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Conservation Tillage in Temperate Agroecosystems

Edited by

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CHAPTER 12

Constraints on Conservation Tillage under Dryland and Irrigated Agriculture in the United States Pacific Northwest

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12.1. INTRODUCTION

The Pacific Northwest (PNW) supports significant areas of both irrigated and rainfed agriculture. This bimodality is also impacted by the diversity of crop and animal agriculture it supports. Drilled grain and pulse crops, row crops, vegetable and horticultural crops, grass sod, and perennial alfalfa (*Medicago sativa* L.) hay are among the choices that can appear in a farm's cropping system. Developing soil management practices and tillage systems to accommodate such diversity has been a challenge to soil conservationists. To date most research published from the region has concentrated on small grain production in the dryland areas. Another smaller body of literature has dealt with conservation tillage of irrigated field crops. The potential for development of conservation tillage in the PNW derives from the region-wide severity of erosion in both dryland and irrigated agriculture. Residue management has been the essential element of the tillage systems in both cases. Although preserving crop residues at the soil surface is a key strategy, conservation tillage in the PNW has embraced other practices as well. Furthermore, greater recognition of the extent and severity of erosion under irrigated conditions is warranted, and research on erosion and conservation tillage for irrigated systems should be a high priority.

Two areas not specifically covered in this chapter are wind erosion and plant pathology. Wind erosion is significantly abated by maintenance of soil vegetative cover, and many aspects of that strategy are dealt with at length in this chapter. Those with an interest in wind erosion in the PNW will find Vomocil and Ramig[1] a good, if somewhat dated, reference. The pathology of conservation tillage in the PNW is a voluminous topic. The aspects of straw management briefly covered herein address cultural principles relevant to pathology as well as the agronomic and soil issues focused on in this chapter. Those wanting more detail are referred to the excellent review by Cook.[2]

12.2. SOIL AND CLIMATIC CONSTRAINTS

Conservation tillage in the PNW has been greatly influenced by soil properties affecting and affected by structure and aggregation, and the climatic interactions with these physical properties. Generally, the PNW has medium-textured loessal soils containing some volcanic ash and little organic matter, with poor structure and few stable aggregates. Dryland production areas frequently utilize long uninterrupted steep slopes. Their cropping systems vary with annual precipitation (200 to 600 mm), but in general, soils under conventional tillage are worked bare in late summer following harvest to accommodate subsequent fallowing or planting of small grain or pulse crops.

Both water and wind erosion are serious problems. Erosion by water is consistently the greatest threat. Soil loss tolerances to water erosion vary from

2.2 to 11.2 t/ha, depending on soil depth and lithic contact. In addition, because of frequency of steep slopes "tillage erosion" (downslope displacement of soil by implement usage) has also been a serious component of upslope soil loss.[3,4] Annual soil loss on nonirrigated soils throughout the region ranges from 4 to 60 t/ha, of which 85% occurs during the winter,[5] compared to 20% for the 37 states east of the Rocky Mountains.[6]

Soil freezing seriously accelerates erosion in these soils by virtually eliminating infiltration and promoting runoff.[7-9] In model simulations using PNW meteorological records, the number of freeze-thaw cycles varied from 1 to 7/year, and averaged 3/year. Soils were frozen 51% of the time in December, 67% of the time in January, and 53% of the time in February.[10] Duration and depth of soil freezing was reduced by maintenance of surface residues, providing increased probability of infiltration from seasonal precipitation.[11] Coupling residue maintenance with chiseling or paraplowing* increased spring infiltration rates threefold over no-tillage alone.[12] An unconstrained soil matrix also maintains greater aggregate stability during freeze-thaw cycles.[13] Thus runoff, and hence erosion, can be minimized by reducing the duration of ice blockage of soil pores, and by increasing the proportion of macropores, which block less easily.

Poor residue coverage promotes soil freezing. Consequently, the potential amount of profile water storage also decreases, especially deep in the profile. This is exacerbated by nocturnal migration of water to the frost depth, where it is exposed to diurnal thawing and evaporation loss.[14-19] The number of diurnal freeze-thaw cycles from November through March varies from 60 to 120.[20] Over a winter season, evaporation losses can be significant. Residue maintenance reduces both the temperature gradients that drive this water movement, and the evaporative loss of soil water from the surface few centimeters of soil where water accumulates during transient diurnal frost episodes.

The effects of freezing and thawing on soil hydraulics couple with effects on soil structure to further aggravate erosion. On a macroscale, Formanek et al.[21] showed that a single freeze-thaw cycle reduced soil cohesive strength by more than half. Subsequent cycles had less effect. Similar strength reduction has been observed in the field,[22] attributed to the separation of aggregates by freezing and thawing.[23] Upon thawing, soil cohesion returns as a function of soil water tension, and throughout these episodes surface soil shear strength provides a reasonable index of erodibility.[21]

12.3. NONIRRIGATED CONSERVATION TILLAGE

PNW conservation tillage research from the 4 million ha of dry farmlands has been reviewed several times in the last 15 years.[3,24-29] These reviews

* Mention of trademarks, proprietary products, or vendors does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

documented the fragility of the region's soil resource and identified technologies and strategies for reducing tillage and preserving residue. Allmaras[24] matched management systems to specific crops and environmental needs. The PNW has promoted conservation tillage more successfully than some regions because of the aggressive manner in which the technology was developed and spread in the Solutions to Environmental and Economic Problems (STEEP) program.[30,31]

12.3.1. Conservation Tillage Programs

The STEEP program, conceived in 1972 and funded since 1976, pooled the resources of Idaho, Oregon, and Washington to wage a coordinated assault on soil erosion. The program initially had five research objectives: (1) development of conservation tillage and plant management systems, (2) plant breeding to suit conservation tillage, (3) pest management for conservation tillage, (4) improved erosion and runoff prediction, and (5) evaluation of soil conservation economics and socioeconomics. In 1982 an extension program was initiated to augment the research program. STEEPs success resulted from a timely conjunction of several key factors. Producer groups were committed to program goals, were frequently consulted, and were involved in its priority setting and operation. The program employed multidisciplinary interaction among experiment stations, the Soil Conservation Service (SCS) the Agricultural Research Service, and the Extension Service components. All participants shared in federal funding, which was equally distributed among the three states. Research funds were allocated through a proposal-review system targeted at solving problems in order of priority and probability of success.

STEEP researched farmer and public attitudes and perceptions of erosion severity, program effectiveness, and needed priorities.[32,33] The specific insight of these surveys showed that the conservation ethic was a less effective motivation for adoption of conservation tillage than demonstration of economic benefit. In the early 1980s minimum tillage became recognized as a management practice that maximized net returns during an era of declining agricultural commodity prices. Farmers knowledgeable about soil erosion were found to be more likely to adopt control practices than uninformed farmers. If they perceived the problem existed on their farm they took conservation action, using available research and advice.

STEEP research results have been shared and discussed at annual meetings and promoted to users through publications, newsletters, slide sets, radio and television coverage, grower meetings, and demonstration plots. This technology transfer was accomplished by the intimate involvement of researchers, county extension agents, conservation district supervisors, and the SCS. The program has also benefitted from strong and coordinated administrative and technical leadership, and from participant commitment and *esprit de corps*.

12.3.2. Management Strategies

The most effective strategy for combatting erosion in PNW dryland systems has been conservation of crop residues at the soil surface through various systems of tillage reduction. The SCS has for many decades promoted stubble mulch farming to prevent soil loss and conserve water and soil organic matter.[34] The positive relationship between "topsoil" depth in the Palouse and the productivity of wheat (*Triticum aestivum* L.) over a range of soil organic matter contents was confirmed by Pawson et al.[35] The relationship of tillage, soil fertility, crop residue management, and organic matter for the region was recently reviewed in depth by Rasmussen and Collins.[29] They recognized the negative impact of excessive tillage and fallowing on the oxidative loss of organic matter for nitrogen mineralization. Long-term effects of conservation tillage on organic carbon and nitrogen in soil were summarized for 11 sites worldwide (Table 12.1).

Specific conservation practices vary widely to suit local needs. Allmaras et al.[26] concluded that on slopes less than 12%, tillage systems and residue management alone could significantly control erosion, but for inclines of 12 to 20% slope length also had to be interrupted through terracing. Their work suggested that for slopes greater than 20%, even combining these approaches would still result in soil loss above tolerance limits. Improved new approaches include slot mulching by placing compacted straw in trenches extending to below the frost layer. Performed on the contour and in conjunction with no-till or chemical fallow, these practices offer another method with which to improve infiltration and reduce runoff and erosion on steep slopes.[36]

Fallowing in the driest of the nonirrigated cropped areas of the PNW is a major contributor to erosion. Stubble left standing over the winter months can increase net soil water storage (SWS) by as much as 90 mm through better snow capture and prevention of soil freezing.[37] The effectiveness of this practice is enhanced by deep chiseling.[19,38] Where surface mulching is practiced and soil water retention is increased, deep chiseling also provides drainage to prevent saturation of surface soil, which can otherwise cause overwinter oxygen stress and denitrification.[39] In all but the most marginal situations, e.g., where shallow soils limit SWS capacity, these increases (especially if coupled with no-till cropping), and/or delayed spring tillage and early maturing varieties make annual cropping more economical than summer fallowing in most years.[28]

Managing previous crop residues significantly impacts conservation tillage success. Straw yields of PNW winter wheat are typically double the grain yield. This can amount to 10 to 15 Mg/ha from a well-managed crop. The once-prevalent practice of burning has been largely discredited and is discouraged both on agronomic merits and air quality considerations. Short-term weed, nutrient, and disease benefits have been shown to be less certain than the long-term reduction of soil organic matter and immediate impact on erosion.[40]

Table 12.1. Change in Soil Organic Carbon (C) and Nitrogen (N) Levels Resulting from Conservation Tillage as Compared to Conventional Tillage

Location and Soil	Annual Precipitation (mm)	Soil Depth (cm)	Length of Study (years)	Tillage System[a]	Increase (%/year) C	Increase (%/year) N	Ref.
South Africa							
Haploxeralf	412	10	10	TT	5.6	3.4	85
Haploxeralf	412	10	10	NT	7.3	5.1	85
Germany							
Podsol		30	5	NT	3.2	1.4	86
Podsol		30	5	NT	2.4	1.6	86
Podsol		30	6	NT	1.3	1.3	86
Australia							
Western							
Psamment	345	15	9	NT	1.6	—	87
Alfisol	307	15	9	NT	0.7	—	87
Alfisol	389	15	9	NT	1.4	—	87
Queensland							
Pellustert	698	10	6	NT	1.2	1.3	88
Saskatchewan, Canada							
Chernozem		15	6	NT	6.7	2.8	89
United States							
North Dakota							
Haploboroll	375	45	25	SM	1.8	1.3	90
Haploboroll	375	45	25	SM	–0.1	0.1	90
Argiboroll	375	45	25	SM	0.5	0.4	90
Kansas							
Haplustoll		15	11	NT	0.7	0.6	91
Nebraska							
Haplustoll	446	9	15	NT	2.8	2.4	92
	446	10	15	NT	1.2	1.0	92
Oregon							
Haploxeroll	416	15	44	SM	0.3	0.4	93
Washington							
Haploxeroll	560	5	10	NT	1.9	2.0	94
Mean					2.2	1.7	
Minimum					–0.1	0.1	
Maximum					7.3	5.1	

Source: From Rasmussen and Collins, *Adv. Agron.*, 45:101, 1991. With permission.

[a] TT, tine-till; NT, no-till; SM, stubble mulch.

Despite the benefits of straw retention, however, it must be managed. Straw kept upright for snow capture and soil protection should be laid down by planting time to assure radiation penetration into developing wheat canopies and for soil warming and maximum photosynthesis.[41]

Combining should generally cut only enough straw to ensure no escape of grain beneath the cutter bar, and may require minor modification of chaff spreaders to prevent an uneven distribution of chaff behind the combine.[42-44] Failure to abide by these precautions can result in greater soil freezing and erosion potential from uncovered areas, and greater disease potential in high chaff areas. Uneven straw decomposition and variable nutrient availability (complicating subsequent fertilization), and uneven implement performance in subsequent tillage and planting operations also result from uneven spreading of residues.

Successful conservation tillage requires development of a sound soil fertility program to meet yield goals and to accommodate changes in nutrient cycling and organic matter retention in the presence of high residue levels.[29,40] Conservation tillage changes both crop nutrient requirements and system dynamics affecting conservation tillage success. With stubble mulching, nitrogen additions can offset reduced mineralization,[45] but the practice can encourage grassy weed competition[46] and crop water use,[47] both of which can limit yield.

The general requirement of no-till drill openers-fertilizer banders was reviewed by Erbach et al.[48] A test of various designs was reported for PNW conditions by Wilkins et al.[49] They stated that the best emergence was produced with a deep furrow opener which placed seeds in contact with soil containing sufficient soil water to allow germination and emergence. Subsequent evaluations[50,51] have shown particular promise for a strip till seeder and for the New Zealand style Cross Slot™ opener (see Chapter 8).

Experience has shown that fertilizer can be optimally placed near wheat roots to favor wheat uptake, and to limit uptake by competing weeds.[52] This concept can be expanded to include twin-row planting of grain (one row on each side of the fertilizer band) to "hide" fertilizer from competing weeds between pairs of wheat rows.[53]

12.4. IRRIGATED CONSERVATION TILLAGE

The irrigated areas of the PNW are generally flatter, occur at lower elevation, and receive less precipitation than adjacent nonirrigated croplands. Many irrigated areas are in river valleys and the soils are commonly alluvial deposits along the floodplain. Over 3.2 million ha are irrigated in the PNW (Table 12.2). About 1.85 million ha are sprinkler irrigated, and about 1.35 million ha are surface irrigated.[54] The conversion from surface to sprinkler irrigation and the development of new sprinkler irrigated lands has taken place mostly during the past 30 years. Drilled field crops are produced on both irrigated and nonirrigated lands, but nearly all row crops and high value cash crops in the PNW are grown under irrigation. The number of different crops grown under irrigation is three or four times greater than in rainfed agriculture, resulting in more diverse and often greater amounts of residue to manage under irrigated agriculture. For

Table 12.2. Summary of Irrigated Farmland in the Pacific Northwest

	Irrigated Area (thousands of hectares)			
Irrigation Type	ID	OR	WA	Total
Center pivot	221	99	185	505
Other sprinkler	605	312	414	1331
Gravity	826	336	191	1353
Drip/trickle	<1	2	12	15
Crop types				
Small grains	646	89	101	836
Row crop/Vegetable	325	97	166	588
Hay/grass seed/pasture	575	494	417	1486
Tree and other horticulture	8	48	113	169

Source: Compiled from *Irrig. J.*, 41(1):23–34, 1991.

example, alfalfa is commonly grown in rotation with other crops on irrigated land in the PNW. This crop has an extensive, deep taproot system, and these roots perform much like buried residue when the alfalfa is killed to allow planting of the next crop in the rotation. The traditional approach has been to kill crowns with herbicides or sweep tillage or both, followed by discing and moldboard plowing to bury taproot residues. To accomplish what has been perceived as necessary for a satisfactory seedbed, an average of ten tillage operations has been used for row crops following alfalfa in rotation.[55]

Irrigation-induced erosion was first recognized as a problem in the 1940s.[56-60] Early research on the subject related slope and stream size to sediment loss, and early researchers warned irrigators against irrigating land that was too steep, cautioning them to use streams as small as possible. These warnings were largely unheeded until Public Law 92-500, the Water Quality Act of 1972, focused attention on the water pollution problems associated with irrigation runoff. Ironically, federal funds to combat erosion from irrigated farmland do not reflect the severity of the problem because conservation funds are distributed in relation to legally recognized estimates of erosion. In the past this has relied heavily on the universal soil loss equation (USLE). The USLE generates erosion estimates based on climate data (rainfall), and current legislation does not make allowances for adjustments of the production to take irrigation into account. Thus, soil loss from irrigated arid land (for conservation funding purposes) has been based on unrealistically low estimates of runoff and erosion.

Tillage for soil conservation on irrigated row crop culture may not always mean no-till, or even maintenance of residues on the soil surface. Subsoiling in furrow or sprinkler irrigation and basin or reservoir tillage under sprinkler irrigation are examples of tillage operations that may take place in otherwise conventional systems to improve infiltration, reduce runoff, and prevent soil erosion. Only in the past 8 to 10 years have no-tillage systems been introduced to irrigated land.[55,61,62]

12.4.1. Furrow Irrigation

From 5 to 50 tons of soil per hectare can be lost per year from typical surface irrigated fields, with three or more times that amount lost near furrow inlets.[63,64] Mech[65] reported the loss of 50.9 t/ha from a single 24-hr irrigation. Figure 12.1 illustrates the erosion that occurs near the inlet ends of furrows. Even on low sloping fields this type of hydraulic leveling proceeds rapidly enough to completely denude the topsoil from upper reaches of some fields in only a few decades.[62,66] Because many PNW soils are underlain with subsurface horizons rich in calcium carbonates, their exposure or mixing with surface soil results in reduced productivity.[66] This productivity loss cannot be restored except by returning topsoil to the denuded area.[67] Figure 12.2 illustrates how erosion, combined with plowing, has mixed white subsoil with surface soil, resulting in a lighter color on the inlet ends of fields.

In most published papers on irrigation-induced erosion, sediment loss from the lower end of the field is referred to as erosion. There must be erosion for sediment loss to occur, but there can be extensive erosion within a field without sediment loss from the field as a result of the deposition of sediment eroded from upper reaches of a furrow at the lower reaches of the furrow before being carried away with the runoff. Upper reach erosion with simultaneous lower reach depostion occurs because irrigation furrows serve as both conveyance channels and infiltrating surfaces for water to enter the soil. This supplies water to satisfy the infiltration needs for the crop over the entire furrow length.[62,67] Water flow rates at the upper reaches, therefore, are significantly greater than at the lower reaches of the furrow because of the cumulative downstream effect of infiltration. The size of the furrow stream required to overcome the cumulative stream size reduction resulting from infiltration is generally large enough to be erosive near the inlet ends of furrows, but the sediment may be deposited before the water reaches the outlet ends of the furrows. Hence, erosion can occur in the upper reaches of the field without sediment loss from the field.

Typical sediment losses for major crops grown with traditional tillage are presented in Table 12.3. These data were mean values from measurements made on more than 100 fields. Sediment loss values vary severalfold at the same slope; therefore, caution should be exercised when applying these data. Sediment loss can be reduced by a variety of approaches, including vegetative filters,[62] settling ponds,[68] minibasins, and buried pipe runoff control systems.[69,70]. Erosion and sediment loss can be reduced by field incorporation of residue and reduced tillage,[71-76] permanent furrow sodding,[77] no-tillage systems,[55,78] selection of furrow spacing, irrigation set duration and plant proximity to furrows,[79] zone-subsoiling beside furrows,[80,81] and with the introduction of flocculating polymers at dilute concentrations in the furrow streams.[82]

In conventional tillage, Sojka et al.[79] found that applying equal amounts of water in shorter duration irrigation sets by using narrower row spacings could improve infiltration and reduce erosion. This effect was both the systematic

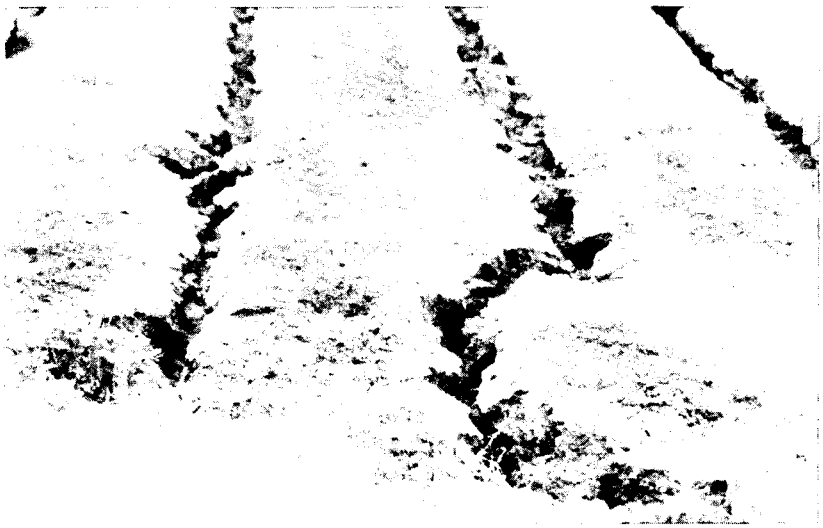

Figure 12.1. Erosion near the inlet ends of irrigation furrows.

result of decreasing runoff time and growing plants in closer proximity to the irrigated furrows. This allowed plants to stabilize furrows with roots and vegetative debris (e.g., flowers shed by dry beans). Yield and quality of corn (*Zea mays* L.) and sugar beet (*Beta vulgaris* L.) were unaffected and yield of dry beans (*Phaseolus* spp.) was slightly improved by narrower rows. Another study[80,81] showed that zone subsoiling decreased runoff and erosion, increased infiltration and yield, and improved tuber grade in furrow-irrigated Russet Burbank potatoes (*Solanum tuberosum* L.) (Table 12.4). Subsoiling was under beds alongside furrows, using the Tye Paratill (i.e., paratilling) in otherwise conventional culture. Recent work has shown an almost complete reduction in both erosion and sediment loss for furrow-irrigated systems in which the water advance was treated with 5 to 10 ppm of polyacrylamide.[82]

No-tillage systems for furrow-irrigated land were developed and evaluated by Carter and Berg[55] and by Carter et al.[78] They showed that cereal or corn can be easily grown following alfalfa, corn following cereal, or corn and cereal following corn without tillage using the same furrows for irrigating the subsequent no-tillage crop as the original. Both erosion and sediment loss were greatly reduced and in many cases completely eliminated. These crops yielded as well and were of equal quality without tillage as with traditional tillage. Not only did no-tillage conserve soil by reducing erosion and sediment loss, but net income increased more than $125/ha each year over a 5-year cropping sequence[78] as a result of reduced tillage costs.

The recent work by Carter and Berg[55] and Carter et al.[78] demonstrated that conservation tillage can be successful on furrow-irrigated land and that it is

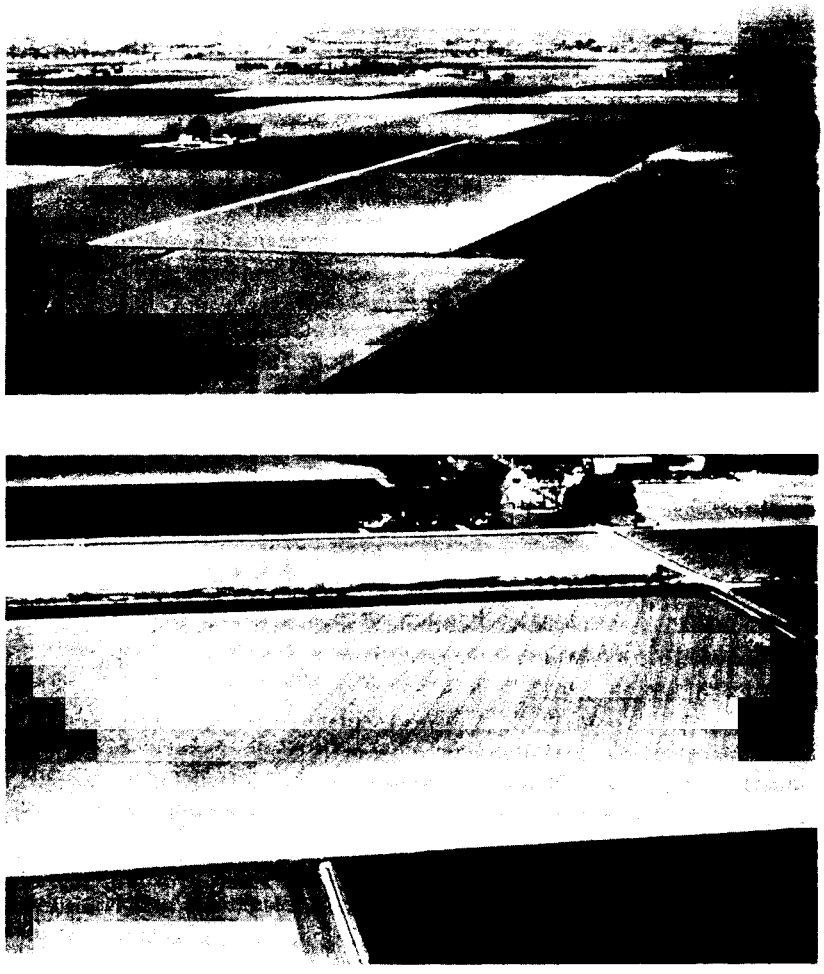

Figure 12.2. White upper ends of irrigated fields caused by loss of topsoil as a result of irrigation furrow erosion and subsoil mixing with topsoil by plowing.

currently the best approach for soil and water conservation on these lands. The data in Table 12.5 illustrate the effectiveness of conservation tillage in reducing sediment loss for dry bean and corn production. The primary difference between the traditional and conservation tillage treatments was burial of crop residues by moldboard plowing in traditional tillage treatments, whereas plowing was not done in any of the conservation tillage treatments.

Table 12.3. Estimated Sediment Losses (t/ha) from Fields of Different Crops Furrow Irrigated from Concrete-Lined Ditches with Siphon Tubes

	Average Field Slope (%)			
Crop	0.5–1	1–2	2–3	>3
Alfalfa	0.0	1.6	5.2	12.6
Cereal grain or pea	2.5	7.2	14.3	23.3
Dry bean or corn	5.6	19.5	41.2	62.8
Sugar beet	7.2	27.1	59.2	98.6

Source: From Carter, D. L., *Irrig. Agric. Lands Agron.*, 30:1148, 1990. With permission.

Note: Run length was 200 m.

Conservation tillage systems generally reduce erosion and sediment loss from 50 to nearly 100% compared to traditional tillage systems for row crop production.[62] The reader will note that the sediment losses in Table 12.5 for dry beans differ substantially from Table 12.3. Table 12.3 presents average sediment losses from nearly 100 fields. Table 12.5 uses data from a limited number of sites in which conservation tillage was compared. The higher erosion rates reflect the choice of these particular highly erosive sites to study conservation tillage.

12.4.2. Sprinkler Irrigation

Sprinkler-irrigated systems generally allow most of the same conservation tillage practices used in dryland farming,[83] particularly no-till, mulch-tillage, deep chiseling, or subsoiling. A major difference is the frequency and intensity of water application, particularly in center pivot systems. Even on relatively shallow slopes, the outer portions of most center pivots apply water at rates that may cause runoff and erosion. Many center pivot systems cover areas of highly variable slope. Therefore, it is almost impossible to design a system to adequately supply water to the growing crop over the entire irrigated area without causing runoff and attendant erosion on part of that area. Actually, more flexibility exists for residue management under sprinkler irrigation than with either rainfed or surface-irrigated areas. More residue can be tolerated on the soil surface under sprinkler irrigation than with surface irrigation because sprinklers apply water more evenly over the irrigated area, whereas excess residue can inhibit water flow with surface irrigation. The advantage of sprinkler irrigation over rainfed culture is the ability to apply water when needed, eliminating the need to sow with deep seeding drills or other specialized drills that still may not work as well with high crop residues. Furthermore, with irrigation, plant emergence is less likely to be restricted on PNW fields if planted shallow.

The erosion processes under sprinkler irrigation, although similar to those under rainfall, do exhibit some differences. For example, once streams begin to flow in sprinkler-irrigated areas, they increase in size as runoff water

Table 12.4. Summary of Water Infiltration and Cumulative Sediment Loss for 1989 and 1990 as Affected by Zone Subsoiling

	Traffic Furrows			Nontraffic Furrows			All Furrows		
Treatment	Sediment Loss (kg/ha)	Infiltration (mm)	Sediment Infiltration[a] (kg/mm/ha)	Sediment Loss (kg/ha)	Infiltration (mm)	Sediment Infiltration[a] (kg/mm/ha)	Sediment Loss (kg/ha)	Infiltration (mm)	Sediment Infiltration[a] (kg/mm/ha)
				1989					
Mean –ZS	1154	281	15.0	315	439	2.31	1469	721	6.90
Mean +ZS	871	306	9.5	297	426	2.27	1168	732	5.24
				1990					
Mean –ZS	8450	254	41.2	976	377	3.21	9428	631	18.52
Mean +ZS	2604	321	10.3	771	398	2.37	3388	718	5.84

Source: Adapted from Sojka et al., *Soil Tillage Res.*, 25:358, 1993. With permission.

[a] Infiltration occurs only during sediment monitoring.

Table 12.5. Sediment Losses from Experimental Plots Where Traditional and Conservation Tillage Treatments were Compared on the Same Fields under Furrow Irrigation

Crop and Previous Crop	Slope (%)	Sediment Loss (t/ha) Traditional Tillage	Sediment Loss (t/ha) Conservation Tillage
Dry beans following wheat	1.3	114	29.4
Dry beans following wheat	3.3	11.0	2.7
Dry beans following wheat	0.6	30.3	14.1
Sweet corn following alfalfa	1.1	11.0	5.8
Silage corn following wheat	0.6	12.6	0.4
Silage corn following corn	1.4	12.1	1.8

Source: From Carter and Berg, *J. Soil Water Conserv.*, 46:140, 1991.

increases. However, once the stream exits the sprinkled area, the stream size diminishes as infiltration removes water from the stream. This latter phase is similar to furrow irrigation erosion processes. Residues on the soil surface or various tillage practices reduce erosion and sediment loss with sprinkler irrigation in the same manner as under rainfall. Effects beyond the zone being sprinkled are the same as for furrow irrigation. In the latter case, more residue can be tolerated than with furrow irrigation, and the reduction of erosion is greater.[62]

An excellent tillage method for combating erosion and sediment loss under sprinkler irrigation is reservoir tillage. It is a process of making small catchment basins, 50 cm or less in length, 20 to 25 cm in width, and 15 to 20 cm deep (Figure 12.3). These small reservoirs trap runoff water when the sprinkler application rate exceeds the infiltration rate. The water is held until it infiltrates the soil, sometimes after irrigation has ceased. Kincaid et al.[84] have developed successful cropping systems using reservoir tillage under sprinkler irrigation. These systems are widely used for potato production and various other crops.

12.5. GENERAL SUMMARY AND CONCLUSIONS

Crop and water constraints on conservation tillage on dryland in the PNW are reasonably well understood because many years of research and technology transfer have identified problems and provided solutions or alternative approaches to most of them. The STEEP program has been particularly effective in encouraging the application of new conservation tillage technology to rainfed agriculture. In contrast, crop and water constraints to conservation tillage of irrigated land are less well understood. Most of the conservation tillage research on irrigated land is recent. Research results are promising, but the application of these results is just beginning. Conservation tillage can be highly successful for conserving water and soil and can increase net income through tillage cost savings. A rapid expansion of conservation tillage technology to irrigated land is encouraged because the conservation impact has great

Figure 12.3. Reservoir tillage basins in a potato field under sprinkler irrigation.

potential. Educational programs, conservation tillage demonstration projects, and incentive programs have been shown to be effective means of accelerating conservation practice implementation.

12.6. REFERENCES

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