Field-scale soil carbon budget for furrow irrigation

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Introduction

In order to quantify the sediment and carbon budget of a furrow-irrigated field, we analyzed water and sediment of irrigation and associated tail waters of a 30 ha corn field in the Central Valley in California. This field was monitored to assess the effects of minimum tillage versus standard tillage on soil C sequestration and greenhouse gas emissions. Water samples of two irrigation events in July and August, 2004, were collected and analyzed for suspended sediment, DOC, DON, total carbon and nitrogen. Field and soil water budgets were estimated from meteorological data, flow measurements of applied irrigation and runoff water, and neutron-probe soil water measurements. The total net irrigation depth during the study period was 270 mm, with an average water application efficiency of 64%. Tail waters contained less sediment but more organic carbon than irrigation waters, due to particle settlement and enrichment in organic matter (OM). Tillage treatment had no significant effect on composition of water or sediment. Furrow irrigation resulted in a net field input of 700 kg sediment ha-1, 21.4 kg C ha-1 and 7.7 kg N ha-1. The corresponding soil C increase associated with these 2 irrigation events was about 20% of reported yearly carbon sequestration rates in long-term soil carbon sequestration experiments. The carbon of the OM of the sediment accounted for about two thirds of the total C addition. The dissolved fraction (DOC) affects short-term CO2 fluxes, due to their higher mineralization potential. Our experiments showed the importance of time scale in carbon budgeting for intensively irrigated agroecosystems where large dynamics and variability of inputs are expected.

Figure 1. Research site at Turkovich farm

Objective: To estimate the temporal dynamics of carbon inputs and outputs of surface-applied water in a furrow-irrigated field, to complement an ongoing C-sequestration experiment that evaluates the effects of minimum tillage on soil C sequestration.

Materials and Methods

Field site

The study site is a 30 ha furrow-irrigated field of the Turkovich farm, located in the Sacramento Valley, near Winters, CA. Mapped soil series within the field include a Myers clay (Fine, montmorillonitic, thermic, Entic Chromoxerert) and Hillgate loam (Fine, montmorillonitic, thermic, Typic Palexeralf). The slope of the field is less than 2 %. Soil permeability is slow and the CaCO3 content in the top soil is lower than 5%. A summary of the field-average topsoil properties is presented below.

	Carbon (%)	Nitrogen (%)	Sand (%)	Silt (%)	Clay (%)
Average	1.05	0.11	29.0	52.9	18.2
Range	0.64-1.61	0.08-0.14	18.9-43.4	41.6-60.9	13.3-22.8

Irrigation

Irrigation water is delivered by a 15 km long non-lined open channel from Clear Lake and Cache Creek, CA, of Yolo County Flood Control & Water Conservation District (YCFC&WCD). Along its way to the farm, drainage and tail water are mixed with the fresh water supply. Whereas water application is mostly by surface irrigation, sprinkler irrigation is often used for seed germination. Table 2 shows the main chemical characteristics of the irrigation and tail waters of the experimental field, indicating that these are carbonate waters with low salinity and sodicity levels.

	pH	Electric Conductivity ($dS\ m^{-1}$)	Sodium Adsorption Ratio	$mmol_c\ l^{-1}$						
				Ca	Mg	Na	Cl	Bo	Bicarbonates	Carbonates
Irrigation	8.4	0.3	< 1	1.0	1.5	0.7	0.3	0.9	2.2	0.5
Tailing	8.4	0.3	< 1	1.1	1.5	0.7	0.4	1.0	2.2	0.5

Management

The field was farmed under minimum till for two cropping seasons through July, 2003. In October, 2003 the field was split into 2 experimental treatments (Fig. 2), representing the grower's standard tillage (ST) and minimum tillage (MT) practices. The ST field was tilled in October, 2003, whereas both fields remained fallow until corn planting in April, 2004. Starting with a pre-irrigation using a moving linear sprinkler system, the fields were furrow-irrigated in 6 subsequent irrigations for a total amount of applied irrigation water of approximately 1,300 mm. The duration of each irrigation was between 2 and 6 days.

Material and Methods

Irrigation

For irrigation events 6 (starting 7/21) and 7 (starting 8/13), we obtained daily discharge measurements and water samples at various sampling points across the field to monitor treatment effects. However, only total field-applied irrigation (I, Fig. 2) and tail water (R, Fig. 2) volumes and field-average water quality measures will be presented, as we found no significant differences between the 2 tillage treatments. To reduce irrigation water application nonuniformity, the field was split in 2 halves in the east-west direction. Each of the 2 sections included a water delivery and tail water ditch. Typically, the first irrigation section was in the NW corner of each field half, with subsequent sections irrigated in the southern direction. After completion of irrigation of the western half of the field, the eastern half was irrigated, starting in the NW corner as well. Most discharge rates in the irrigation and tail water ditches were determined from flow velocity measurements with a current meter, considering the dimensions of the channel network. In addition, we installed a fiberglass 2-inch trapezoidal flume in early August, 2004, in the main tail water ditch at the down-slope end of the field (R in Fig. 2). The flume included a stilling well, through which a pressure transducer was inserted, allowing for continuous tail water discharge measurements at 30-minute intervals.

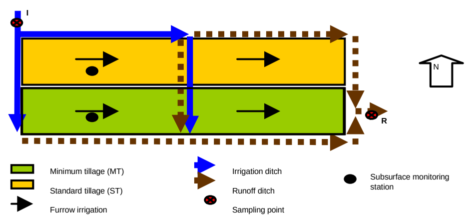

Figure 2. Sampling schemes; I: Irrigation, R: runoff

Water Analysis

Water was sampled with 1 L plastic bottles in the center of the ditches, using three replicates for each sampling. Presented data will be average values. The samples were filtered through a pre-burnt and pre-weighted 0.45 mm Millipore glass filter, so that the total suspended solids (TSS) could be estimated. The filtered water and sediments were frozen for further analysis. Soil solution samples collected from the tensiometers were obtained by applying vacuum with a hand pump, and collecting soil solution after 24 hours.

Sediment Analysis

Sediment samples were ground, homogenized,, and analyzed for total C and N with a Carlo-Erba C/N analyzer. The presence of carbonates was checked for selected samples by HCl fumigation. Irrigation and tail waters were analyzed for DOC, total dissolved N (TDN), nitrates and ammonium. DON was calculated by subtracting nitrates and ammonium from TDN. Soil water was analyzed for total C and N with a DOC/DON analyzer.

Figure 3. Images of irrigation & drainage ditches and flume.

Results

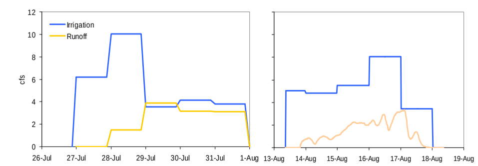

Figure 4. Hydrographs of irrigation and tail water of irrigation events 6 and 7, with water application efficiencies of 58 and 75%, respectively.

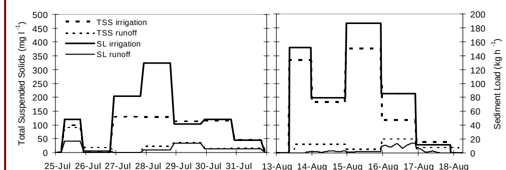

Figure 5. Total suspended solids (TSS) with corresponding sediment load (SL) for irrigation and runoff water of irrigation events 6 and 7.

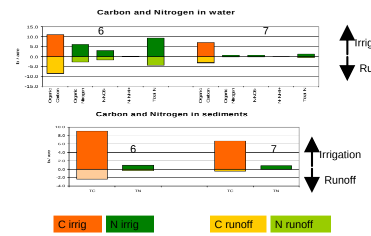

Figure 6. Carbon and Nitrogen (lbs/acre) in water and sediments for both irrigation and tail water (No significant differences between MT and ST treatments.

Event			pound per acre				
			C	DON	N-NO_3^-	N- NH_4^+	Total N
6	water	Irrigation	11.1	6.1	3.1	0.1	9.2
		Runoff	8.5	2.8	1.7	0.0	4.5
		Drainage	0.2				0.0
		I-D-R	**2.4**	**3.3**	**1.3**	**0.1**	**4.7**
	sediment	Irrigation	9.0				0.9
		Runoff	2.3				0.3
		I-R	**6.7**				**0.6**
	Total		**9.1**	**3.3**	**1.3**	**0.1**	**5.3**
7		Irrigation	7.1	0.6	0.7	0.0	1.3
		Runoff	3.1	0.3	0.3	0.0	0.5
		Drainage	0.3				0.0
		I-D-R	**3.7**	**0.3**	**0.4**	**0.0**	**0.7**
	sediment	Irrigation	6.7				0.9
		Runoff	0.4				0.1
		I-R	**6.3**				**0.8**
	Total		**10.0**	**0.3**	**0.4**	**0.0**	**1.6**
6 and 7			**19.1**				**6.9**

Table 3. Field mass balance of C and N (kg ha-1) for the two last irrigation events.

Discussion

The 2 surface irrigations during the one-month study period resulted in C and N additions of 21.4 kg C ha^{-1} and 7.7 kg N ha^{-1}. Although these amounts are not large for agronomic purposes, they can be significant within the context of carbon sequestration. Carbon gains for this short period represent about 20% of reported yearly carbon sequestration rates in published long-term experiments. No significant differences were found between tillage treatments, likely because tillage differences were established only one year before sampling. Moreover, our data show high temporal variability in suspended solids and dissolved components. The limited information collected to date show that the variations of C input by irrigation may mask the effects of tillage or management practices on soil C sequestration. Our data also indicate that the spatial redistribution of C in irrigation and tail water between fields may be large. Yet, our results clearly show for the first time that C imports by irrigation water must be considered in field-scale C sequestration studies.

References

Poch, Rosa M., Jan W. Hopmans, J.W. Six, D.E. Rolston, and J.L. MacIntyre. 2005. A field-scale soil carbon budget for furrow irrigation. Submitted. Agriculture, Ecosystems and Environment.