CONTROLLING EROSION AND SEDIMENT LOSS FROM FURROW-IRRIGATED CROPLAND

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ABSTRACT: Irrigation-induced erosion and subsequent sediment loss is a serious agricultural and environmental problem. Recent recognition of this problem has stimulated the development and evaluation of erosion and sediment-loss-control technology. Research results indicate that the application of the technology available today can reduce sediment loss by 70–100%. Important practices include irrigation-water management, sediment-retention basins, buried-pipe tailwater-control systems, vegetative filter strips, tailwater-recovery systems, keeping crop residues on the soil surface and in furrows, and implementing conservation tillage practices.

INTRODUCTION

Irrigation-induced erosion and subsequent sediment losses to rivers and streams cause agricultural and environmental problems. Sediment lost from irrigated fields pollutes streams, fills reservoirs, covers and destroys fish-spawning beds, reduces the quality of water for subsequent use, and reduces soil productivity (Carter 1990, 1993; Carter and Berg 1991). As water-supply utilization has increased, reuse has also increased, and as a result, water pollution is receiving more attention from all users. This increased attention has motivated legislative actions at the national, state, and local levels aimed toward preventing water pollution and removing various pollutants from runoff and discharge waters. Irrigation has been targeted as a major contributor to water pollution, and sediment in irrigation return flow has been identified as one of the most serious water pollutants. In response to this attention, considerable research has been directed toward controlling irrigation erosion to reduce sediment concentrations in irrigation return flows.

The seriousness of sediment pollution in irrigation return flow depends upon subsequent uses of the water, which in turn depends on the geographic area. Return flow water that will be used for subsequent surface irrigation in a low population density area may receive little attention even if sediment concentrations in it are several thousand mg/L. In contrast, a few hundred mg/L in irrigation return flow water can present a serious problem attracting much public attention, if that water is a drinking water source or if it is used for water-sport recreation near heavily populated areas.

Regardless of the water-quality problem it presents, sediment in irrigation return flow waters represents soil out of place that has been lost from its role to grow crops. We must implement erosion control technology in irrigated agriculture to save our natural soil resources and to reduce water

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pollution. Our efforts must be directed toward reducing within field erosion as well as to prevent soil loss from the field. The redistribution of topsoil caused by furrow erosion can severely reduce crop production. Much damage has already been done to the soil-resource base, and we must act quickly to curtail additional damage (Carter 1993).

The present paper reports results from research conducted on furrow-irrigation erosion rates and to evaluate erosion-control technology for furrow-irrigated cropland. The results reported are from a wide variety of research approaches applied to several geographic areas representing a broad range of soils and agricultural practices, crops, and levels of irrigation-water management.

FURROW-IRRIGATION EROSION STUDIES IN CALIFORNIA

Furrow irrigation is still the most widely practiced irrigation application method in California. This section presents sediment production investigations for two midseason irrigations in furrow-irrigated tomato fields on the west sides of the San Joaquin and Sacramento Valleys.

One tomato field was in the Panoche water district in the San Joaquin Valley and was monitored for tailwater production and recovery (Tanji et al. 1980). The supply water was obtained from the California Aqueduct through the Delta-Mendota Canal. This 69 ha (170 acre) field was divided into three subfields, I, II, and III, for cultural operations. All of the tailwater produced from subfield I was reused in subfields II and III. Table 1 presents measurements of tailwater production for a 3.9 ha (9.6 acre) portion of subfield I comprised of 63 furrows. There were 36 check dams in the supply ditch for subfield I. Typically, irrigation water was diverted into 55–65 furrows (4–6 checks) at a time, using 2–3 siphons of 38 mm (1.5 in.) diameter per furrow. The water was applied for about a 6–8 h duration for the 305 m (1,000 ft) run.

On-site measurements for turbidity were made with a HACH DR-EL portable meter. The turbidity of the supply water averaged 112 Jackson turbidity units (JTU). The tailwater was so turbid that a fourfold dilution with distilled water was required to obtain 2,240 JTU. The relationship between suspended solids (SS) in mg/L and JTU for a nearby drainage station is given in Fig. 1. A 112 JTU reading is comparable to about 180 mg SS/L.

The Panoche loam soil in this field did not appear to have much aggregation. It tended to slake upon wetting. With an increased time of travel and reduction of water flow velocities in the sump, the turbidity of tailwater decreased as a result of sedimentation to 300 JTU at the return flow sump.

Unlike the runoffs from flooded rice fields (Koluvek et al. 1993), the tailwater from this furrow-irrigated tomato field contained a substantial

TABLE 1. Tailwater Production Test in 68.8 ha (170 acre) Furrow-Irrigated Tomato Field in Panoche Water District, July 16, 1975

Water source (1)	Amount: m^3/ha (2)	Amount: acre-in./acre (3)
Applied water	952	3.75
Tailwater	229	0.90
Tailwater	24% of applied water	—

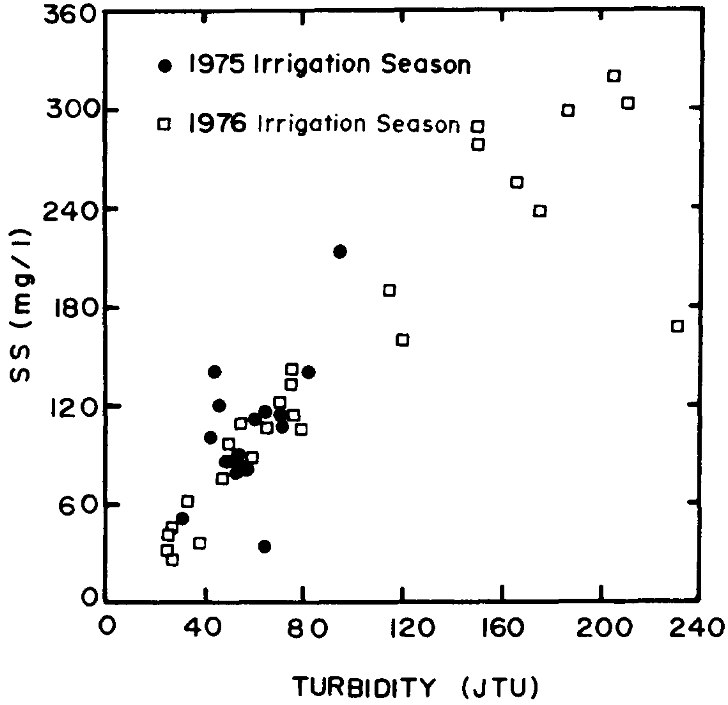

FIG. 1. Relation between Suspended Sediment (SS) and Turbidity for Station D-2 for 1975 and 1976 Irrigation Seasons

loading of suspended sediment. The results obtained from this tomato field clearly indicate that the tailwater recovery system contributes to more efficient water use as well as pollution abatement for sediments.

A second study on soil erodibility and sediment production was made near Dunnigan, Calif. in the Sacramento Valley (Tanji et al. 1981). The monitoring was done on a 12.2 ha (30 acre) portion of a 70 ha (173 acre) tomato field. The supply water was a 113 L/s (1,800 gal./min) well. Water was applied to the furrows through gated pipe. Intensive field tests were carried out by measuring water inflows and outflows and SS in furrows from 1/2 h to 2 h intervals over the duration of the irrigation.

The test section had 210 furrows with furrow lengths of about 379 m (1,245 ft) and a slope of 0.001. The inflow to the furrows ranged from 0.2 to 0.9 L/s (3–15 gal./min), as measured by the bucket-and-stop-watch method. V-notch weirs were installed at the end of individual furrows to measure outflow. A 0.6 m (2 ft) rectangular weir was installed in the return flow ditch and total outflow was measured every 1/2 h. Irrigation water was applied for 27 h and tailwater was produced for 18.5 h. The water supplied and runoff for this 12.2 ha (30 acre) tract are given in Table 2.

Frequent samples of the furrow outflow and inflow waters were obtained to determine SS. Table 2 gives a summary of the results. The SS concentration in the supply water from the well ranged from 1 to 2 mg/L. The initial tailwater produced from the furrows was very high in SS (4,500–10,300 mg/L) but within about 1/2 h the concentration dropped to 10 to 48

TABLE 2. Tailwater Production Test in 70 ha (173 acre) Furrow-Irrigated Tomato Field in Dunnigan, Sacramento Valley, California

	Test 1[a] (6/20–6/21/78)		Test 2[b] (7/22–7/23/78)	
Source (1)	SI units (2)	English units (3)	SI units (4)	English units (5)
Irrigation applied	762 m^3/ha	3.0 acre-in./acre	940 m^3/ha	3.7 acre-in./acre
Furrow runoff	229 m^3/ha	0.9 acre-in./acre	406 m^3/ha	1.6 acre-in./acre
Furrow runoff	30%		43%	
SS in supply water[c]	1.5 mg/L		5.0 mg/L	
SS in supply water	1.12 kg/ha	1.0 lb/acre	4.71 kg/ha	4.2 lb/acre
SS in furrow runoff	481 mg/L		171 mg/L	
SS in furrow runoff	117.71 kg/ha	105 lb/acre	67.26 kg/ha	60 lb/acre
SS in drain discharge[d]	887 mg/L		—	
SS in drain discharge	216.37 kg/ha	193 lb/acre	—	

[a] Irrigation after tillage.

[b] No tillage between irrigations.

[c] Wellwater.

[d] Pickup of SS in collector ditch from bank erosion and increased current velocity.

mg/L, giving an average of 481 mg/L. The SS concentration in the drain discharge averaged 887 mg/L. This increase in sediment concentration in the field return flow ditch as compared to the outlet from furrows was attributed to higher flow velocities in the ditch and the consequent erosion of the ditch channel.

The sediment load produced from this one irrigation over a 12.2 ha (30 acre) site was 1.5 Mg (1.6 tons) as measured at the rectangular weir in the return flow ditch, and 2.6 Mg (2.9 tons) as measured at the drain canal. The unit mass emission of SS in the surface runoffs during this irrigation was 188 kg/ha (105 lb/acre) at the rectangular weir and 216 kg/ha (193 lb/acre) at the drain canal. The applied water contributed only 1.1 kg/ha (1 lb/acre). This difference of 99 kg/ha (88 lb/acre) of sediment pickup in the freshly graded return flow ditch is substantial.

A second test was conducted in a 9.3 ha (23 acre) portion of this tomato field nearest the main drain. The total number of furrows involved was 162 with a length of 398 m (1,245 ft). The water applied and runoff are given in Table 2 with runoff representing 43% of the applied water.

The SS concentration in the irrigation water averaged 5 mg/L (Table 2) and in the tailwater from 30 to 1,410 mg/L or an average of 171 mg/L. On a unit surface area basis, 4.7 kg/ha (4.2 lbs/acre) of SS were introduced into the furrows and 67 kg/ha (60 lbs/acre) were discharged.

A comparison between these two sediment-production tests at Dunnigan showed that the sediment discharged from the first irrigation test in subfield I was about twofold greater than sediment produced from the second test in subfield II, mainly because this tomato field was cultivated periodically up to the first test, but not between the first and second tests. The sediment production was smaller in the second test because the soil surface was undisturbed. The other significant finding was the substantial pickup of sediments between outflow from furrows and discharge into the drain canal from increased current velocity and channel erosion of a freshly constructed drain channel.

EROSION AND SEDIMENT LOSS STUDIES IN IDAHO

Many erosion and sediment loss studies have been conducted on erosive silt loam soils in southern Idaho during the preceding 20 years. The first study measured sediment inflows and outflows for two large irrigated tracts. Sediment concentrations ranging from 20 to 15,000 mg/L were measured. The seasonal sediment loss from fields into drains on a 65,350 ha (161,500 acre) tract was 4.0 Mg/ha (1.78 tons/acre). Most of this sediment deposited in drains requiring mechanized removal. The seasonal loss from an adjacent 82,030 ha (203,000 acre) tract was 1.42 Mg/ha (0.63 tons/acre) (Brown et al. 1974; Carter 1976).

Individual irrigation and seasonal sediment losses have been measured on more than 100 furrow irrigated fields over the preceding 20 years in attempts to relate furrow slope, furrow stream size, run length, tillage management, crop, and residue to sediment loss (Berg and Carter 1980; Carter and Berg 1983, 1991). Results from these studies have been used to develop tables of expected sediment losses for different slopes, crops, and run lengths, and depending upon the presence or absence of a convex end condition (Table 3).

The presence of a convex end, which is a progressive slope increase with distance over the last 12–18 m (40–60 ft) into the tailwater ditch (Carter and Berg 1983), significantly increases sediment losses. These convex ends have developed from maintaining the tailwater ditch 150–300 mm (6–12 in.) deeper than the ends of the furrows. This causes erosion first by headcutting where the water enters the ditch, and head-cuts formed there move up slope. Over time the slope of the lower end of the field increases toward the tailwater ditch, and erosion rates are greater on these increasing slopes than on fields without the convex end problem.

General average values (Table 3) are useful for developing predictive models and mathematical relationships (Kemper et al. 1985), but we must recognize that these data are highly variable. Therefore, predicted sediment losses may range widely from measured values on any particular field.

Sediment losses are greater where water application is with gated pipe or from an earthen ditch with cutouts than with siphon tubes because of greater stream flow variability for the first two methods (Trout and Mackey 1988).

Run length also influences sediment loss. Some irrigators use smaller furrow streams for shorter run lengths, thereby reducing erosion and subsequent sediment loss. Others, however, use streams about the same size on both short and long runs. This allows more sediment to reach the lower ends of the short furrows, and sediment loss is higher than for longer runs.

There are several recognized reasons for the variability in sediment losses from fields. Slope often varies over the run length. The previous crop has an impact on erosion and sediment loss, and usually was not considered when selecting fields for study. Tillage management, which influences erosion and sediment loss, also varies from field to field. Irrigation management, including stream size and its adjustment during an irrigation, irrigation duration, and number of irrigations varies with the operator and influences erosion and sediment loss. There are also other, not completely understood, parameters that influence sediment loss.

FURROW-IRRIGATION EROSION STUDIES IN WYOMING

Fornstrom et al. (1985) reported results from field studies of furrow irrigation in Wyoming. They studied a large number of fields including

TABLE 3. Generalized Sediment Yields for Different Crops, Convex Ends and Increasing Field Slope Irrigated from Concrete-Lined Ditches with Siphon Tubes, Based on Over 100 Trials (Runlength = 201 m (600 ft)

	AVERAGE FIELD SLOPE (%)[a]											
	0.5–1			1–2			2–3			>3		
Crop (1)	N (2)	M (3)	S (4)	N (5)	M (6)	S (7)	N (8)	M (9)	S (10)	N (11)	M (12)	S (13)
Alfalfa (tons/acre)	0.0	0.0	0.0	0.7	0.9	1.2	2.3	2.9	4.1	5.6	7.0	9.8
Alfalfa (Mg/ha)	0.0	0.0	0.0	1.6	2.0	2.7	5.2	6.5	9.2	12.6	15.7	22.0
Cereal grain or peas (tons/acre)	1.1	1.3	1.8	3.2	4.0	5.6	6.4	8.0	11.2	10.4	13.0	18.2
Cereal grain or peas (Mg/ha)	2.5	2.9	4.0	7.2	9.0	12.6	14.3	17.9	25.1	23.3	29.1	40.8
Dry beans or corn (tons/acre)	2.5	3.1	4.4	8.7	10.9	15.3	18.4	23.0	32.2	28.0	35.0	49.0
Dry beans or corn (Mg/ha)	5.6	7.0	9.9	19.5	24.4	34.3	41.2	51.6	72.2	62.8	78.5	109.8
Sugar Beets (tons/acre)	3.2	4.0	5.6	12.1	15.2	21.2	26.4	33.0	46.2	44.0	55.0	77.0
Sugar Beets (Mg/ha)	7.2	9.0	12.6	27.1	34.1	47.5	59.2	74.0	103.6	98.6	123.3	172.6

[a] N = no convex end; M = moderate convex end; S = severe convex end.

different slopes and different soil types. They concluded that soil loss is highly dependent on soil types, furrow flow rate, furrow length and slope, and furrow type. These findings agree with those reported by Carter (1976). They further point out that flow rate, furrow type, and furrow length can be adjusted and considered in the design and operation of an irrigation system. Their results showed that soil loss from wheel-track furrows were 30% greater than from soft or non–wheel-track furrows.

EROSION AND SEDIMENT LOSS STUDIES IN WASHINGTON

Several studies of furrow erosion have been conducted in Washington. King et al. (1982) reported a significant relationship between total phosphorus and total sediment in runoff water from furrow irrigation. They measured seasonal sediment losses ranging from 1 to 30 Mg/ha (0.5 to 13.5 tons/acre). They suggested the following on-farm practices should be applied to reduce sediment losses: (1) Reduce furrow stream size; (2) reduce total water application; (3) convert to sprinkler irrigation; (4) install sediment ponds; (5) redesign existing sediment ponds; and (6) use filter strips.

Miller and Aarstad (1983) reported the effects of combined tillage and residue treatments on furrow erosion. They found that both wheat and corn residues in the furrows reduced erosion and sediment loss, and that only small quantities of residues were needed to significantly reduce sediment loss.

PRACTICES FOR CONTROLLING EROSION AND SEDIMENT LOSSES

During the preceding 20 years, several research projects have been conducted to develop and evaluate different management alternatives for reducing water erosion and sediment loss from furrow-irrigated land. The efficiencies of various "best management practices" (BMPs) for reducing sediment losses have been established, and based on those efficiencies and cost considerations, BMPs can be selectively applied by farmers. These BMPs have been applied in various combinations to determine potential reductions in sediment loss by applying best known technology. The BMPs will be discussed followed by a discussion of their application to watersheds.

Sediment Retention Basins

Several types of sediment retention basins, ranging from ponds of 0.4 ha (1 acre) or more located on a main drain to minibasins receiving runoff from only 4 or 5 furrows, are effective for reducing sediment loss. Each has its best application. Large sediment basins on main drains are often formed by constructing an earthen dam across the drain at a suitable site and installing a proper outlet. These large basins have sediment removal efficiencies of 65–95% depending upon the sediment concentration in the inflow water and the time required for water to pass through the pond (Brown et al. 1981). Smaller sediment retention basins are often excavations receiving runoff water from one or more fields. Their sediment-removal efficiencies range from 75% to 95%. Minibasins are formed by excavating a sequence of small basins along the lower end of a field or by placing earthen checks across a tailwater drainage ditch. With controlled outlets into a separate drainage ditch for each minibasin efficiencies range from 80% to 95%. If water is allowed to pass from one basin to the next, efficiencies are only 40% to 70%. The accumulated flow volume sometimes destroys the checks and basins are washed out under these latter conditions (Brown et al. 1981; Carter and Berg 1983).

Another type of minibasin is the "I slot" or "T slot." These are slots excavated with a backhoe in the tailwater drainage ditch in the shape of an I or T as the names indicate. The first is a rectangular trench about 2 m long. The second is a similar trench with a cross trench about 1.5 m in length at the downstream end of the first trench. As drainage water passes down the drainage ditch, the flow velocity is slowed down by these excavations, and sediment settles out into them. The efficiencies of these basins are 40–70%, or the same as for minibasins where the tailwater flows sequentially through the entire series. There is no hazard that I or T slots will wash out because they are below the bottom of the drainage ditch.

Buried-Pipe Erosion and Sediment-Loss-Control System

An erosion and sediment-loss-control system comprised of a buried drain pipe along the lower end of a field with vertical inlets at intervals was developed by Carter and Berg (1983). The first season these vertical inlets serve as outlets for minibasins. Small earthen dams or checks are constructed across the lower end of the field perpendicular to a berm along the lower field end and extending 2–5 m (6–15 ft) into the field, immediately downslope from each vertical inlet into the buried pipe (Fig. 2). This system was developed to correct convex end problems. As the minibasins fill with sediment, a convex-end problem can be corrected, erosion on the convex end is decreased, and more land can be cropped because the tailwater ditch has been replaced by the buried pipe (Fig. 3). This BMP has a sediment-removal efficiency of 90–95% while minibasins are filling with sediment and about 70% after they have filled.

The advantages of buried-pipe erosion and sediment-loss-control systems can be recognized by understanding the processes involved. Therefore, the following discussion is provided to assist in that understanding. When a system is first put into operation, sediment eroded from the upslope edge of the convex end settles into the minibasins along with sediment reaching

FIG. 2. Buried Pipe Runoff and Sediment Control System in Operation

FIG. 3. Corrected Convex End Resulting from Installation of Buried Pipe Runoff and Sediment Control System

the lower end of the furrow from erosion further upslope. As the minibasin fills with sediment the erosion from the convex end decreases until it is eliminated by the elimination of slope change. From that point, the only sediment reaching the lower end of the furrow is that derived from upslope erosion that reaches the lower end of the furrows. This quantity of sediment is generally much less than when erosion was also occurring on the convex end. Basically, the process is one of hydraulically leveling the lower end of the field. This process continues, at a slower rate than initially, for years, gradually moving further upslope as sediment continue to settle out on the lower end of the field. The extent of the leveling can be controlled by adjusting the elevation of the inlets to the buried pipe. these systems should function for many years; the oldest continued to function well 19 years after installation.

The initial cost of the buried-pipe erosion and sediment-loss-control system is higher than for some other practices, but it has the potential of paying for itself in 4–8 years. Correcting the convex end and eliminating the tailwater ditch adds productive area to fields. The increased production from this added area increases income from the fields, which offsets the initial installation costs and adds to net return from the fields for future years (Carter and Berg 1983).

Vegetative Filter Strips

Strips of cereal, grass, or alfalfa seeded along the lower end of row crop fields can reduce sediment losses by 40–60% depending on the sediment load in the runoff water, the placement of the vegetative filter strip, and how far furrows are made into the strip (Fig. 4). These vegetative filter strips can be harvested for some financial return from the land although yields per unit area are usually only 50–70% of field yields for the same crop. Such vegetative filter strips can also be placed along the upper ends of fields to reduce erosion where furrow streams are largest. Basically, this application is to reduce energy of the relatively larger furrow stream at the upper end of the fields.

FIG. 4. Vegetative Filter Strip Installed on Sugar Beet Field to Reduce Sediment Loss

Vegetative filters must be properly installed and managed if they are to be an effective BMP. They are a relatively low-cost alternative, but their effectiveness is less than that of most other BMPs, and they can take land out of production.

Irrigation-Water Management

There are a number of irrigation-water-management practices that can reduce sediment loss. Blocking furrow ends to increase infiltration and reduce runoff can be effective where furrows are rather large and stream size carefully controlled. In some areas, the lower 25–30% of the field is graded to a flatter slope to increase infiltration and decrease runoff. This practice also increases sedimentation, thereby reducing sediment loss. Adjusting the furrow inflows one or more times during the irrigation can also reduce sediment loss. Usually furrow stream sizes can be reduced after the stream has reached the lower end of the furrow.

Tailwater Reuse System

A tailwater catchment basin equipped with a pump and pipeline to return tailwater to the supply at the head of the field or to a different field provides 100% control of the sediment loss because no water is allowed to leave the system. The catchment basin serves as a sediment pond, and will require cleaning the same as sediment retention basins. These systems, known as tailwater-recovery pumpback systems, were first developed to improve irrigation efficiencies and conserve water. The sediment-loss control is a secondary benefit.

Crop Residues in Irrigation Furrows

Placing small amounts of cereal grain straw, corn stalk residues, and other plant residues in furrows can significantly reduce erosion and sediment loss (Aarstad and Miller 1981; Miller and Aarstad 1983). Berg (1984) applied small amounts of straw in furrows on 4–5% sloping furrow segments in an attempt to control erosion from those segments and deposition on downslope segments of lower slope. This practice not only controlled erosion and deposition but also improved irrigation uniformity and markedly increased corn silage yield. Brown and Kemper (1987) successfully applied this same approach to dry bean fields with slopes ranging from 1.9% to 3.9%. Erosion and sediment loss were decreased and bean yields were increased.

Conservation Tillage on Furrow Irrigated Land

Carter and Berg (1991) initiated the development of conservation tillage systems for furrow-irrigated land for erosion control in late 1985. They have demonstrated that no-till systems can be effectively used for some crops and reduced tillage systems can be effectively used for others. They suggested that cropping sequences could be altered in an attempt to reduce the number of tillage operations to a minimum over a rotation cycle, and demonstrated that this approach not only reduced erosion and sediment loss but also increased net income to farmers. Crop yields and quality were the same for traditional and conservation tillage systems. Farmers saved money by doing only about one-fourth as many tillage operations over a five-year rotation. The savings were reflected in net profit increase of \$125 ha^{-1} or more each year over the five-year period. Soil erosion was essentially eliminated with some of the conservation tillage systems they introduced.

Applying conservation tillage systems is the best BMP for erosion control on irrigated land because these systems reduce erosion and keep topsoil in place rather than just reduce sediment loss. Some of the control practices discussed earlier function primarily to reduce sediment loss from the lower ends of the fields. Further development and evaluation of conservation tillage systems are in progress.

APPLYING BMPS TO IRRIGATED WATERSHEDS

LQ Drain Evaluation

A 1,336 ha (3,300 acre) furrow irrigated watershed draining into the Snake River in southern Idaho was studied during the period 1977–80. Earlier measurements of high sediment losses made in 1972 led to selecting this particular watershed for study. All drainage water enters the Snake River at one point where water and sediment outflows were measured. The watershed comprised 25 farming units. Water and sediment inflows and outflows were measured for the 4 year period. The first study year, 1977, was considered the baseline year, but it was a drought year and water delivery was 20–40% lower than normal. Most BMPs discussed earlier, except conservation tillage and placing residue in furrows, were applied on fields, farms, and on the main drain. The BMPs applied to each particular farm or field were selected through discussions with farmers and an evaluation of which BMPs appeared most promising on each field and farm. In addition to the BMPs discussed earlier in the present paper, improved water conveyance and control structures, and improved water-management practices including using gated pipe to shorten run lengths, and some improved irrigation systems were installed. Vegetative filter strips and sediment retention basins comprised most BMPs applied.

The application of these BMPs as best available technology did significantly reduce sediment loss from the watershed (Table 4). Two large sediment ponds on the main drain accounted for much of the reduced sediment loss. The slight increase in sediment loss in 1980 over 1979 resulted from greater water outflow at a lower sediment concentration in 1980 compared to 1979.

TABLE 4. LQ Drain Flow and Sediment Discharge to Snake River

Season (1)	Total outflow ($m^3 \cdot 10^3$) (2)	Sediment loss Mg (3)	Sediment loss as percent of 1972 (4)	Sediment loss as percent of 1977 (5)
1972	10,855	11,385	200	—
1977	10,084	8,709	76	100
1978	12,304	3,447	30	40
1979	11,595	1,769	16	20
1980	13,969	2,086	18	24

It was unfortunate that the baseline year was one of two water-short years in the 72 year period the watershed has been irrigated. Return flow that year was the lowest of the study years. Perhaps 1972 should have been used as the baseline year. Even greater BMP benefits were evident from comparing sediment losses in 1978, 1979, and 1980 to those in 1972. Regardless of which year was used as a baseline, the BMP's applied dramatically reduced sediment loss from the watershed. Each successive year, as more practices were installed on the watershed, the sediment concentration in the runoff water was decreased. The study shows that the application of known erosion and sediment-loss-control technology can effectively control sediment loss by 75% from furrow-irrigated land.

Rock Creek Rural Clean Water Project Watershed

The Rural Clean Water Act Program project was initiated in 1981 in south-central Idaho. This watershed comprises about 18,225 ha (45,000 acres) of furrow-irrigated cropland. BMPs were applied to additional farms and fields each year through 1990. A change in thinking based upon new research results led to the approval of conservation tillage systems as a BMP for the final three years of the project.

The project area was initially divided into subbasins according to erosion severity. The most critical subbasins received higher priority for installing BMPs. All of the control practices discussed earlier were applied on a farm plan basis similar to the program for the LQ Drain project. Sediment basins, irrigation water management, and vegetative filters comprised the majority of the BMPs. By the end of 1990, sediment loss into Rock Creek and subsequently into the Snake River had decreased by 75%. Those subbasins treated most intensively exhibited even greater reductions in sediment loss. A beneficial off-site benefit was a tremendous enhancement of the fisheries in Rock Creek.

The impact of introducing conservation tillage practices as a BMP was very positive. Trends in erosion and sediment loss indicate that sediment loss from the Rock Creek Basin will be decreased to only 15–20% of the 1981 level by 1995. Results from the Rock Creek project are having a positive impact on other areas in southern Idaho with similar serious erosion and sedimentation problems. Several new state-funded erosion-control projects have been initiated in the preceding five years. These projects are bringing about significant progress in the application of erosion and sediment control technology (Rock Creek Report 1991).

EROSION AND SEDIMENT LOSS

Research and technology application through the 1970s and early 1980s were directed toward reducing sediment losses to rivers and streams. Hence, much of the available information from these years concerns trapping sediments to prevent them from polluting waters. There are costs associated with the initial installation and maintenance of sediment trapping BMPs, and many farmers cannot afford or are not willing to spend resources for such practices, without cost sharing from outside sources.

Only a portion of the damage caused by erosion is represented by the sediment that exits furrow-irrigated land. Tragic crop-yield reductions have resulted from the dynamic erosion and sedimentation processes along irrigation furrows (Carter 1993). Brown (1985) has shown that severe erosion occurs along upper length segments of furrows and sedimentation occurs along length segments further down the furrows. What happens along any furrow segment varies with each irrigation. Carter et al. (1985) concluded that the redistribution of topsoil from upper to lower ends of fields by this erosion and sedimentation process markedly reduced crop yield potential up to 25% in about 85 years. Controlling erosion of upper ends of furrows is the only way to limit this negative effect on crop-yield potential. Hence, future research efforts need to focus on erosion control more than on sediment-loss control. Conservation tillage on irrigated land has great potential to provide this erosion control (Carter and Berg 1991).

CONCLUSIONS

Irrigation-induced erosion is a serious environmental problem needing continued research and demonstration aimed toward prevention. For many years, the problem was unnoticed, while each year an additional increment of damage and loss resulted. Research during the preceding 20 years has led us to the threshold of major advances in erosion control and the prevention of sediment loss into rivers and streams. The potential is high for controlling furrow erosion, but continued extensive and intensive research will be required to develop needed technology to accomplish these major advancements. Programs providing education, technology transfer, and financial incentives will be needed to get farmers to apply conservation practices to control irrigation-induced erosion and associated sediment pollution.

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