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Long-Term Erosion Trends on Cropland in the Pacific Northwest

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Abstract. *Winter erosion from non-irrigated cropland in northwestern Oregon, southeastern Washington, and northern Idaho appears to have decreased during the past 20 years. Assuming this effect is real and not just apparent, is there a single cause? Is this the effect of climate change, changes as the result of the 1985 farm bill, or a combination of these and other factors? We can't answer all these questions, but a unique 43-year data set obtained from monitoring winter erosion on a large number of sample fields in Whitman Co, WA from Water Year (WY) 1940 through WY 1982, provides an opportunity to examine historic trends in erosion and corresponding climate conditions. During this period, the winter wheat/summer fallow rotation was used on much of the area, including the higher precipitation zone more suitable for annual cropping. There were several consecutive years in the 43-year data set when erosion was low. Weather records for these years indicate reduced freeze/thaw activity with rain or snowmelt during the period of thaw. We examined diurnal freeze/thaw cycles, length and severity of frozen periods, snow-melt accumulation during cold periods, and rain during early stages of the thawing process. Our analysis of 1983 through 2005 climate data indicate reduced erosion hazard from freeze/thaw effects. U.S. Department of Agriculture progress records for 1979 and 1994 indicate increased application of conservation practices in 1994 as compared to 1979, with a large estimated reduction in erosion. Measurement of sediment at the mouth of the Palouse River indicated a large reduction from the 1962 through 1971 period to the 1993 to 1996 period. Sediment in runoff and flooding from snowmelt on frost impacted soil occurred in WY 1996 and WY 1997, but erosion rates were not catastrophic.*

A close inspection of weather records from near the McCredie Experiment Station in Central Missouri, with mean winter temperatures and precipitation values comparable to those at Pullman, WA, and source of a large data set frequently used in calibrating or validating erosion models, provides confirmation of the unique climate characteristics of the non-irrigated cropland region of the Pacific Northwest.

Keywords. Erosion, freeze/thaw, winter, climate, cropland

Introduction

The Northwestern Wheat and Range Region (NWRR), comprised of much of eastern Washington and northeastern Oregon, and northern and southern Idaho, includes approximately 4 million ha of non-irrigated cropland (Fig. 1). Non-irrigated crops are grown in a 2-year winter wheat /summer fallow rotation with as little as 230 mm of annual precipitation, in a 3-year rotation including one year of fallow in the zone from 305 mm to 405 mm of precipitation, and in an annual crop rotation in areas with greater than 430 mm of precipitation. The region's hydrologic and erosion processes are dominated by winter storms, particularly freeze-thaw events. Soil freezes and thaws and snow accumulates and melts multiple times throughout the winter, with the freeze/thaw cycle of multiple-day occurrences typically occurring from zero to five times during any given winter (Zuzel, 1994). On cropland in higher elevation or foothill areas subject to colder temperatures, snow accumulates during most winters and melts during a melt period at the end of winter. In the most productive cropped areas, soils are silt loams, have low organic matter content, and traditionally have been intensely managed with multiple tillage operations. As a result, these soils are weakly aggregated, and are susceptible to high erosion rates during freeze/thaw events. Rills, the predominant erosion process in the region, develop quickly when low-intensity rain or snow-melt occurs as the soil thaws from the surface.

The objective of this paper is to consider the question of whether erosion has decreased in the past 20 years, and if so, is it due to a change in weather pattern, of cyclical or long-term nature, or is it due to changes in management practices perhaps caused by the requirements of the 1985 farm bill. A second objective is to examine what is unique about the Pacific Northwest dryland area as compared to areas influenced by continental air mass rather than coastal weather patterns.

Long-term Erosion Trends in Whitman County

Winter erosion data for Whitman County, Washington, obtained during a 43-year period from water year 1940 through 1982, provides a unique data set for determining the effect of climate, and specifically cold periods, on soil erosion in the region. The data was collected by Mr. Verle Kaiser (deceased), agronomist with the Soil Conservation Service, by annual spring sampling of erosion from a large number of representative fields across the more than 400,000 ha of cropland in Whitman County in southeastern Washington (See area surrounding Pullman in Fig. 1). The same fields were visited in consecutive years, thus the data included erosion from all years in the producers' rotations. For the purposes of this analysis, it was assumed that the major source of erosion was fall seeded small grain; thus the total observed erosion was divided by the acres of seeded small grain to determine a soil loss rate in t ha^{-1}. Table 1 contains the Kaiser soil erosion data and various weather parameter data, including annual water year precipitation, snowfall, diurnal freeze/thaw cycles, freezing index, days with mean temperature less than 0^oC, and number of freezing periods (greater than 25 freezing degree days (^oC)) for water years 1940 through 1982.

The Kaiser data set from water year 1940 through 1972 was previously used in an analysis of the effect of frozen soil on erosion (McCool and Molnau, 1974). The data was augmented by local stream flow data to assist in determining when the soil had thawed after a freezing period. One finding from this study was that during the period from water year 1940 through 1972, frozen soil was a dominant factor in soil erosion in at least 7 of the 33 years, coinciding with the highest erosion seasons. It was also found that many high volume runoff events occur independently of frozen soil conditions. For water years 1953 through 1972, for runoff events totaling greater than 12.7 mm, only 7 of 23 runoff events were definitely associated with rain on frozen soil, and one more was probably associated with runoff on frozen soil. The remaining 15 were caused by warming and rain on snow (McCool and Molnau, 1974). In the current study, which extended the previous analysis through water year 1982, we found that major precipitation or snowmelt events on previously frozen soil were a factor in erosion during each of the 11 years in which approximately 42 percent of the total erosion occurred during the 43-year period (Fig. 2).

Mean precipitation was 555 mm, and ranged from 335 mm in 1977 to 789 mm in 1959; during water year 1977, the NWRR experienced one of its most severe recorded droughts on non-irrigated cropland. Mean snowfall for the 29 years with available data was 98.5 cm, with 19.8 cm recorded in water year 1959, and 189.2 cm recorded in water year 1969 (well remembered by residents both for the snow and also for the extremely cold temperatures). The mean number of diurnal freeze-thaw cycles was 103, with a range from 65 to 135. This was slightly less than the 120 cycles suggested from an analysis by Hershfield (1974). Mean freezing index was 211 degree days (^{o}C) and ranged from 31 in 1967 to 654 in 1949. Days with mean temperature less than 0^{o}C averaged 50 with a range from 21 to 81. The average number of frozen periods with greater than 25 degree days (^{o}C) was 2.4, and ranged from 1 to 5. Mean soil loss was 53.8 t ha^{-1} with a range from 2.7 t ha^{-1} during a drought in water year 1977 to 153.4 t ha^{-1} in water year 1942. Analysis of the data in Table 1 indicated that soil loss was not correlated with diurnal freeze-thaw cycles, or with annual snowfall, or with snow at the time of thaw. Winters with very long frozen periods actually had less erosion than did those with slightly shorter frozen periods. Annual precipitation was positively correlated with winter soil erosion. Precipitation during thaw was positively correlated with soil erosion, as was shown in the McCool and Molnau study in 1974.

Period Since 1982

Since 1982, erosion in the eastern Washington and surrounding areas appears to have decreased. Is this due to changes in the weather pattern or changes in farming practices brought about by the 1985 Farm Bill or other causes? Data in Table 2 indicates there are some differences in the winter weather of water years 1940 through 1982 and 1983 through 2004. Precipitation is less, average snowfall is less, freeze/thaw cycles are slightly less, total freezing index is less, total days with mean temperature less, and the number of extended frozen periods is less during the latter period.

Data on erosion control practices applied in the Palouse River Basin are presented in Table 3 (Ebbert and Roe, 1998). Based on estimates using the Universal Soil Loss Equation (Wischmeier and Smith, 1978), erosion control practices in the Basin in 1994 might reduce total erosion by 1,700,000 U S tons annually as compared to 1979. Soil erosion estimates correlate well with suspended-sediment yield from the Palouse River (Ebbert and Roe, 1998) as shown in Figure 3. Suspended-sediment yield in the Palouse River at Hooper has decreased from the value for the 1962 through 1971 period to a value of one-half that for the 1993 through 1996 period (Figure 4). Assuming the relationship in Figure 3 is also applicable to the more recent Palouse River data indicates a major reduction in soil erosion in the Basin. The cause of this reduction appears to be a combination of a more benign weather pattern and increased application of conservation practices.

Comparison of Pacific Northwest and Eastern U. S. Weather Patterns

The November through March mean monthly temperature and precipitation data for WY 1971 through 2004 for Pullman, WA and Columbia, MO are shown in Tables 4 and 5. Pullman mean monthly winter temperatures are lower in November and March, but higher in January than in

Columbia. Precipitation data show the same pattern, with Pullman showing lower values in November and March but higher in January than Columbia. On the average, one might not consider these differences of major importance. Table 6 shows average annual precipitation, average annual snowfall, average freeze/thaw cycles, total freezing index, total days with mean temperate less than 0 degrees Celsius, and number of extended frozen periods. Pullman has more snowfall, more freeze/thaw cycles (but a smaller freezing index), about the same number of days with mean temperature less than 0 degrees Celsius, and the same number of extended frozen periods. However, Table 7 shows the number major freezing events followed by rains of 25mm or more for Pullman and for Columbia. Here is where the real difference between the Pacific Northwest and the eastern U. S. weather patterns appears. During the 34-year WY 1971 through 2004 period, Pullman had 14 occurrences of more than 25 mm of precipitation during the early stages of soil thaw, whereas Columbia had only 2 such occurrences. The Whitman County erosion data showed a strong correlation between winter erosion and precipitation during thaw. This would suggest that opportunities for winter erosion at Columbia are much less than at Pullman, and by inference, this difference would hold true for the Pacific Northwest region and the Eastern U.S. in general.

Conclusions

The first objective of this paper was to consider whether erosion has decreased in the past 20 years on non-irrigated cropland in the Pacific Northwest, and if so, is it due to a change in weather pattern, of cyclical or long-term nature, or is it due to changes in management practices perhaps caused by the requirements of the 1985 farm bill. Available data presented in this paper indicates that erosion has indeed decreased in the past 20 years, and that it is a result of a combination of a more benign weather pattern and increased application of conservation practices.

A second objective was to examine what is unique about the Pacific Northwest dryland area as compared to areas influenced by continental air mass rather than coastal weather patterns. Data from a 43-year erosion survey in southeastern Washington and analysis of climate records indicated that major precipitation or snowmelt events on previously frozen soil were a factor in erosion during each of the 11 years in which approximately 42 percent of the total erosion occurred during the 43-year period. Precipitation during thaw was positively correlated with soil erosion. During the 34-year WY 1971 through 2004 period, Pullman, WA had 14 occurrences of more than 25 mm of precipitation during the early stages of soil thaw, whereas Columbia, MO had only 2 such occurrences. Assuming that each location is representative of its region, there is much less opportunity for winter runoff and erosion in the Midwestern U.S. than in the Pacific Northwest. Rain or snowmelt on thawing soil is one of the characteristics that makes winter hydrology of the Pacific Northwest unique.

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Appendix

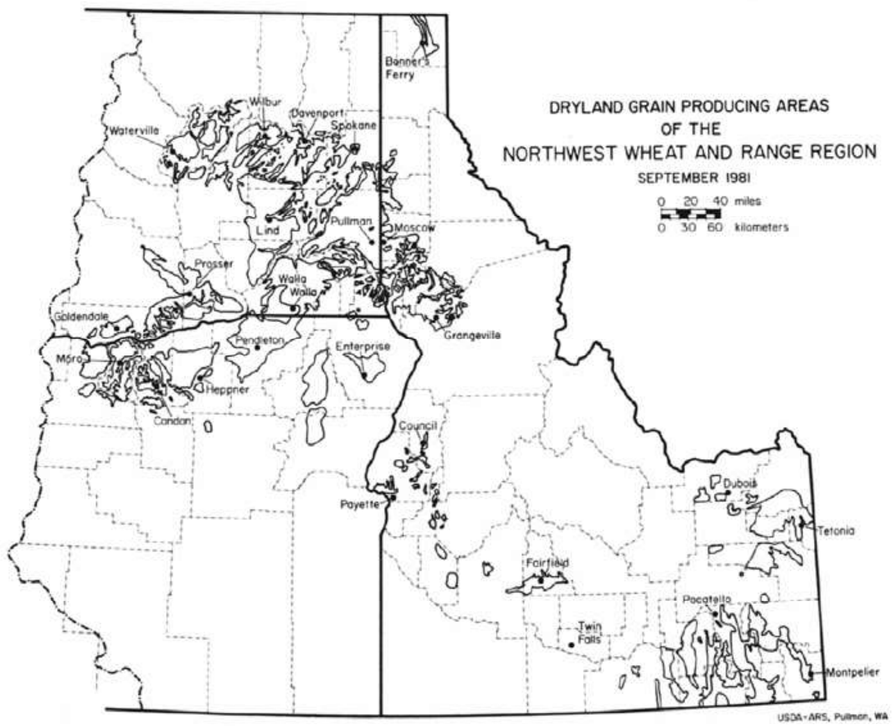

Figure 1. Non-irrigated grain producing areas of the Northwestern Wheat and Range Region.

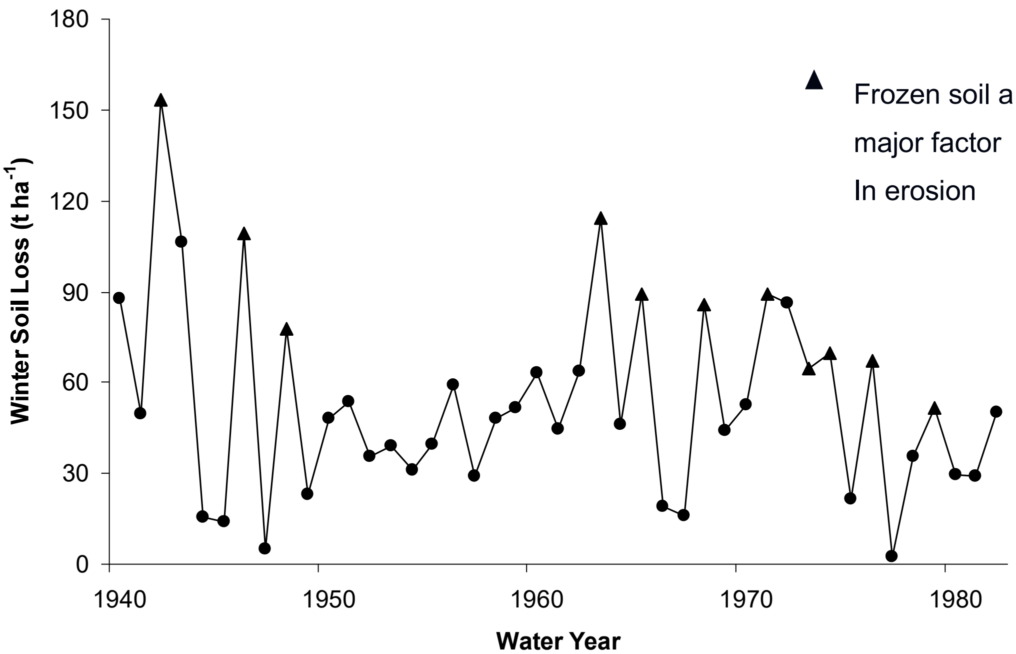

Figure 2. Winter soil loss from Water Years 1940 through 1982 in seeded small grain areas in Whitman County, Washington.

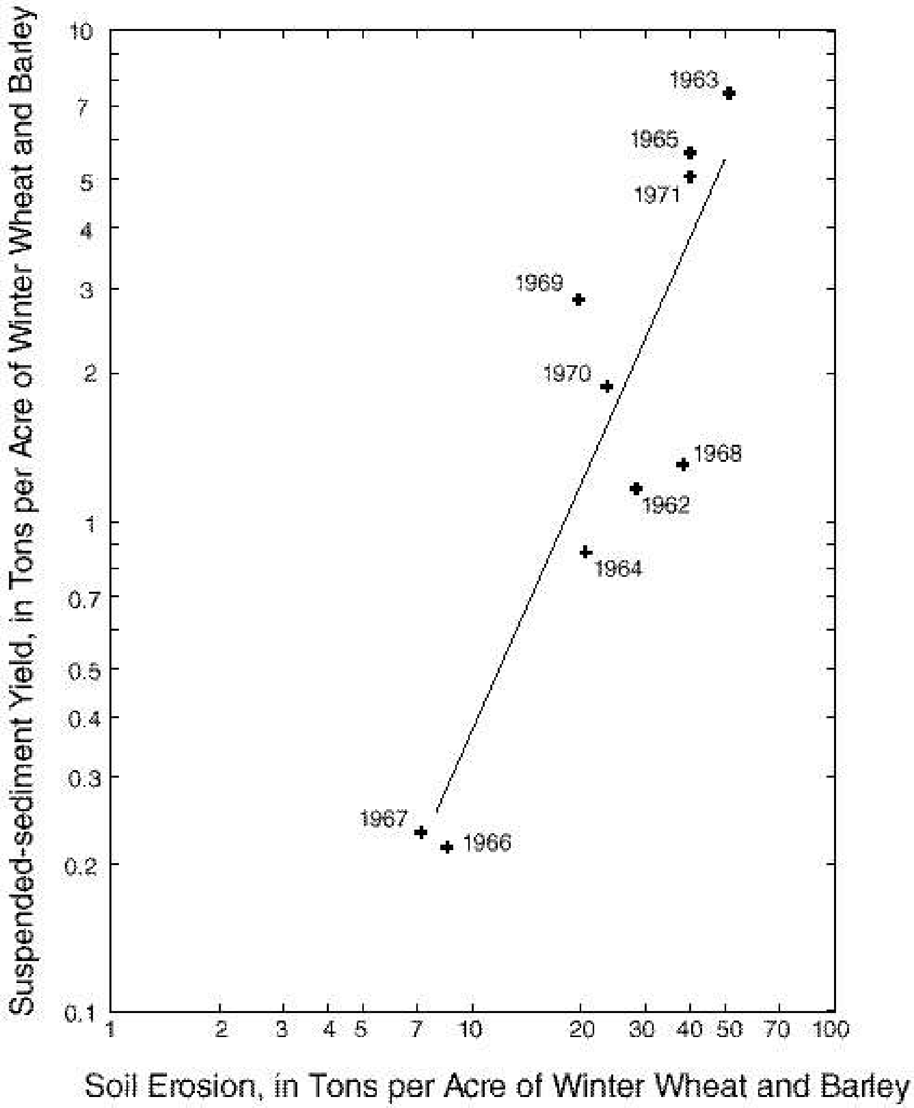

Figure 3. Soil erosion estimates correlate with suspended sediment yields from the Palouse River, 1962-71 (Ebbert and Roe, 1998).

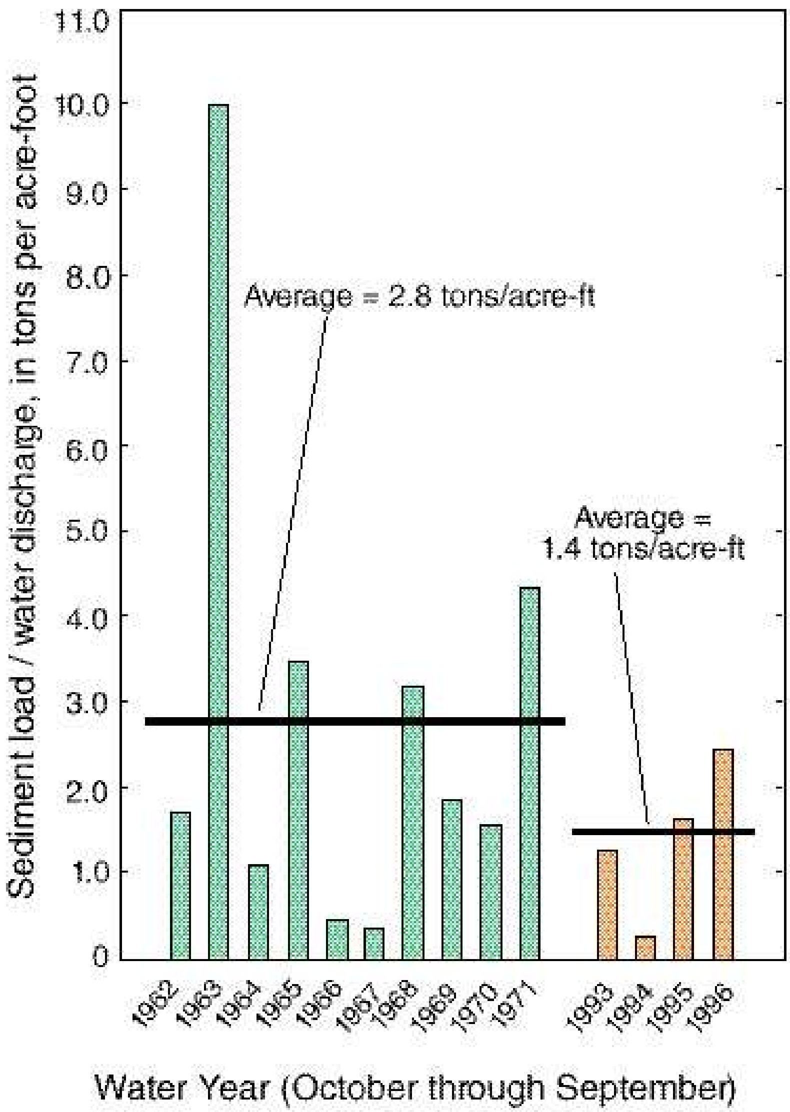

Figure 4. Comparing the historical record (1962-71) to recent years (1993-96) from the Palouse River at Hooper shows a decrease in the average annual concentration of suspended sediment (Ebbert and Roe, 1998).

Table 1. Winter soil loss from seeded small grain in Whitman County, Washington and Pullman, Washington weather data for Water Years 1940 through 1982.

Water Year	Precipitation (mm)	Snowfall (cm)	Diurnal Freeze/Thaw Cycles†	Freezing Index (°C)‡	Days with Mean Temp < 0°C	Number of Frozen Periods§	Mean Soil Loss ($t\ ha^{-1}$)¶
1940	479	40.6	65	73	22	1	87.6
1941	611		105	121	37	3	49.7
1942	442		100	289	58	2	153.4
1943	584		108	246	60	2	106.2
1944	354		112	203	72	2	15.5
1945	463		100	203	56	3	13.9
1946	605		107	194	52	3	109.5
1947	563		102	215	46	2	4.9
1948	732		119	202	52	2	77.5
1949	464		86	654	75	1	23.1
1950	595		96	466	56	2	47.9
1951	606		105	137	42	2	53.8
1952	636		103	326	73	2	35.4
1953	545		110	78	29	2	39.0
1954	575	61.5	118	104	25	1	30.9
1955	430	137.9	123	228	74	4	39.6
1956	702	183.6	89	399	77	5	59.1
1957	526	113.8	90	414	65	3	29.1
1958	630	19.8	99	33	24	1	47.9
1959	789	68.8	98	126	36	2	51.7
1960	595	95.8	94	305	57	3	63.2
1961	705	71.9	96	114	40	3	44.8
1962	565	137.9	94	319	58	4	63.6
1963	526	39.6	97	213	36	2	114.2
1964	607	129.8	135	121	47	2	45.9
1965	586	106.4	109	216	61	2	89.4
1966	343	86.9	104	146	46	3	19.0
1967	497	38.1	127	31	21	1	16.1
1968	495	38.1	92	163	43	3	85.6
1969	535	189.2	105	362	62	2	43.9
1970	515	65.5	111	152	44	2	52.9
1971	641	119.4	113	198	56	2	89.4
1972	604	178.8	108	263	44	3	86.2
1973	365	50.3	99	307	46	3	64.5
1974	671	158.8	100	246	41	1	69.7
1975	532	131.3	125	206	50	3	21.7
1976	584	109.0	116	194	53	4	67.2
1977	335		116	216	50	3	2.7
1978	544	94.7	88	172	47	2	35.8
1979	479	117.3	91	583	81	2	51.5
1980	565	86.4	93	240	51	4	29.8
1981	550	43.2	104	108	27	2	28.9
1982	680	141.5	97	227	50	2	50.0
Average	555	98.5	103	211	50	2.4	53.8

† Based on 0°C.

‡ Based on mean temp < 0°C.

§ Based on accumulated freeze index > 25 degree days (°C).

¶ Based on spatially distributed samples of fall-seeded small grain fields in Whitman County, Washington.

Table 2. Pullman, Washington weather comparisons, WY1940-1982 vs. WY1983-2004.

Water Year	Avg Precip (mm)	Avg Snowfall (cm)	Freeze/Thaw Cycles	Total Freezing Index (^{o}C)	Total Days with Mean Temp $< 0^{o}C$	Number of Extended Frozen Periods (>25dd ^{o}C)
1940-1982	555	99	103	228	49	2.1
1983-2004	509	78	100	201	46	2.0

Table 3. Erosion control practices in the Palouse River Basin (Ebbert and Roe, 1998).

Erosion control practice	Acres under erosion control[1]		Predicted average annual reduction in erosion[2]	
	1979	1994	Tons per acre	Total tons [3]
No-till seeding	600	56,000	9	500,000
Crop Reserve Program	6,400	60,600	5	270,000
Stripcropping divided slopes	0	239,000	1	240,000
Terraces	680	4,500	2	7,600
Grass water-ways	[4]82	[4]1,550	[5]1	1,500
Planting trees and shrubs	0	3,670	10	37,000
Conservation tillage	0	81,000	8	650,000
Totals[3]	7,680	445,000		1,700,000

1 U.S. Department of Agriculture progress records for 1979 and 1994.

2 Prediction based on Universal Soil Loss Equation (Wischmeier and Smith, 1978). For grass waterways, based on gross erosion prediction method (Renard and others, 1997).

3 Numbers have been rounded.

4 Linear feet.

5 Tons per linear foot.

Table 4. Mean monthly temperature (^{o}C) comparisons between weather stations in Pullman, Washington and Columbia, Missouri in WY1971-2004.

Weather Station	Mean Monthly Temp ($0^{o}C$) November	Mean Monthly Temp ($0^{o}C$) December	Mean Monthly Temp ($0^{o}C$) January	Mean Monthly Temp ($0^{o}C$) February	Mean Monthly Temp ($0^{o}C$) March
Pullman	2.7	-1.1	-1.3	1.0	4.5
Columbia	6.5	0.4	-2.2	0.9	6.6

Table 5. Mean monthly precipitation (mm) comparisons between weather stations in Pullman, Washington and Columbia, Missouri in WY1971-2004.

Weather Station	Mean Monthly Precip (mm) November	Mean Monthly Precip (mm) December	Mean Monthly Precip (mm) January	Mean Monthly Precip (mm) February	Mean Monthly Precip (mm) March
Pullman	70.1	68.7	64.4	51.2	54.5
Columbia	83.7	62.4	44.2	56.0	82.0

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Table 6. Comparisons between Pullman, Washington and Columbia, Missouri in WY1971-2004.

Weather Station	Avg Precip (mm)	Avg Snowfall (cm)	Freeze/Thaw Cycles	Total Freezing Index (°C)	Total Days with Mean Temp < 0°C	Number of Extended Frozen Periods (>25dd °C)
Pullman	522	87	102	217	47	2.2
Columbia	1019	53	79	270	48	2.3

Table 7. Major freezing events followed by rains of 25mm or more at weather stations in Pullman, Washington and Columbia, Missouri.

Weather Station	WY1940-1982 (43 years)	WY1983-2004 (22 years)	WY1941-2004 (64 years)	WY1971-2004 (34 years)
Pullman	17	7	24	14
Columbia	--	--	--	2