with topsoil losses from erosion (Table 3). Yield reductions of up to one-third along the upper ends of fields represent a significant loss to farmers. We must apply all reasonable practices to prevent further erosion and subsequent yield losses.

Conclusions

Significant advances have been made in controlling erosion and sediment loss on furrow-irrigated land. The buried-pipe runoff control system is the most cost-effective practice evaluated to date. It, therefore, is the preferred practice in most instances, particularly where convex ends are present. Vegetative filters and minibasins are useful control practices, but both require more intensive management than the buried-pipe runoff control system. The two practices are considerably less costly, however, and thus should be considered as short-term controls. Placing straw in furrows on critical slope areas can be a useful control practice. Sediment basins will always have a place in sediment removal schemes on furrow-irrigated silt loam soils. They are costly to clean, but their use greatly reduces sediment loss into rivers and streams. Furthermore, when other practices fail, sediment basins are a good back-up control. Applying the practices available to a basin will decrease sediment loss about 80 percent. This represents a major step forward in soil conservation on furrow-irrigated land. Using the conservation technology available is important to avoid further crop productivity reductions from the loss of topsoil.

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