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Effects of long-term winter wheat, summer fallow residue and nutrient management on field hydrology for a silt loam in north-central Oregon

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Abstract

In a region where water is the primary limiting factor of crop production, loss of water from fields by overland flow represents an economic loss to producers. Traditional crop management practices in north-central Oregon have led to crop water loss by overland flow. In 1931, a long-term experiment was begun near Pendleton, Oregon, in a Walla Walla silt loam (coarse-silty, mixed, mesic Typic Haploxeroll—US; Kastanozems—FAO), to examine the influence on soil fertility and crop production by nutrient amendments and crop residue management practices. This experiment provided the opportunity to evaluate the influence of a several traditional farming practices on field hydrology. Tillage in all treatments consisted of moldboard plowing and multiple passes with secondary tillage equipment to smooth the surface for planting and for weed control. The treatments were combinations of nutrient amendments (0.90 kg N ha^{-1} commercial fertilizer, and 145 kg N ha^{-1} from manure) and residue management (fall-burn, spring-burn, and no-burn), whose soil organic carbon increased with increasing nutrient amendments. These treatments were in a winter wheat–fallow system and represent a set of past and current cultural practices. Overland flow from these treatments was measured. Lister furrows separated the plots of 12 m × 40 m (≈0.05 ha) to prevent overland flow from treatment to treatment and were instrumented with weirs to capture and measure overland flow. To determine if hydrologic differences existed between treatments, we tested the overland flow to precipitation (Q/P) ratio. The Q/P ratio ($P < 0.15$) was greatest within crop year/low soil fertility (0 kg N ha^{-1}, burn) whereas the high fertility (145 kg N ha^{-1}, no-burn) treatment crop year plots Q/P ratios were similar to fallow, standing stubble plots. Most notably, the manure amendment plots in crop, produce significantly less overland flow than the other residue and nutrient management practices, and marginally less overland flow than treatments in stubble. This research demonstrates that overland flow was greater from low fertility and stubble burned treatments. Increased overland flow increases the risk of soil erosion and loss of water to overland flow is potentially a loss of needed soil water for crop growth and production.

Keywords: Agricultural hydrology; Cropping systems; Dryland crops; Fallow; Residue management; Pendleton; Oregon

1. Introduction

As soil fertility is depleted, the hydrologic cycle is shortened and a negative feedback system develops wherein infiltration decreases, overland flow increases, mineral soil and nutrients are lost, soil water available for vegetation growth decreases, total vegetation biomass decreases, and soil structure deteriorates (West, 1986; Satterlund and Adams, 1992). This process leads to a further decrease in infiltration and yet another downward turn in the cycle,

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resulting in negative consequences in semi-arid, rainfed crops grown in silt dominated soils with low intrinsic soil organic matter. Because soil resources change slowly, evaluation of an agronomic practice requires decades of implementation, as is the case with many non-agronomic ecologic processes (Risser, 1991; Janzen, 1995). Dormaar et al. (1997), Campbell et al. (1991, 1996), Rasmussen and Parton (1994) and Rasmussen et al. (1998) reported on changes in soil nutrients and yield based upon research conducted in long-term agronomic plots at Lethbridge, Alberta, Indian Head, Saskatchewan, and Pendleton, Oregon. Consistently, these authors report that over time intensive tillage combined with fallow depletes soil organic matter and nitrogen, and results in lowered crop yields.

Changes in field hydrology associated with long-term agronomic practices remain largely speculative, often based upon space for time substitution (Pickett, 1989), small plot data (ring infiltrometers, rainfall simulation) and model extrapolation (e.g. Mielke and Wilhelm, 1998). An exception is Carroll et al. (1997), who recently evaluated changes in soil physical properties, overland flow, and erosion resulting from crop type (wheat, sorghum, and sunflower), crop rotation, and tillage practices (no till, reduced tillage, and conventional) in plots established in 1982. Direct measurement of overland flow from fields with established agronomic practices provides the opportunity to evaluate the influence those practices have on field and soil hydrology.

The purpose of this study was to determine if soils with a measured depletion of soil nutrients would also produce more overland flow than soils in a cropping system where soil nutrients have been maintained near the levels found in 1931, near Pendleton, OR.

2. Materials and methods

2.1. Study site

Research was conducted on a long-term crop residue experiment located at the Pendleton Experiment Station (LTCR-PES), approximately 15 km northeast of Pendleton, OR, at 45°43′N, 118°38′W, and an elevation of 458 m. The USDA-ARS Columbia Plateau Conservation Research Center (CPCRC) and Oregon State University Columbia Basin Agricultural Research Center share responsibility for the property and management of this experiment. This research was the first field scale evaluation of hydrologic characteristics of these long-term (70 years) treatments.

2.2. Meteorological records and soils

Thirty-nine years of meteorological records at the CPCRC show minimum, maximum, and mean annual air temperatures of −34, 46 and 11 °C, respectively. Frost-free days range from 135 to 170. Approximately 70% of precipitation occurs between November and April and results from maritime fronts that produce low intensity storms with a median duration of 3 h, 50% with duration ranging from 1 to 7 h. The maximum, recorded 1 h storm intensity is 13 mm h^{-1} and median storm size is 1.5 mm at 0.5 mm h^{-1} (Brown et al., 1983). Mean annual precipitation is 422 mm, with extremes of 243 mm minimum and 583 mm maximum. Snow cover is transient, snow water equivalent dependent upon whether the storm develops from continental or maritime fronts, and accumulated snow subject to rapid melting by frequent, warm maritime fronts. A meteorological station immediately adjacent to the plots recorded precipitation, wind speed and direction, solar radiation, relative humidity, and air and soil temperature from planting until harvest. Soil frost tubes monitored soil-freezing depth (Ricard et al., 1976). The soil type was Walla Walla silt loam (coarse-silty, mixed, mesic Typic Haploxeroll—US; Kastanozems—FAO). Slope ranges from 2 to 6% on a northeast aspect. Soil development occurred within a mantle of loess derived from Pleistocene alluvial deposits onto basalt flows of the Miocene Epoch (Johnson and Makinson, 1988).

2.3. Cropping systems

Initiated in 1931, the long-term crop residue experiment was to determine the influence of residue management and nutrient amendments on crop yields and soil fertility. Cropping systems monitored for this research were combinations of residue management (no-burn, spring-burn, and fall-burn), and nutrient amendments of 22 Mg manure (averaging 145 kg N ha^{-1} per crop since 1931), commercial fertilizer (90 kg N ha^{-1} per crop) and no amendment

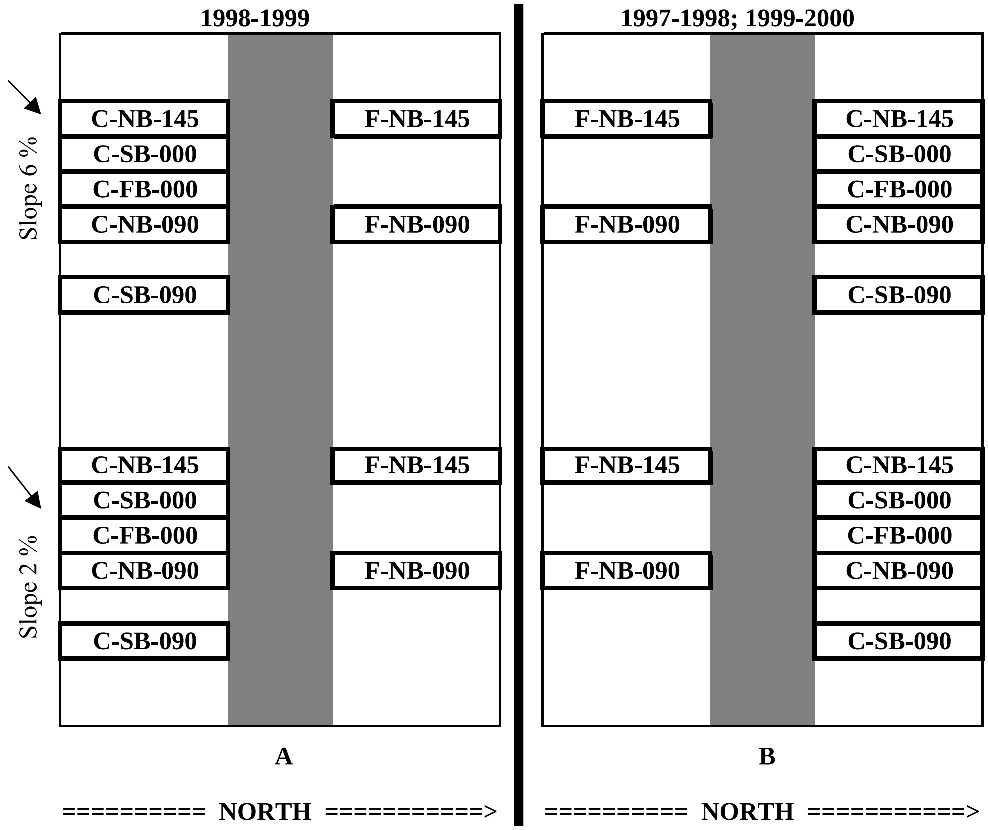

Fig. 1. Treatment layout for a crop–fallow cycle: columns 'A' and 'B' depict the same ground. Column 'A' shows plots sampled during 1998–1999, column 'B' shows plots sampled during 1997–1998 and 1999–2000. Treatments are replicated between 2 and 6% slopes. Fallow ground has standing stubble from previous years crop. Shaded area between crop and fallow plots is equipment traffic area. Treatment key—C/F: crop/fallow; NB, SB, and FB: no-burn, spring-burn and fall-burn, respectively; 000, 090, and 145: no nutrient amendment, 090 kg N ha^{-1} commercial nitrogen, and 145 kg N ha^{-1} nitrogen in livestock manure, respectively. For example, C-SB-000—C: in crop, SB: spring-burn, 000 = 0 kg N ha^{-1}. F-NB-145 and C-FB-000 monitored 2 years (1998 and 1999 crop years), all others monitored 3 years (1997, 1998 and 1999 crop years).

(Fig. 1). A local animal (bovine) feed lot has supplied partially dried, mixed straw and manure for the manure treatment since 1931. These treatments represented farming practices in the 1930s. The same tillage and residue management practices, in combination with the 90 kg N ha^{-1} application rate, are still commonly used in 2001.

2.4. Tillage operations

The crop rotation at each site was soft, white winter wheat (*Triticum aestivum* L.), harvested in mid-July, followed by a fallow period of 15 months. Primary tillage occurs in April using a moldboard plow (200–250 mm deep), followed by a field cultivator to smooth the plots, and then numerous (2–5) passes throughout the summer with secondary tillage equipment to control weeds.

2.5. Measurements

Plots were separated by lister furrows (small ditches made by a single-bottom moldboard plow) to prevent overland flow from one treatment to the next (Brakensiek et al., 1979). We installed weirs (Bonta, 1998) and stage recorders at the furrow outfall to measure overland flow (Fig. 2). Flow rates were calculated from standard stage/flow rating curves developed by

Fig. 2. Lister furrow leading into drop-box weir and digital stage recorder. Flow is from a rain storm (duration 18 h, average intensity 4 mm h^{-1}, three peaks of 15 mm h^{-1} intensity for a total of 10 min, total event 30 mm) on thawed soil in C-FB-000 treatment, 14 February 2000. Peak flow coincided with peak rainfall intensities in the ninth and tenth hours of the storm.

Bonta (1998). When rainfall or snow thaw events were adequate to produce overland flow, it was recorded digitally by stage recorders. Samples were also collected in 1 l bottles, timed using a stopwatch, and the flow rate calculated to provide quality control for the digital data. A weather station at the site recorded soil and air temperature, wind speed, and precipitation. In the discussion that follows, the term infiltration is used with the understanding that it is estimated from the direct measurement of overland flow (Brakensiek et al., 1979).

Historic soil organic carbon (SOC) was determined in each of the plots by sampling in 1931, 1941 and 1951 to a depth of 600 mm in 300 mm increments. In 1964, 1976 and 1986 the cores where subdivided into 150 mm increments. Samples were composites of 8–16 cores collected from positions in the central region of the plots. SOC values were determined for the 1931 and 1941 samples by the loss-on-ignition method (Rather, 1917). SOC values in 1976 and 1986 were determined by dry combustion (Tabatabai and Bremner, 1970). There is no record of how the SOC values in 1951 were obtained, and there is no record of SOC sampling for 1964. Rasmussen and Parton (1994) transformed SOM values from 1931 and 1941 based on SOM/N and total C/N ratios, and extrapolated the missing data for 1964 from 1951 and 1976 C values, and the relative changes in N values between 1951 and 1964. Projections of continued loss of SOM beyond 1986 were made using the carbon sequestration model 'CQESTR' developed and presented by Rickman et al. (2001).

2.6. Experimental design and analysis

In crop year 1997, 10 plots (12 m × 40 m (≈0.05 ha)) were monitored—four cropping practices plus one fallowed treatment replicated on two slopes. In crop years

Table 1
Winter wheat–fallow treatments on which overland flow was measured[a]

Treatment	Amendments/fertilizer	Years measured
Stubble, no-burn, manure amendment	F-NB-145[b]	1999, 2000
Stubble, no-burn, commercial fertilizer	F-NB-090[c]	1998, 1999, 2000
Crop, no-burn, manure amendment	C-NB-145	1998, 1999, 2000
Crop, no-burn, commercial fertilizer	C-NB-090	1998, 1999, 2000
Crop, spring-burn, commercial amendment	C-SB-090	1998, 1999, 2000
Crop, spring-burn, no nutrients added	C-SB-000	1998, 1999, 2000
Crop, fall-burn, no nutrients added	C-FB-000	1999, 2000

[a] Treatments were established 1931, near Pendleton, Oregon. F-NB-145 and F-NB-090 treatments were in fallow with standing stubble. These plots, in alternate years, were the C-NB-145 and C-NB-090 treatments. Overland flow was only captured during crop years in treatments C-SB-090, C-SB-000, and C-FB-000. Treatment key—C/F: crop/fallow; NS, SB and FB: no-burn, spring-burn and fall-burn, respectively; 000, 090 and 145: no nutrient amendment, 090 kg N ha^{-1} commercial nitrogen and 145 kg N ha^{-1} nitrogen in livestock manure, respectively.

[b] Manure amendments average N application of 145 kg ha^{-1} crop per year.

[c] Commercial fertilizer average N application 90 kg ha^{-1} crop per year.

1998 and 1999, an additional four plots were monitored, 14 plots total—five cropping practices plus two fallowed treatments replicated on two slopes (Table 1). Duplicate plots were established on 2 and 6% slopes (Fig. 1). We chose these treatments because they represent extremes in soil fertility and potential for water and soil loss or conservation.

Overland flow to precipitation (Q/P) ratios events, where overland flow was generated in at least one of the cropping practices, were used to determine if hydrologic differences existed between the cropping practices. Because additional treatments were monitored after the first year, two separate analyses were conducted to account for the different lengths of data collection. Q/P ratios from treatments monitored for 3 years were based upon $n = 45$ overland flow events, and ratios for 2 years based upon $n = 28$ events. Plot and treatment layout predate now standard experimental and statistical designs (Fig. 1), because treatments or crop–fallow rotations were not randomly assigned (Hurlbert, 1984; Janzen, 1995). With acknowledgment of these limitations and how they might violate assumptions of ANOVA, we tested data for normality, calculated the Q/P ratio and performed a log transformation to meet the assumption of normality, and conducted an analysis using ANOVA (SAS Mixed Procedure) type 3 tests of fixed effects ($F = 0.05$) (SAS, 1998). Once variance was found to be significantly different among treatments, means separation tests using least squares analysis were performed (SAS, 1998). The results are presented to demonstrate the probability of difference among treatments.

3. Results

Measurements of two early season overland flow events were missed during each of the 3 years of study. The distribution of climate events generating overland flow was weighted towards events not associated with frozen soil (Table 2). With minor exceptions, precipitation and temperatures during the erosion season for

Table 2
Number of overland flow events and the soil and climate conditions associated with them during 3 years of monitoring long-term crop residue experiment at Pendleton, Oregon

Crop year	Frozen soil, snowmelt	Frozen soil, rain, snowmelt	Frozen soil, rain	Thawed soil, snowmelt	Thawed soil, rain, snowmelt	Thawed soil, rain	Total number of events
1997–1998	0	3	3	1	0	11	18
1998–1999	0	1	1	0	0	12	14
1999–2000	0	0	0	1	2	11	14
Total	0	4	4	2	2	34	46

Table 3
Precipitation and temperature values recorded during 1998–2000 water-year research period in relation to 68-year weather record at agricultural experiment station, Pendleton, Oregon[a]

	68-Year mean ± S.D.	Water year		
		1998	1999	2000
Precipitation (mm)				
November	53 ± 27	40	120[b]	55
December	52 ± 26	36	75	48
January	50 ± 24	72	30	61
February	39 ± 19	22	55	85[b]
March	43 ± 20	36	31	86[b]
Minimum temperature (°C)				
November	−5.0 ± 8.2	−3.9	−3.9	−2.8
December	−8.1 ± 9.7	−8.3	−20.6[b]	−5.6
January	−12.1 ± 10.8	−16.1	−5.6	−5.0
February	−11.3 ± 8.8	−5.0	−9.5	−3.9
March	−7.3 ± 4.3	−5.0	−4.4	−3.9
Maximum temperature (°C)				
November	18.9 ± 2.9	19.5	17.8	25.6[b]
December	15.5 ± 2.9	15.6	14.5	15.0
January	14.4 ± 3.6	15.0	15.6	13.9
February	16.3 ± 3.0	16.7	16.1	17.2
March	20.5 ± 2.5	20.0	18.9	21.7

[a]Precipitation and temperature conditions averaged for the 3 years of study, or the combined erosion season (November–March), were not different from the previous 68 years of record.
[b]Numerical values outside of 1 standard deviation of 68 years of record.

Table 4
Least squares means separation *P* values for tests conducted on overland flow to precipitation ratios for the long-term crop residue cropping practice study, Pendleton, Oregon[a]

Management practices	*P*
F-NB-090 < C-SB-000	≤0.00[b]
F-NB-145 < C-SB-000	≤0.01[c]
F-NB-145 < C-SB-090	≤0.01[c]
F-NB-090 < C-SB-090	≤0.01[b]
C-NB-145 < C-SB-000	≤0.01[b]
F-NB-145 < C-FB-000	≤0.01[c]
F-NB-145 < C-NB-090	≤0.02[c]
C-NB-145 < C-SB-090	≤0.02[b]
C-SB-000 < F-NB-090	≤0.02[c]
F-NB-090 < C-NB-090	≤0.03[b]
C-SB-090 < F-NB-090	≤0.04[c]
C-FB-000 < F-NB-090	≤0.06[c]
C-NB-090 < C-SB-000	≤0.08[b]
C-NB-145 < C-NB-090	≤0.09[b]
C-NB-090 < F-NB-090	≤0.09[c]
C-NB-145 < C-FB-000	≤0.11[c]
F-NB-145 < C-NB-145	≤0.14[c]
C-NB-145 < C-NB-090	≤0.17[c]
C-NB-090 < C-SB-090	≤0.23[b]
F-NB-145 < F-NB-090	≤0.24[c]
F-NB-090 < C-NB-145	≤0.32[b]
C-SB-000 < C-SB-090	≤0.40[c]
C-FB-000 < C-SB-000	≤0.55[c]
C-NB-145 < F-NB-090	≤0.68[c]
C-NB-090 < C-FB-000	≤0.73[c]
C-FB-000 < C-SB-090	≤0.80[c]

[a]Treatment key—C/F: crop/fallow; NB, SB and FB: no-burn, spring-burn and fall-burn, respectively; 000, 090 and 145: no nutrient amendment, 090 kg N ha^{-1} commercial nitrogen and 145 kg N ha^{-1} nitrogen in livestock manure, respectively.
[b]Based on 3 years of data, 6 degrees of freedom.
[c]Based on 2 years of data, 4 degrees of freedom.

the 3 years of monitoring were within 1 standard deviation on the long-term averages (Table 3).

The *Q*/*P* ratio (Fig. 3) increased with decreasing soil fertility (Fig. 4) and cover, i.e., the no-burn manure amendment treatment (C-NB-145) produced significantly lower *Q*/*P* ratios than all other treatments in the crop year of the winter wheat–fallow cycle. As one would expect, these relationships were most strongly shown in the analysis of data from treatments that had been monitored for 3 years; the statistical relationships held for the 2-year data with one exception, where the *Q*/*P* ratio from the no-burn commercial fertilizer treatment (C-NB-090) was no longer discernible from the C-NB-145 treatment (Table 4).

4. Discussion

4.1. Previous research on the Columbia Plateau

Before this study, overland flow in this region was generally believed to be infrequent, and largely limited to rain on frozen soil, rain on snow and frozen soil, or snow melt over frozen soil events. Previous studies reported that 86% (from 0 to 7 events per year) of overland flow resulted from such conditions during 12 years of monitoring 33.5 m × 4.05 m plots used in the development of the Universal Soil Loss Equation (Zuzel, 1994; Zuzel et al., 1982, 1986, 1993). However, of the 46 overland flow events recorded in this current study; only 8 (18%) were under frozen soil conditions.

In the above previous studies, the plots were 15 km to the east of LTCR-PES on steeper slopes (16%), with greater precipitation, and 225 m higher in elevation. Zuzel et al. (1982) reported *Q*/*P* ratios as high as 0.87 from frozen soil conditions. However, the

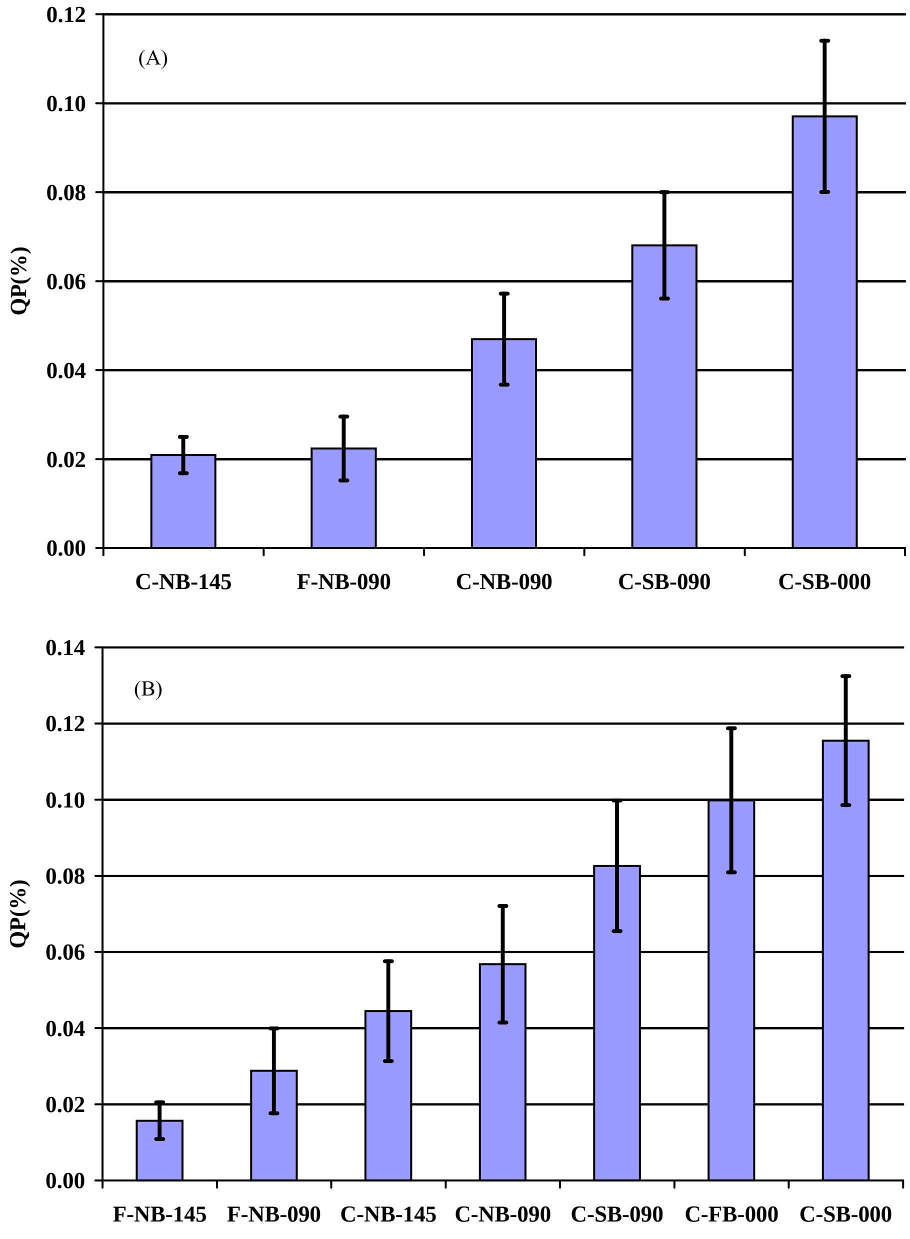

Fig. 3. Overland flow to precipitation ratio (%) averages and standard errors (0.05) for crop residue and nutrient cropping practices: shown are four cropped and one fallow plot that were monitored for 3 years (A), and the five cropped and two fallow plots monitored for 2 years (B). Treatment key—C/F: crop/fallow; NB, SB and FB: no-burn, spring-burn and fall-burn, respectively; 000, 090 and 145: no nutrient amendment, 090 kg N ha^{-1} commercial nitrogen, and 145 kg N ha^{-1} nitrogen in livestock manure, respectively.

treatment creating this high Q/P value was in continuous (plowed) fallow, whereas the treatment cropped to winter wheat had Q/P ratios one-quarter of this high value (Zuzel, 1994). On the LTCR-PES plots, the Q/P ratio from one treatment (C-SB-000) during one frozen soil event equaled 0.91, but only 1% of Q/P ratios recorded (all treatments generating overland flow) were greater than 0.50.

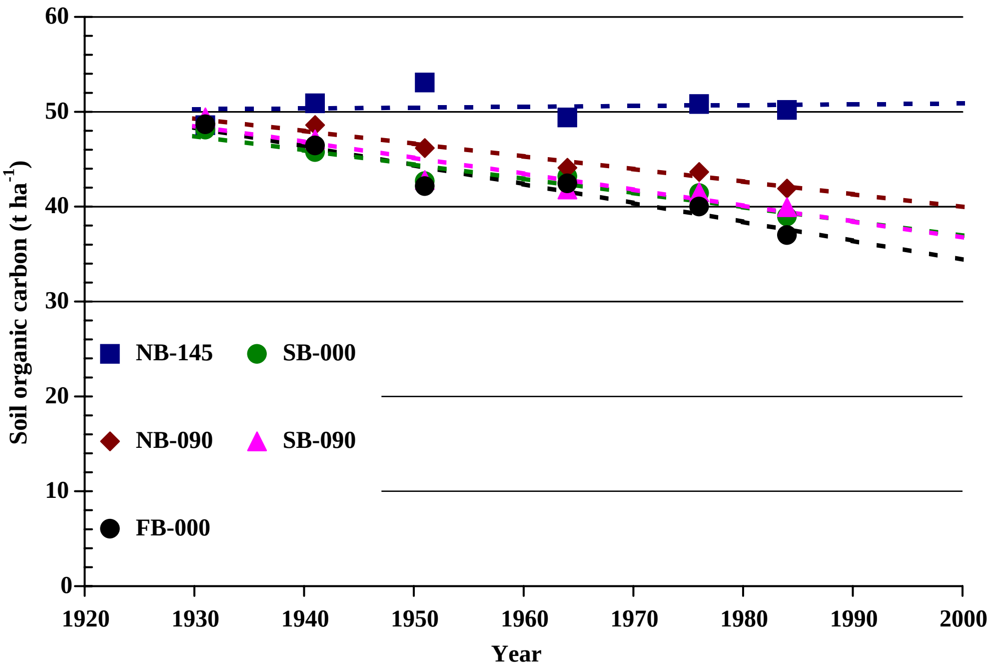

Fig. 4. Soil organic carbon decline in winter wheat–fallow cropping system (Rasmussen and Parton, 1994; Rickman et al., 2001). Treatments are—NB-145: no-burn, manure amendment, 145 kg N ha^{-1}; NB-090: no-burn, commercial fertilizer, 90 kg N ha^{-1}; SB-090: spring-burn, commercial fertilizer, 90 kg N ha^{-1}; SB-000: spring-burn, no commercial fertilizer, 0 kg N ha^{-1}; F000: fall-burn, no commercial fertilizer, 0 kg N ha^{-1}.

4.2. Infiltration in stubble and crop ground

A comparison of *Q*/*P* in crop versus stubble demonstrates the link between soil carbon, infiltration, and overland flow. A generally accepted paradigm is that overland flow is lower in stubble fields that are more adequately covered, compared to overland flow for land under winter wheat and some residue from the previous crop cycle. This is due to the reduced effect of raindrop impact and surface sealing in the former. Zuzel and Pikul (1987) reported only a marginal difference in overland flow from winter wheat in crop or in stubble treatments. However, after 30 min of simulated rainfall that marginal difference became a binomial relationship because infiltration ceased in the winter wheat treatment. This relationship is clearly demonstrated in the results reported here, where the F-NB-090 treatment, with nearly complete soil cover, generated a significantly lower *Q*/*P* ratio than C-NB-090, C-SB-090, C-SB-000, or C-FB-000, each of which had ground cover values of less than 20%. Zuzel et al. (1982) demonstrated that overland flow events on the Columbia Plateau were more a function of surface saturation and impaired infiltrability than raindrop impact leading to particle sorting and sealing of the soil surface. Our results support their conclusions and demonstrate that water infiltrates into fall planted wheat, where manure has maintained SOC, at rates similar to stubble ground (Fig. 3). The structure of the soil surface and near-surface profile, regardless of whether the soil is thawed or frozen, must therefore control infiltration, which is determined by levels of SOC. This concept is supported by Pikul and Zuzel (1994) who, reporting on analysis of soils from the LTCR-PES plots, found the following relationships among treatments: (a) significant differences in SOC (C-FB-000 $<$ C-NB-090 $\ll$ C-NB-145); (b) significant difference in porosity (C-FB-000 $<$ C-NB-090 $\approx$ C-NB-145); (c) however no difference in aggregate mean weight diameter of soil aggregates. Visually, the C-NB-145 soil surface appears dark and somewhat rough when wetted, frozen or thawed, whereas the C-FB-000 and C-SB-000 soil surfaces begin to glisten (indicating surface saturation) following a light rainfall or thawing without precipitation. Pikul and Allmaras (1986) reported significantly faster hydraulic conductivity ($P = 0.05$) in C-NB-145 than C-NB-090 and C-FB-000 after 54 years of study. Our results demonstrate an even more pronounced relationship after an additional 20 years into the study.

4.3. Residue and nutrient management, soil organic carbon, and infiltration

Manure amendment plots produced less overland flow than the other residue and nutrient management practices. This relationship is most notable with the standing stubble, no-burn, 90 kg N ha^{-1}. Generally considered to have the most superior hydrologic conditions for high rates of infiltration in this cropping system with nearly complete ground cover and little soil moisture following the previous crop, it is only marginally different than the manured treatment. Loss of SOC among the non-manured treatments in this system of winter wheat–fallow is well documented (Fig. 4) (Rasmussen and Parton, 1994; Rickman et al., 2001). This loss is because carbon return by crop growth in non-manured treatments, did not replace carbon lost by erosion and SOC mineralization (Rasmussen and Parton, 1994; Rasmussen et al., 1998). In the manured treatment there was no net loss of SOC, with 1.5 t C ha^{-1} added with manure each crop year (Rasmussen and Albrecht, 1998), in addition to the 2.8 t C ha^{-1} added to the soil by above-ground crop residue. Relative to carbon returned by the manured treatment, the carbon returned by C-SB-000 is 15% (0.63 t C ha^{-1}), C-FB-000 is 21% (0.89 t C ha^{-1}), C-SB-090 is 36% (1.55 t C ha^{-1}), and C-NB-090 is 58% (2.47 t C ha^{-1}) (Rasmussen and Parton, 1994; Rasmussen et al., 1989, 1998). Consequently, soil fertility has declined in those treatments with depleted SOC (Rasmussen and Parton, 1994). A soil with poor infiltration ability has developed, as demonstrated by the differences of Q/P ratios.

A mechanism to explain the process is yet undetermined. The Q/P ratios found in the C-NB-090 and C-SB-090 treatments suggest that the infiltration in the two commercial fertilizer treatments (burn or no-burn) is essentially the same. Campbell et al. (1991) hypothesized that roots contribute more to soil organic matter than above-ground plant material, thus explaining the narrow differences in SOC between the burn/no-burn treatments in conjunction with the commercially applied fertilizer. The manure treatment had the best infiltration, which may be explained by the greater longevity of macroaggregates developed from manure amendments (Monreal et al., 1997).

The practical implication of this analysis is that where SOC decreases, infiltration capacity deteriorates, and the rate of deterioration is faster where nutrients are not being replaced. Nonetheless, SOC depletion with the fallow–crop rotation is also occurring with the application of commercial fertilizer, whether crop residue is burned or not. Presumably as SOC declines, there will be reductions in infiltrability. Although the practice of not adding commercial fertilizer to a crop ended sometime in the 1930s or 1940s, the tillage practices in combination with fertilizer rates used in this experiment are still common throughout the Columbia Plateau and Palouse regions of the northwestern USA.

5. Conclusions

The purpose of this research was to quantify the long-term hydrologic effects of past and present crop residue and fertility management typical in the dryland crop area of the Columbia Plateau. The results presented here compliment the findings of research examining soil fertility previously conducted on these specific plots. Overland flow was least from the high fertility treatments with manure amendments and greatest from low fertility (0 kg N ha^{-1}) in which crop residue from the previous crop had been burned. The importance of maintaining high fertility levels to soil hydrology is demonstrated by the manure amendment treatment, in crop, losing as little water to overland flow as the treatments in stubble. Farming practices, such as using manure amendments and not burning residue from the previous crop, can maintain SOC in this region and create soil conditions that reduce or retard overland flow. Water not lost to overland flow in rainfed crops can increase soil water availability and contribute to increased crop yield.

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