SUSTAINABLE AGRICULTURE FARMING SYSTEMS PROJECT
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Temperature effect on runoff and dissolved organic carbon in furrow irrigation system

by Damodhara Mailapalli, Wes Wallender, Will Horwath and Zahangir Kabir

California has the largest agricultural economy in the U.S. and is noted worldwide for its high productivity, quality and efficiency in producing fresh market and value-added food. In spite of a Mediterranean climate that is dry during the growing season, irrigation allows the state to produce high yields. Because of its low capital investment, furrow irrigation is the most commonly used irrigation system, however, the agricultural practices used to produce the quality products are affecting the sustainability of crop production systems.

One of the experiments in the SAFS fields at UC Davis' Russell Ranch Sustainable Agriculture Facility is looking at the effect of temperature on runoff, and the amount of dissolved organic carbon (DOC) that appears in the runoff.

The runoff from furrow-irrigated fields enters surface waters and potentially causes downstream water quality impairment. Since surface water is the major source of drinking water for over two-thirds of Californians, measures need to be taken to reduce the impact of irrigation runoff. Organic materials, which produce DOC in runoff, are responsible for degraded taste, odor and color of water and the formation of carcinogenic disinfection byproducts during water treatment. Mitigation of DOC in runoff has been recognized as a critical part of the irrigation water management.

One of the important methods of controlling surface water pollution is to use best management practices (BMPs) in agricultural fields, which reduce organic materials such as DOC in the runoff. BMPs such as conservation tillage (CT) and use of cover crops (CC) can reduce runoff by promoting water infiltration into soil. During an irrigation event, DOC can be released through the leaching of soluble components of residue, and the diffusion of soil organic matter in running water. The DOC concentration increases with higher temperatures, changes in farming practices, and the amount and quality of water flow over and through the soil. Increasing temperature can increase microbial activity and associated decomposition of crop residues and may enhance the DOC concentration in runoff water. The objective of our research is to determine the effect of temperature on irrigation runoff DOC concentration from furrow irrigation system under various conservation practices.

A furrow irrigated field of 366 m (1200 feet) in length with three treatments, cover crop (CC), no-till (NT) and standard tillage (ST) with three replications was used in our study. The average measured surface residue cover was 42% for CC, 32% for NT and 11% ST at the beginning of irrigation. Table 1 shows the sequence of various cultural operations used for residue management on these plots.

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photos by Damodhara Mailapalli

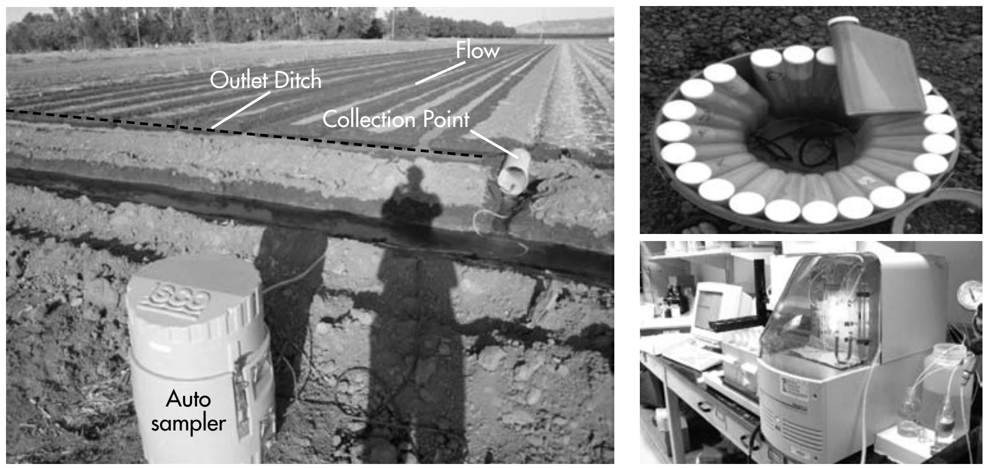

Figure 1. Runoff collection using ISCO auto-sampler from the furrow field (left). Sample analysis for DOC estimation in the laboratory (right).

Table 1: Field condition before summer 2007

Season	Cover crops (CC)	No-till (NT)	Standard tillage (ST)
2006			
Summer	Sunflower grown & harvested	Sunflower grown & harvested	Sunflower grown & harvested
Fall	Sunflower stalks left over the surface	Sunflower stalks left over the surface	Sunflower stalks incorporated
2007			
Winter	Cover crop (wheat) grown	Bare soil	Bare soil
Spring	No till	No till	Tilled
Summer	42% residue cover	32% residue cover	11% residue cover

Irrigation water was delivered to the treatments at a typical inflow of 0.054 $m^3 s^{-1}$ (850 GPM). The outflow from each treatment was collected using ISCO auto-samplers at an interval of 2.5 hours during the first 24 hours and an interval of five hours thereafter (Fig. 1). ISCO auto-samplers also measured the runoff rate to determine the amount of water leaving the field. The DOC was analyzed using UV-persulfate oxidation and its concentration combined with runoff and temperature was used to analyze the effect of temperature on runoff and DOC concentration in the different treatments.

The runoff rate generally decreased with increasing temperature for all treatments (Figure 2). The rise in temperature may increase water evaporation both from the field surface and from the ponding water in furrows. However, the evaporation was negligible compared to the inflow rate. Water draw from the irrigation canal by neighboring growers may also have reduced water input to our fields. The runoff rate ranged from 0.0032 to 0.0002 m^3/s for CC, 0.0054 to 0.0002 m^3/s for NT and 0.0021 to 0.0002 m^3/s for ST, indicating that NT has more runoff than CC and ST. The CC treatment increases soil aggregation and thus infiltration, which decreases runoff, but the lack of tillage did not have the same effect in the NT treatment as seen in other studies.

The DOC concentration was highest at the beginning of runoff and gradually decreased (Figure 3). At the beginning of irrigation, dry soil has the capacity to infiltrate more water. Thus the water entering the furrows has more residence time to interact with soil and residue producing more DOC. The DOC mixes with the soil water and is convected to the tail-end as an initial flush resulting in maximum DOC concentration at the beginning of runoff. The DOC decreased over the irrigation event.

The results also show that DOC dissolution in soils increases as temperatures rises. Higher temperatures increase microbial activity, and accelerate release of DOC. The series of DOC peaks corresponded to diurnal temperature swings. The increase in DOC concentration for every 1oC increases in temperature varied between 0.3 to 0.08 mg/l for CC, 0.4 to 0.05 mg/l for NT and 0.2 to 0.08 mg/l for ST. The DOC concentration varied between 8 to 3 mg/l, 12 to 3 mg/l and 6 to 2 mg/l for CC, NT and ST treatments. Hence, NT releases more DOC followed by CC then ST.

The CC treatment releases less runoff and DOC followed by ST then NT. The results show that these treatments have varying effects on DOC export from agriculture fields. This information is important in devising strategies to reduce DOC export and to maintain irrigation efficiency

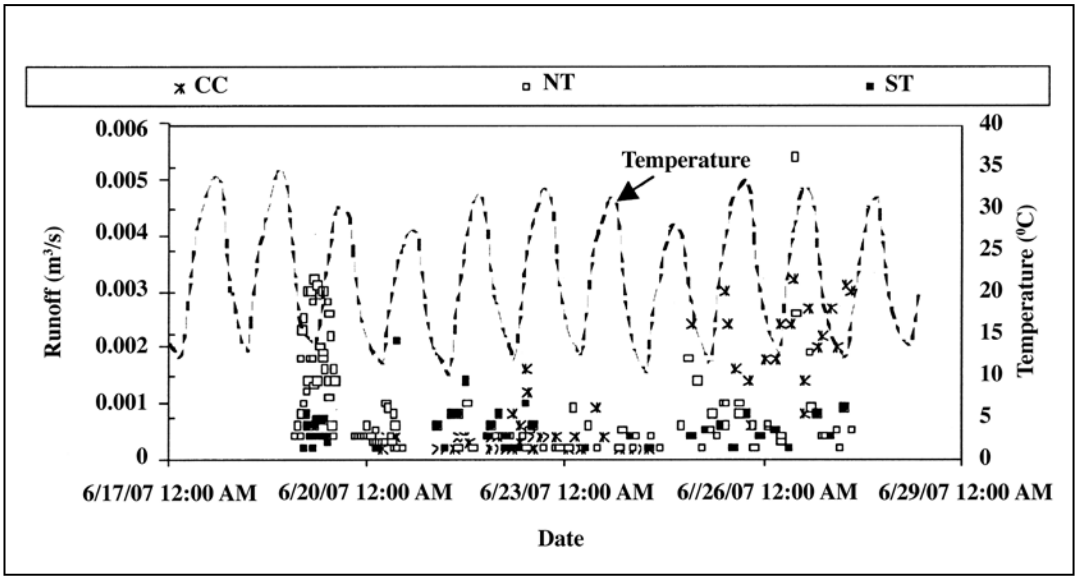

Figure 2. Temperature and treatment effects on runoff

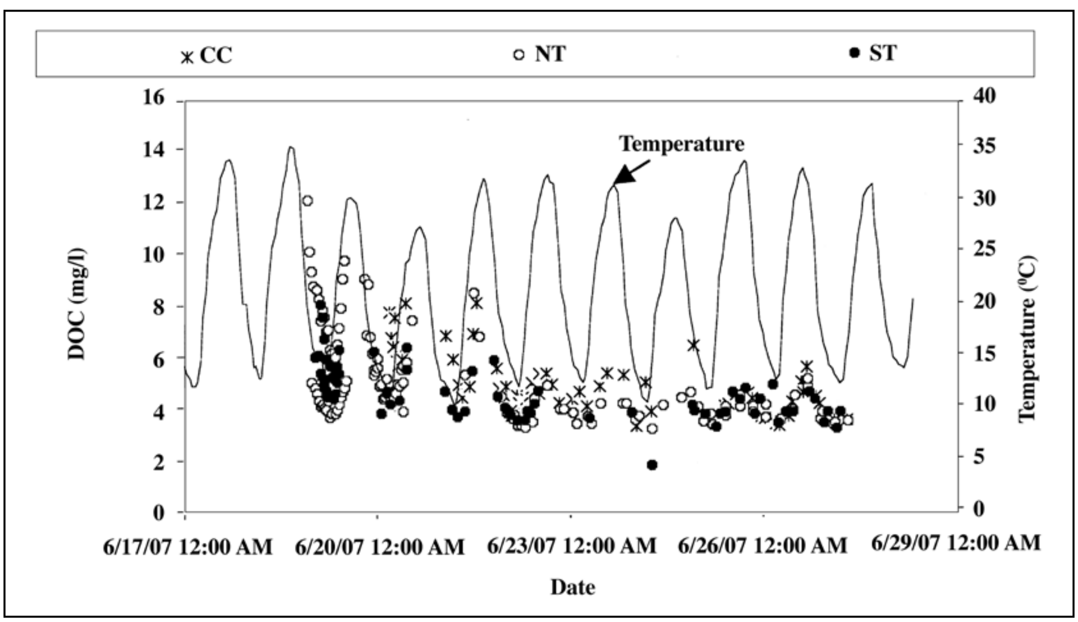

Figure 3. Temperature and treatment effects on DOC concentration in runoff

California agriculture's role in addressing climate change

by Will Horwath, SAFS project leader

California continues to show its leadership in addressing environmental issues through the passage of Assembly Bill 32, *The California Global Warming Solutions Act of 2006*. The most important requirement of this legislation is to establish a statewide greenhouse gas (GHG) emissions cap for 2020 that will reduce emissions to 1990 levels. California is the tenth largest emitter of carbon dioxide (CO_2) and other GHG in the world. The state produces 475 million metric tons (MMT) of CO_2-equivelent gases annually. Agricultural activities contributed approximately seven percent to these total emissions, which may not seem like much, however, half of the emissions occur as nitrous oxide (N_2O), the most potent GHG. A molecule of N_2O is 296 times more potent in trapping solar radiation than a molecule of CO_2. The N_2O emissions are a result of inefficient fertilizer nitrogen (N) use by crops leaving soil bacteria to convert nitrate to N_2O through a process called denitrification.

In order for agriculture to provide solutions to address AB 32, it must either sequester GHG out of the atmosphere into a sink or reduce their emission to the atmosphere. During photosynthesis, crops capture CO_2 in order to grow. When crops are harvested, the remaining residue (straw, vines, roots) is transformed into organic matter. Storing this C in soil represents sequestration of carbon (C) into a sink. In contrast, reduced tillage approaches such as no till or conservation tillage (CT) can reduce diesel fuel consumption and thus reduce the emission of CO_2. Likewise, increasing fertilizer N use efficiency would decrease denitrification and thus the potential to emit N_2O, which represents a reduction in the emission of GHG. To date, our studies at the UC Davis Russell Ranch Sustainable Agricultural Facility in the Sustainable Agriculture Farming Systems (SAFS) and Long-term Research on Agricultural Systems (LTRAS) projects show little effect of CT on soil C sequestration. Other reductions in GHG emissions can occur through the use of waste (biosolids, manure, etc.) and biological N fixation from legumes to reduce the fossil fuel required to synthesize chemical fertilizer N.

Our results show that certain practices, such as the use of cover crops, can address both CO_2 and N_2O emissions. Systems using winter cover crops can store up to three tons of C per hectare in 10 years compared to a traditional winter fallow system. Organic systems can sequester an additional two tons of soil organic matter for a total of five tons per hectare over 10 years. Regardless of the management used to sequester soil C, two things must be considered. First, consistent management is required. Inconsistent management (not practicing annual cover cropping or manure additions) will lead to no or only a small amount of soil C sequestration. Second, there is a finite capacity of soils to sequester C. In California, the limits to soil C sequestration are influenced strongly by climate. The warm Mediterranean climate works to limit the amount of soil C that can be sequestered through maintenance of seasonal microbial activity compared to colder climates.

SAFS and LTRAS research results and results from other studies across the state reveal that 75 to 90 percent of the potential soil C sequestration occurs within five years of implementing these management strategies. This shows that though soils can be significant C sinks, they are a one-time solution or offset. If consistent management for SOM is not practiced, soils will release CO_2 back to the atmosphere.

By 2020, the state will need to offset 174 MMT of CO_2 to return to 1990 emissions levels. Irrigated row crops represent 3.5 million hectares of land use. Table 1 provides an example of irrigated row crop land's potential to sequester soil C and address the 2020 AB 32 emissions cap. If 100 percent of growers plant winter cover crops they could sequester 39 MMT of CO_2 or almost 25 percent of what's needed to meet AB 32 requirements. However, practicing cover cropping on all irrigated row crop land is not likely considering the challenges of planting the crops before winter rains. In addition, field entry in the spring to manage (cut and incorporate) the cover crops before planting summer crops is also dependent on the weather. It is more likely that growers could achieve planting cover crops on 25 percent of their land, representing 10 MMT of CO_2 sequestration or six percent of the reduction in GHG emission required by AB 32. Also it must be remembered that this represents a one time offset, since the soil has a finite capacity to sequester C.

Table 1. The range of winter cover crop adoption and corresponding sequestration of soil C over a 10-year period.

Adoption of winter cover cropping	Total Soil C sequestration (total tons)	MMT CO_2 eq
25	2,645,466	10
50	5,290,932	20
75	7,936,398	29
100	10,581,864	39

An increase in fertilizer N-use efficiency could be achieved by reducing N inputs by about 15 percent. Many fertilizer rate studies suggest that reducing N inputs by this amount will not impact yields in most crops. About 10 to 15 percent of fertilizer N is typically denitrified and about 10 to 15 percent of this is released as N_2O. If growers reduced fertilizer N inputs by 25 kg per hectare, this amounts to about 1.0 MMT of CO_2 equivalents resulting from reduced N_2O emission. Though small compared to the 174 MMT CO_2 required, it represents an annual offset compared to the one-time result of soil C sequestration. Using CT could potential reduce diesel fuel consumption by 20 to 30 percent, representing an additional yearly 0.5 MMT of CO_2 offset that growers could achieve.

As markets for C trading evolve, growers may someday have a financial incentive to sequester soil C and reduce emission of GHG. Overall, California irrigated row crop farmers can contribute significantly to achieving the goals of AB 32 if they adopt the above approaches. In addition, these approaches promote soil productivity—a win-win for growers, the environment and food consumers.

New year, new research manager, new grant

Welcome to the *Sustainable Agriculture Farming Systems (SAFS) Project, Winter/Spring 2008, Vol. 8/No 2* newsletter, which presents research results from the UC Davis Russell Ranch Sustainable Agriculture Facility and from the fields of cooperating farmer members. We start the year saying goodbye to **Z. Kabir**, who was the SAFS research manager for the last three years. We are grateful to Kabir for his excellent work. He contributed to all aspects of the successful SAFS project and team, and helped us secure important grants. He has begun work as a Staff Scientist at the California Department of Pesticide Regulation. We won't let him go completely, though, as he'll be helping us complete research and outreach projects he initiated. Thank you, Kabir, for your many contributions.

I would like to welcome our new research manager, **Martin Burger**, who will be helping us move forward on the innovative work we are doing at SAFS. Martin was a post doctoral researcher in Arnold Bloom's plant physiology lab at UC Davis, and will work with me, our 20 SAFS principal investigators and UC Cooperative Extension farm advisors, several dozen farmers and many other researchers, graduate and undergraduate students. He will help guide our field research work and manage our research efforts at UC Davis and grower fields.

I am also happy to announce that we have secured a new grant for the SAFS project. The Kearny Foundation of Soil Science announced that we will receive $90,000 for a project looking at the positive effects of cover crop residues on water quality and water use efficiency in furrow irrigation. **Wes Wallender**, professor of hydrology, and I will be the principal investigators; we will primarily be working with **Damodhara Mailapalli**, who worked hard on the grant proposal with Kabir, Wes and me. We look forward to a good year of collaborative innovative research, and our continued work with the UC Sustainable Agriculture Research and Education Program (SAREP) on outreach.

—Will Horwath, project leader

More information on UC Davis sustainable agriculture farming systems projects is available online at
safs.ucdavis.edu,
including expanded newsletter articles, SAFS/LTRAS updates, and other resources.

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