

EROSION, CONTROLLING IRRIGATION-INDUCED

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INTRODUCTION

Erosion is the greatest threat to agricultural sustainability. Most irrigation is on fragile arid soils that have enormous crop yield potential when irrigated. However, that yield potential is easily lost if the thin veneer of "topsoil" is eroded (1). Erosion prevention on irrigated land is, arguably, more important than on rainfed land. Yields from irrigated land are more than double those from non-irrigated land, with nearly triple the crop value per hectare (2). In addition, runoff and irrigation return flows (necessary in many surface irrigation schemes) deliver sediment; human, animal and plant pathogens; nutrients and pesticides to downstream fields and riparian waters. These pollutants accumulate in runoff primarily as a result of erosion.

IRRIGATION'S UNIQUE EROSION CHARACTERISTICS

Irrigation-induced erosion and rainfall-induced erosion result from the same physical and chemical processes. However, the processes come together and interact very differently in each case (2-4). The magnitude of the differences depends upon the type of irrigation system and on soil and water properties^a. Briefly, the most important differences stem from soil and water chemistry, wetting rate, water application and infiltration patterns, and, for surface irrigation, absence of water drop impact. These factors are the basis for many erosion control practices unique to irrigation (4, 5-7). Since 1990, advances in irrigation erosion control have resulted from improved understanding of water quality and antecedent soil condition effects on erosion and from development of polyacrylamide (PAM) use.

The key to controlling erosion is controlling runoff. Runoff is controlled in two ways. It is minimized by scheduling irrigation to meet, but not exceed, crop water and salt leaching requirements (i.e. avoid over-irrigation), and it is managed by using application rates during each scheduled

irrigation that minimize runoff and erosion for that event. Systems should be designed and operated to minimize over-irrigating some areas in order to adequately irrigate others. In furrow irrigation this is accomplished by reducing the length of furrows; managing inflow rates and advance times, and where possible, cutting back inflow rates once runoff begins; or through use of surge irrigation (surge irrigation sometimes erodes near the inlet because of higher flows during initial pulsing of water). Sprinkler systems can reduce runoff with variable rate emitters that match application rates to soil infiltration rates at specific field locations.

Erosion reduction from improved scheduling and application management is usually proportional to runoff reduction. Reducing over application also reduces pumping costs and losses of applied nutrients and agri-chemicals. In surface irrigation systems, where 20 to 40% runoff is often required to achieve field application uniformity, erosion remediation can be integrated into water supply enhancement by pumping sediment-laden drain water back onto fields. This does not prevent erosion, but does replace most of the eroded soil along with the saved water, for only the pump-back cost.

METHODS OF CONTROL

Conversion to Sprinklers

One effective way to prevent irrigation-induced erosion is conversion from surface to sprinkler irrigation. Again, the soil conservation benefit from conversion to sprinklers derives from and is proportional to the reduction of runoff. Sprinkler irrigation has higher technical, capital, energy and infrastructure requirements than surface irrigation. Therefore, sprinklers are used on only a small fraction of global irrigated area, whereas, nearly 60% of US irrigated land uses sprinklers. Properly designed and managed sprinkler systems eliminate 100% of off site sediment losses. However, with sprinklers, there is a tendency to extend irrigation to steeper slopes or otherwise more erosive lands. On steep land, when sprinkler systems are poorly designed or managed, erosion can occur.

^a See *Irrigation Erosion* on page 742.

Center pivots can cause erosion problems due to water running in wheel ruts, down steep slopes, or because of high application rates at outer reaches of the pivot (8), especially when using extendable booms and high volume end-guns to reach corners. Erosion from high application areas, or where runoff concentrates, can be reduced using tillage, pitting and mulching between rows to increase surface roughness storage and reduce runoff (9–11).

Soil Protection and Tillage

Many approaches developed to control rainfall-induced erosion can prevent irrigation-induced erosion, particularly under sprinklers, e.g. no-till and conservation tillage, which rely on crop residue to protect the soil surface. Yet, despite typical erosion reductions > 90%, often with increased yields (12), no-till and conservation tillage are rarely practiced by surface irrigators. Floating residue often migrates along and clogs irrigation furrows, washing out adjacent beds and furrows, while under-irrigating the blocked furrow. In basin flood irrigation, floating debris can interfere with water spreading, sometimes concentrating initial flows, eroding some areas and elsewhere burying emerging plants with sediment or debris. No-till farming with furrow irrigation is further complicated by crop rotations that require different row (and furrow) spacings each season.

Sojka et al. (13) demonstrated 60% reduction in field sediment loss from furrow-irrigated potatoes that were paratilled (subsoiled) following planting. Slight yield increases and significant tuber grade improvements raised profitability under both furrow and sprinkler irrigation with paratilling (14). Because irrigation assures crop water availability, yield benefits from improved root development are not consistently seen with subsoiling in irrigated crops (15). Subsoiling is practiced commonly with sprinkler irrigation to enhance infiltration and decrease runoff, thereby reducing erosion. However, farmers are cautious about subsoiling furrow-irrigated crops because of the potential for irregular water flows in subsurface cracks to interfere with irrigation uniformity. Field preparation or land forming practices that reduce water application uniformity or increase runoff, are avoided by irrigators.

Placing mulch or growing sod in irrigated furrows reduces erosion. Sod nearly eliminated runoff sediment (16). Straw mulching reduced sediment loss 52 to 71% (17–20). Drawbacks of these techniques relate to management of sodded furrows, the added operations and equipment needed to place straw, and debris migrating along and clogging mulched furrows.

Site Modification

Various “engineering” approaches have been used to reduce field sediment losses from surface irrigation. The most common is use of settling basins. Large quiescent pools to facilitate particulate settling from runoff collected from fields up to 20 hectares are fairly typical. Settling pond size depends upon the area served, rate and volume of runoff, sediment concentrations expected and particle size distribution. Small settling basins along the bottoms of surface irrigated fields, serving a few rows per basin, are sometimes easier to manage at season’s end, when trapped sediment can be spread back onto the field using farm equipment. Big ponds require large scale equipment for construction, cleaning and soil redistribution. For medium-textured soils about 60% of suspended mass entering settling ponds is retained. The non-retained soil is in the clay size range (21). Since clay carries most of sediment’s adsorbed nutrient and chemical load, failure of ponds to retain clay impedes retention of agricultural chemical pollutants, despite the high percentage of sediment mass captured. Furthermore, effectiveness declines as ponds fill with sediment, reducing water residence time. Another variation on ponds is installation of buried drains and stand pipes to regulate water level in tail ditches (22). The stand pipes force ponding and prevent gradual concaving of field tail ends. They do not, however, prevent loss into the drain of sediment entrained in runoff from upper field reaches.

Altering canopy configuration can reduce erosion. Sojka et al. (23) halved field sediment loss using narrow or twin row plantings. Water ran between closely placed furrows, reducing irrigation duration (and runoff) and allowing root systems and canopy debris to reduce soil detachment in the furrow. Filter strip crops drilled at right angles into the final three to six meters of furrow-irrigated row crops also remove entrained sediments from runoff (6), but do not prevent sediment migration from field inlet to tail end. Because filter strip management is a compromise between two crops, yield from the strips is typically half that expected for either crop alone.

Water Properties

Both the physical and chemical properties of irrigation water affect erosion. Erosion is greatly reduced by reducing sprinkler droplet size or energy (24, 25) or by reducing stream flow in furrows (26). These physical changes require adjustments in application timing, furrow lengths and irrigation durations to properly match water application constraints with crop water needs.

Water electrolyte chemistry greatly affects the erosiveness of irrigation water (27–30). High sodium adsorption

ratio (SAR) and low electrical conductivity (EC) contribute to soil aggregate detachment, disruption and dispersion of fine primary soil particles in runoff. The effect of low EC and high SAR are synergistic. Increasing electrolyte concentration with a calcium source lowers SAR, shrinks the ionic diffuse double layer around charged soil particles, and prevents dispersion, thereby maintaining aggregate stability and resisting erosion. The conjunctive use of waters from different sources or the addition of calcium can raise EC and/or lower SAR to reduce erosion potential and improve infiltration by stabilizing surface-soil structure.

Adding large polymeric compounds to irrigation water is an effective erosion prevention technology (31–33). These compounds, when delivered in dilute concentrations (typically 1 to 10 ppm) by the irrigation stream, increase aggregate stability and inter-aggregate cohesion as water infiltrates. Erosion reduction of 95% is typical for application of 1 to 2 kg ha⁻¹ per treated irrigation. Adoption has been greatest for furrow irrigation erosion reduction, but interest in extending the technology to sprinklers is growing, as much to improve infiltration uniformity as to reduce erosion (34–36). The most successful class of polymers has been anionic polyacrylamide (PAM), allowing safe, easy and effective erosion prevention for seasonal application rates of 3 to 5 kg ha⁻¹, or under \$35 ha⁻¹ per season (37).

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