Long-term declines in carbon fluxes from the Palouse

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The Palouse region, located in the dryland cropping region of the inland Pacific Northwest, is well known for excessive soil erosion rates. Soil erosion rates have been measured as high as 200 tonnes/ha, with average annual erosion rates often exceeding 45 tonnes/ha during early century periods. A benchmark study in 1978 by the U.S. Department of Agriculture estimated that 40% of the topsoil in the Palouse Basin, as defined by the watershed area upstream of a long-term U.S. Geological Survey (USGS) stream gauging station at Hooper, Washington, had been lost to erosion.

IMPACT

Since the 1960s, mean annual carbon transport has declined nearly 90% at the outlet of the Palouse River Basin, mainly as a result of increased conservation tillage practices. In terms of equivalent CO_2 production, the annual reduction in carbon load is equivalent to the annual carbon emissions from 15,747 cars.

Although soil erosion rates and sediment yield have been widely documented, few studies have focused on quantifying the transport of soil organic carbon at various scales within the basin via erosion and stream sediment transport. Understanding the impact of management and scale on carbon transport will improve our understanding of the effectiveness of future mitigation practices, which aim to increase overall carbon storage in the region. A 2-year study was conducted to quantify long-term declines in soil carbon storage and transport at the outlet, and at various scales within the Palouse Basin, in response to increased adoption of reduced tillage practices in the region.

Five study sites ranging in size from 11 to 647,947 ha were monitored for streamflow in 2012 and 2013. Event-based water samples were analyzed for suspended sediment concentration (SSC), particulate organic carbon (POC), and dissolved organic carbon (DOC). At the field scale, two fields were monitored to detect the influence of management on carbon transport: (1) a 14-ha conventionally tilled farm in Idaho (Figure 1), and (2) an 11-ha catchment within the Washington State University Cook Agronomy Farm that was managed using direct-seed practices. At the watershed scale, soil carbon measurements were made at the USGS Paradise Creek stream gauge location (4,890 ha) and at the Paradise Creek at Darby Road station (2,930 ha) (Figure 2) near Moscow, Idaho. At the basin scale, historic carbon and sediment data were obtained from the USGS stream gauging station on the Palouse River at Hooper, Washington (647,497 ha). These data were compiled with data collected in this study.

Figure 1. *Water quality monitoring at the outlet of the 14-ha Idaho conventional tillage site. Photo by Erin Brooks.*

Total sediment and carbon loads were calculated. In 2012, POC and SSC were highly correlated at each of the stream gauge locations, with the mass fraction of carbon ranging from 0.6% in the Paradise Creek watershed to 1.6% at the Hooper stream gauge location. Figure 3 shows the POC/SSC relationship at the Palouse River gauge at Hooper, Washington for all years. Dissolved organic carbon measurements showed little variability at each station, with an average annual concentration of 6.5 mg/L at the Hooper, Washington stream gauge location.

Total sediment and carbon yields from the Palouse Basin have declined more than two orders of magnitude from 1960 to 2012 (Table 1). Total sediment yield declined from 2 million tonnes/year from the 1962–1971 period to 70,000 tonnes/year during the 2010–2012 period. Similarly, the carbon yield at the Hooper, Washington gauge decreased from 25,000 tonnes/year to 4,400 tonnes/year for the same time periods, respectively. This is more than a 95% decrease in sediment and an 82% reduction in carbon load since the 1960s. The decrease in carbon load has occurred primarily through the reduction in delivery of POC. During the 1960s, only 12% of the total carbon load was delivered in the form of DOC, whereas currently 83% of the total carbon delivered from the basin is transported as DOC.

To provide some perspective, the reduction in carbon load expressed as CO_2 equivalent (i.e., the potential amount of CO_2 that could be released from a given amount of carbon) is equivalent to the CO_2 emitted from 15,736 cars per year. Assuming the reduction in sediment and carbon load has occurred primarily from agricultural lands, then for CO_2 emissions from 111 cars.

While it is clear that carbon and sediment yields are declining in the Palouse Basin, the vast majority of the soil and carbon that is transported by erosion in the region is deposited and stored within the basin. Using a conservative soil erosion estimate of 3.3 tonnes/ha/year, the sediment yield data measured at the Hooper station indicate that less than 5% of all the carbon transport by erosion within the basin will be transported out of the basin. The

Figure 2. *Water quality monitoring station at the outlet of the 2,930-ha Paradise Creek watershed. Photo by Erin Brooks.*

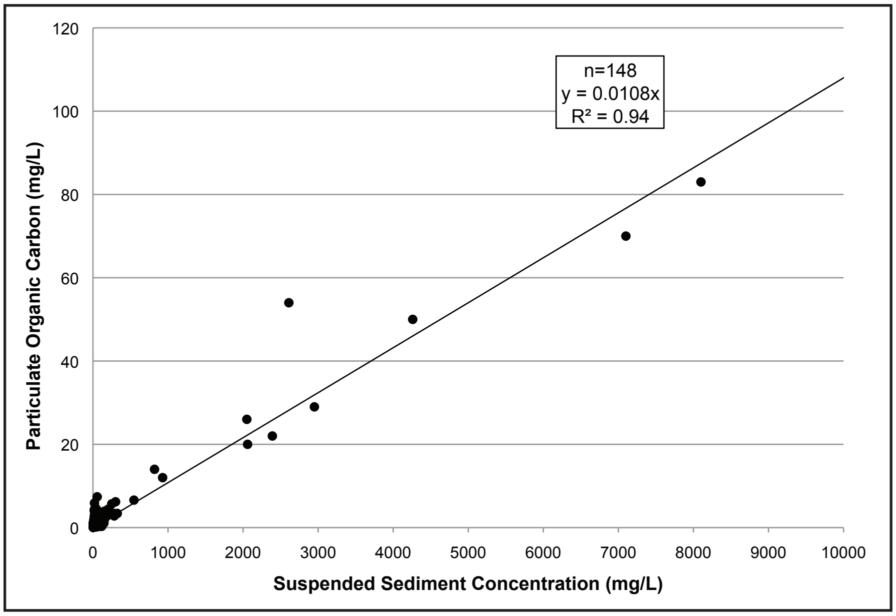

Figure 3. *Relationship between particulate organic carbon and suspended sediment concentrations from historic sampling data at Hooper, Washington (1992–2004).*

remaining 95% is deposited and stored in the landscape.

The dramatic reduction in carbon yield can be largely attributed to the adoption of conservation tillage management practices. As seen in Table 1, despite the similar size catchment, the total carbon delivered from the Cook Farm no-till site is two orders of magnitude smaller than the carbon delivered from the Idaho conventional tillage site.

Overall, the decline in total carbon delivery in the Palouse Basin is impressive. The adoption of soil conservation tillage practices has not only dramatically reduced carbon export from the region, but the rebuilding of lost topsoil is undoubtedly improving agricultural production in the region as well.

Table 1. *Annual sediment and total carbon loads at the five catchment sites over time, percentage delivered as dissolved organic carbon, and equivalent CO_2 emissions.*

Site	Total agricultural area (hectare)	Time period	Sediment yield (tonne/year)	Total carbon yield (tonne/year)	Percentage delivered as dissolved organic carbon (%)	Equivalent CO_2 emissions by number of cars[1]
All years						
Paradise Creek (ID)	4,890 (3,032)	1979–1995	2,000	55	63	42
		2002–2011	700	48	85	37
Hooper, WA	647,497 (283,600)	1962–1971	2,000,000	25,000	12	19,097
		1992–2004	360,000	7,600	48	5,806
		2010–2012	70,000	4,400	83	3,361
2012 only						
Idaho CT outlet[2]	14	2012	79	0.8	2	0.6
Cook Farm (WA) NT[3]	11	2012	0.9	0.02	63	0.0
Paradise Creek at Darby Rd. (ID)	2,930	2012	1,600	57	84	43.8
Hooper, WA	647,497	2012	120,000	6,008	68	4,589

[1] Assumes 4.8 tonnes CO_2 emissions per vehicle per year
[2] CT = Conventionally tilled
[3] NT = No-till (direct-seed)