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Seasonal trends in furrow irrigation erosion in southern Idaho

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Abstract

A study was conducted to measure the seasonal irrigation furrow erosion pattern in the absence of cultivation and a growing crop. This erosion pattern was compared to those of previous measured plot experiments for different years in the presence of cultivation and a growing crop. Erosion for sugarbeets, corn and beans was low early in the season and increased to a maximum during the same 3-week period, from 24 June to 10 July over several years. Erosion decreased as the irrigation season progressed after the erosion peak. The erosion pattern from the uncultivated, non-cropped plots resembled the pattern from previous studies on cropped soil with the maximum erosion occurring about the same time of season. The pattern trends differed only after peak erosion. For the cropped plots, there was a sudden erosion decline after peak erosion, followed by a continual gradual decrease. In contrast, for the uncultivated, non-cropped plots, there was a sudden erosion decline after peak erosion, followed by a gradual increase in erosion. Although the seasonal erosion pattern cannot be completely explained, it is important to report it because of the implication for erosion modeling. Sediment loss rates measured from these soils in southern Idaho in late June or early July would significantly overestimate seasonal erosion, whereas sediment loss rates measured in May or early June or after mid-July would underestimate seasonal erosion. These results show that researchers cannot rely upon a one-time measurement for model validation if attempting to predict irrigation furrow erosion over an entire irrigating season.

Keywords: Aggregate stability; Crop residue; Headcuts; Infiltration; Runoff; Sediment concentration; Sediment loss

1. Introduction

Many furrow irrigation erosion and sediment loss studies have been conducted in southern Idaho during the past 15 years (Berg and Carter, 1980; Brown, 1985; Kemper et al., 1985;

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Brown and Kemper, 1987; Brown et al., 1974, 1988; Sojka et al., 1992; Lehrsch and Brown, 1995). Sediment losses have been measured from fields of sugarbeets, dry beans, corn, potatoes, wheat and barley (*Beta vulgaris* L., *Phaseolus vulgaris* L., *Zea mays* L., *Solanum tuberosum* L., *Triticum aestivum* L. and *Hordeum vulgare* L., respectively) (Berg and Carter, 1980). Studies have been conducted to determine the effect of soil compaction by farm implement wheels in furrows (Brown and Kemper, 1987) and the effect of placing crop residues in furrows on furrow erosion and sediment loss (Brown et al., 1974). Other studies have related to erosion and sediment loss, stream size, slope, crop and tillage practices (Berg and Carter, 1980). During the conduct of most of these studies, the erosion and sediment loss changed during the irrigation season, usually decreasing during the latter part of the season (Brown et al., 1974; Berg and Carter, 1980; Kemper et al., 1985).

Several explanations have been offered for these seasonal changes in erosion and sediment loss. One has been the discontinuing of cultivation by farmers about mid-season. Another has been that leaves of maturing plants drop into or hang down in furrows and dissipate some energy of the flowing water, thus reducing energy for erosion. A third is that roots cover the sides and bottoms of furrows, serving as vegetative structures against which the flowing water could dissipate its energy, thus decreasing its erosive potential (Sojka et al., 1992).

The general perception has been that furrow erosion was highest the first irrigation after tillage, furrowing, or cultivating. However, some observations were inconsistent with that pattern. Therefore, we studied the seasonal erosion pattern of furrow irrigation, including erosion of furrows on non-cropped plots, in a way that would be free of these effects.

2. Study methods

Sediment loss data for a number of replicated field experiments (Berg and Carter, 1980; Brown, 1985; Brown and Kemper, 1987; Sojka et al., 1992; Lehrsch and Brown, 1995) were evaluated for seasonal trends. These experiments included several different crops, different seasons, a range of slopes and different soil conditions. All of these experiments were conducted on plots growing crops. Therefore, crop influences on sediment loss were present. On these previous experiments, each test furrow was used for every irrigation during the growing season. In contrast, each test furrow in this replicated study was used only once during the growing season for the non-cropped 1988 experiment which was not cultivated.

The effect of crops on sediment loss was eliminated by conducting erosion and sediment loss measurements on non-cropped plots. The site selected for this experiment was one that had been previously studied by the USDA Water Erosion Prediction Project (WEPP) team as one of the many U.S. sites used to develop a new process-based water erosion equation. Erosion control studies that demonstrated how placing small amounts of straw in furrows reduced erosion, increased infiltration, and increased bean yields had also been conducted at this site (Brown and Kemper, 1987). The study area had two slope sections, 1.6% and 4.0%. These two slopes provided an opportunity to simultaneously evaluate furrow erosion for two different slopes on each furrow. Soil at the site was a Portneuf silt loam, *Durixerollic Calciorthids*.

The plot area was disked and furrowed in the fall of 1987. Furrows for this study were made with the same equipment as those in some of the earlier studies reported. Thereafter, the area was kept free of vegetation with contact herbicides. No additional tillage or cultivation was performed.

On 18 May, 21 June, 6 July, 26 July, 8 August, and 17 August 1988, randomly selected sets of four adjacent furrows, not previously irrigated, were irrigated for 6.5 h. During these irrigations, flows were measured using small trapezoidal furrow flumes (Brown and Kemper, 1987) and water samples were collected from each furrow below each slope section to determine sediment concentration. The inflow to the upper 1.6% slope section was maintained at 11.4 l min^{-1} (3 gal min^{-1}). The measured flow leaving that 30.4 m (100 ft) section was the inflow to the lower 4% slope section. The inflows into the lower slope section ranged from 6.4 to 6.8 l min^{-1} (1.7 to 1.8 gal min^{-1}).

One-liter (0.26 gal) water samples were collected at 15-min intervals the first 2 h, at 30-min intervals the next 2 h, and at 60-min intervals for the remainder of each irrigation. These samples were transported to the laboratory, vacuum-filtered through preweighed filter paper, and the collected residue was oven-dried and weighed to determine sediment concentration. The sediment concentration and flow volume for each time interval were used to calculate sediment loss from the respective section of the field. Sediment loss per irrigation from plot areas was measured and used as the indicator of erosion.

The data for this study were obtained as averaged values over irrigation duration and furrow length. For irrigation duration, the effects of sorptivity and initial soil water content can be taken as negligible.

3. Results and discussion

In the first stage of this study, we evaluated sediment loss data from several previous irrigation furrow erosion studies to summarize the seasonal patterns. Results are reported for several years and several crops (Fig. 1). Early season erosion and sediment loss were lower than at mid-season when peak erosion and sediment loss occurred. Following this peak, erosion and sediment loss decreased. The decrease late in the season had been reported several times (Brown et al., 1974; Berg and Carter, 1980; Kemper et al., 1985).

Erosion for sugarbeets, corn and beans was low as the season began (Fig. 1). The irrigation season started during April for sugarbeets, May for corn, and June for beans. Even though irrigations for the different crops began at different times, the maximum erosion for all three crops occurred during the same 3-week period, from 24 June to 10 July. Aggregate stability changes that occur in the Portneuf from April to June (Bullock et al., 1988) do not explain the high erosion rates observed in late June and early July. From April to June, the Portneuf silt loam's cohesion, measured using aggregate stability, often increases (Bullock et al., 1988; Lehrsch and Brown, 1995) which would tend to decrease rather than increase erosion rates (Kemper et al., 1985). Results from this study tend to indicate that this cohesion recovery has not fully taken place or there are other over-riding factors involved. As the irrigation season progressed, erosion decreased. This decrease in erosion can be partly attributed to increased crop maturity and aggregate stability. The large sugarbeet leaves hang into the furrows to increase both the wetted perimeter and infiltration, thus reducing runoff and lessening erosion (Brown, 1985; Sojka et al., 1992). This decrease in erosion also occurs to a lesser extent with the lower, older corn and bean leaves dying and falling

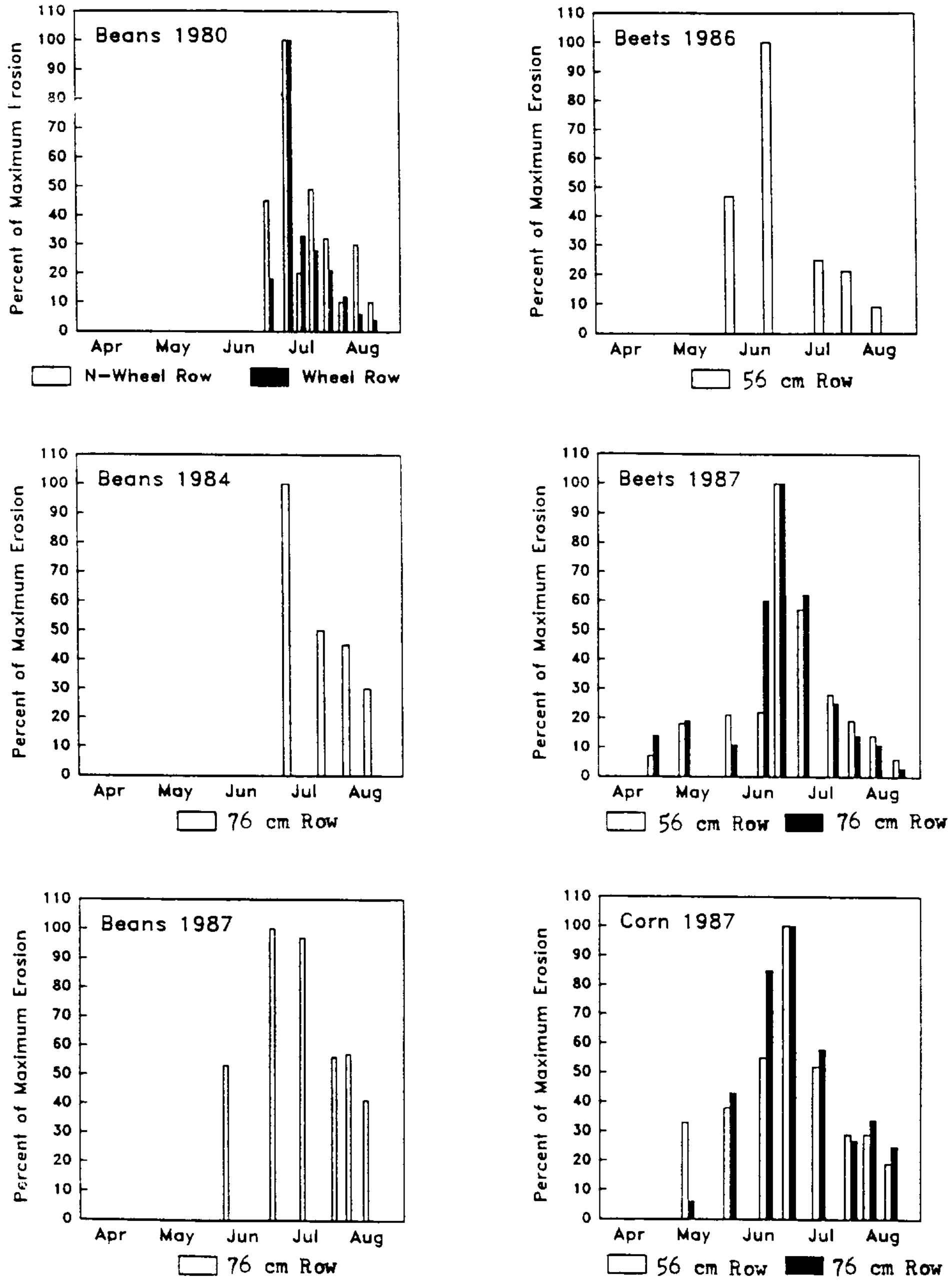

Fig. 1. Seasonal soil erosion patterns for sugarbeets, corn and dry beans as indicated by sediment loss.

Table 1
Average flow and sediment loss data from 30.4 m (100 ft) sections of furrows at a 1.6% slope. The area was not cropped or cultivated and each test furrow was irrigated only once

Irrigation number	Date	Flow rate		Infiltration rate		Sediment loss	
		On (l/min)	Off (l/min)	(l/min)	(%)	Rate (kg/furrow)	% of maximum (%)
1	18 May	11.4	6.8	4.6	43	18.4	70
2	21 Jun	11.4	6.4	5.0	46	26.4	maximum
3	06 Jul	11.4	6.6	4.8	45	7.2	27
4	26 Jul	11.4	6.5	4.9	45	10.9	41
5	08 Aug	11.4	6.7	4.7	43	13.4	51
6	17 Aug	11.4	6.8	4.6	43	14.6	55

into the furrows. The continued increase in aggregate stability or cohesion from a low in the spring to a maximum in the fall (Bullock et al., 1988; Lehrsch and Jolley, 1992) would result in less aggregate breakdown with fewer relatively small aggregates subsequently entrained in the furrow stream.

Results from the 1988 experiment on non-cropped plots showed that erosion and sediment loss for the 1.6% slope section was highest for the 21 June irrigation (Table 1). Interestingly, infiltration was also highest on that date. One would expect sediment loss to be inversely proportional to infiltration because increased infiltration results in reduced runoff. Also, increased infiltration reduces the furrow stream's sediment carrying capacity as well as the shear force exerted on the furrow's wetted perimeter (Lehrsch and Brown, 1995). This simultaneous occurrence of the maximum sediment loss with the highest infiltration indicates that the erosion and sediment losses were not merely an artifact related to increasing or decreasing runoff volumes. A relatively low soil water content of 4.4% mass-basis at the soil surface on 21 June may have contributed to the high sediment losses. The relatively

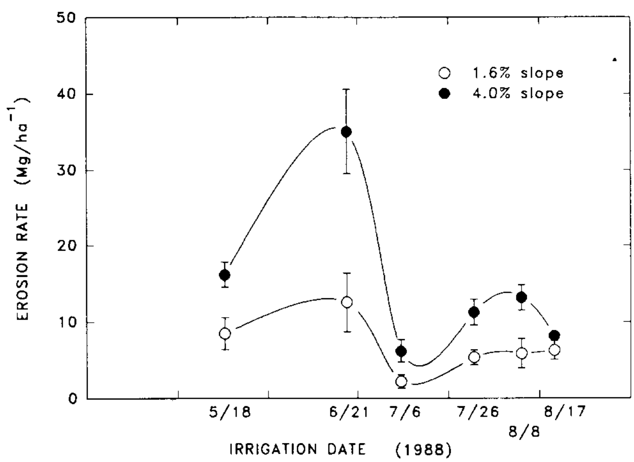

Fig. 2. Seasonal soil pattern in the absence of cultivation and a growing crop.

Table 2
Average flow and sediment loss data from 30.4 m (100 ft) sections of furrows at 4.0% slope. The area was not cropped or cultivated and each test furrow was irrigated only once

Irrigation number	Date	Flow rate		Infiltration rate		Sediment loss	
		On (l/min)	Off (l/min)	(l/min)	(%)	Rate (kg/furrow)	% of maximum (%)
1	18 May	6.8	5.3	1.5	27	37.6	47
2	21 Jun	6.4	5.4	1.0	20	79.5	maximum
3	06 Jul	6.6	5.0	1.6	33	16.6	21
4	26 Jul	6.5	4.7	1.8	34	21.8	27
5	08 Aug	6.7	5.5	1.2	28	30.2	38
6	17 Aug	6.8	4.8	2.0	29	18.7	24

dry aggregates in the Portneuf furrows, when wet quickly by the advancing furrow stream, were unstable (Kemper et al., 1985) and, upon disintegration, likely contributed to the high sediment loss rates. The erosion and sediment loss pattern from these bare plots (Fig. 2) resembles the pattern from previous studies on cropped soils (Fig. 1). Erosion and sediment loss rates similar in pattern but different in magnitude were obtained for the 4.0% slope section (Table 2). Again the greatest sediment loss was measured on 21 June. On 6 July for both slopes, sediment loss was lowest for the season. After that date, sediment loss increased slightly throughout the remainder of the irrigation season at the 1.6% slope (Fig. 2). However, at the 4% slope, after the 6 July irrigation, sediment loss increased slightly over the next 4 1/2 weeks but then dropped in mid-August. As expected, erosion and sediment loss was greater on the steeper 4% slope compared to the 1.6% slope.

The erosion and sediment loss decrease at the end of the irrigation season may possibly have resulted from an observed decrease in headcut occurrence. Headcuts developed on the 4% slopes, thus resulting in increased erosion and sediment loss until the plow layer was reached where resistance to erosion increased (Fig. 3). As the headcuts moved upstream, the furrows deepened and the water level dropped. With the dropping water level, the soil wetted perimeter decreased which reduced infiltration rates to 2.0 l/min or less as compared to 4.6 l/min or more at the 1.6% slope where no headcuts occurred.

These results clearly indicate that the seasonal erosion and sediment loss pattern observed in earlier cropping studies (Fig. 1) was not caused by a crop effect alone. More likely, changes in measured sediment loss rates over an irrigating season result from a combination of seasonal changes in soil erodibility and vegetative intrusion into furrows. A crop effect was indicated by the data from previous cropped studies that showed a continuous sediment loss decrease after the mid-season maximum was measured, whereas the data from the uncropped 4% slope indicated that following the mid-season maximum there may be a decrease for several weeks, and then an increase toward a secondary late season peak. Perhaps there is some late-season effect of plant leaves and roots, as mentioned earlier, but that effect appears small compared to the other changes occurring during the season.

We are unable to provide an adequate explanation for the seasonal erosion pattern, in particular for the increasing trend in erosion and sediment loss rates from late April to late June (Fig. 1 and Fig. 2). Climatic processes such as rainfall or dew occurrence, that alter

Fig. 3. A headcut eroding upstream (4% slope).

surface soil water contents immediately prior to irrigation, may be involved (Lehrsch and Brown, 1995). We can, however, suggest processes that may be causing the changes seen from July onward. The decrease in erosion rates as the growing season draws to an end is likely caused by a number of factors including aggregate stability increases (Bullock et al., 1988; Lehrsch and Jolley, 1992; Lehrsch and Brown, 1995), soil consolidation, vegetative influences (Sojka et al., 1992) and infiltration increases (Lehrsch and Brown, 1995). Obviously, some soil properties, that affect erodibility, change as the season progresses. The pattern is consistent over several years, with several crops and with no crop. Additional research will be needed to pinpoint the factors and mechanisms involved.

These experiments demonstrate the contrarious action of two processes: (i) aggregate destruction which leads to increased transport of soil at the same carrying capacity of water, and (ii) increased infiltration which results in lower carrying capacity of water that consequently influences a decreased transport of soil. In furrow irrigation, the aggregate destruction is dominant over the carrying capacity of water when the intensity of soil erosion is considered.

Although this seasonal pattern cannot be completely explained, it is important to report it. A one-time erosion and sediment loss measurement for use in any model or prediction equation could be misleading and introduce error into a model's predictions unless the change in erodibility is considered.

4. Summary

Erosion patterns of cropped and uncultivated, non-cropped plots were measured during several different growing seasons and compared. The erosion patterns were similar until

after peak erosion. Peak erosion occurred during the same 3-week period from 24 June to 10 July over several years. For the cropped plots, there was a sudden erosion decline after peak erosion, followed by a continual gradual decrease. In contrast, for the uncultivated, non-cropped plots, there was a sudden decline after peak erosion, followed by a gradual increase in erosion.

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