Dynamics of soil microbial respiration of rotations with durum as winter crop in Arizona: A preliminary study to define the role of durum production in maintaining soil health.

Project AGRPC #22-03

Final report

Introduction

It is widely accepted that there is a need to increase our understanding of key principles governing soil health in the local agricultural context of Arizona. The general aim of this project is to contribute in the initial phases of scientific exploration of soil processes that will determine the preservation of the sustainability of Desert Durum production systems. Although being of preliminary nature, this project produced unprecedented baseline information on soil respiration, which is meant to be used as an initial assessment of rates in carbon sequestration taking place in Arizona durum wheat production systems.

Methods

Study location. One 15-acre field grown with durum wheat in the Somerton AZ area was selected for this study along with a fallow field in the same area. The durum wheat field was grown under conventional management with seed production as the main objective. In this field we identified zones of different soil properties and selected two monitoring points with the aim to capture differences between zones of highest and lowest soil quality through soil measurements. The same measurements were repeated in one point in a field in the same area left fallow during the spring of 2022.

Pre-season soil measurements. At the start of the project execution we surveyed the commercial field with on-the-go instrumentation recording simultaneously soil apparent electrical conductivity, organic matter, Cation Exchange Capacity (CEC), temperature and moisture content. These geo-referenced data were mapped and analyzed to delineate areas of similar characteristics and assign location of two monitoring points. Figure one below shows the instrumentation and output map of this step.

Figure 1. Picture of soil spectroscopy sensor (upper left) deployed in a commercial field during soil preparation. Map on the right side shows the distribution of soil CEC values in the field under study.

In-season soil measurements. At the core of this project is the objective of generating high-quality data sets of soil respiration and microbial composition during the growing season. The research framework is founded on creating a research protocol for field measurement of CO2 released at the soil-atmosphere interface through the deployment of a low-cost gas (i.e. CO2) analyzer sensor coupled with high-capacity micro-electronics (i.e. Arduino board). The design of this field-ready sensor included electronics board and housing for continuous deployment between irrigation events. Figure 2 shows the actual sensor unit developed for this study and deployed in the durum wheat field under study.

In addition to in-situ sensor-based soil respiration measurements, the data set was enhanced with lab-based estimations of soil active carbon and soil respiration after four days of incubation

Figure 2. Left picture: Field deployment of low-cost soil respiration sensor in a durum wheat field in Somerton AZ. Right picture: Close view of sensor installed for continuous measurement of CO2 released at the soil surface due to below-ground microbial and crop root activity.

Results

Daily measurements of soil respiration provided an initial assessment of the dynamics involved in this process driven by soil micro-organisms and plant roots. As an example, Figure 3 below shows the simultaneous recordings of CO2 in three locations on the same 24 hr span (April 19, 2022). From this figure we can visually identify the highly significant effect that a growing crop has on the absolute values of soil respiration when compared to fallow land. In this figure we noticed the complexity of soil respiration during a diurnal cycle where fallow land remains relatively constant while soil with a growing crop exhibits high fluctuations associated with day/night conditions due to plant photosynthesis above ground, and below ground symbiotic relationships between plant roots and micro-organisms.

For comparison purposes, these full-day measurements were compiled for 17 full days between irrigation events (i.e. March 25-29, April 7-12, and April 21-26). Average daily values during this period of the growing cycle are presented in tabulated form in Table 1. From these data we estimated the effect of growing a wheat crop on soil respiration to be 54.4% and 57.3% larger than fallow land for soil of lowest and highest in-field soil variability respectively. Is worth mention that there were no significant differences in soil respiration rates between the two monitoring points inside the field with a growing crop.

The trends in lab-based observations of soil respiration and soil active carbon presented in Figure 4 indicate that there are no major differenced in the active carbon fraction of these three locations, which is expected as these soil have similar characteristics. Moreover, these data are proof that there is a residual microbial mass in the soil of a fallow field that is quickly activated with the addition of water. The observations in Figure 4 show that there is a substantial amount of variation which speaks for the complexity of the soil biological composition.

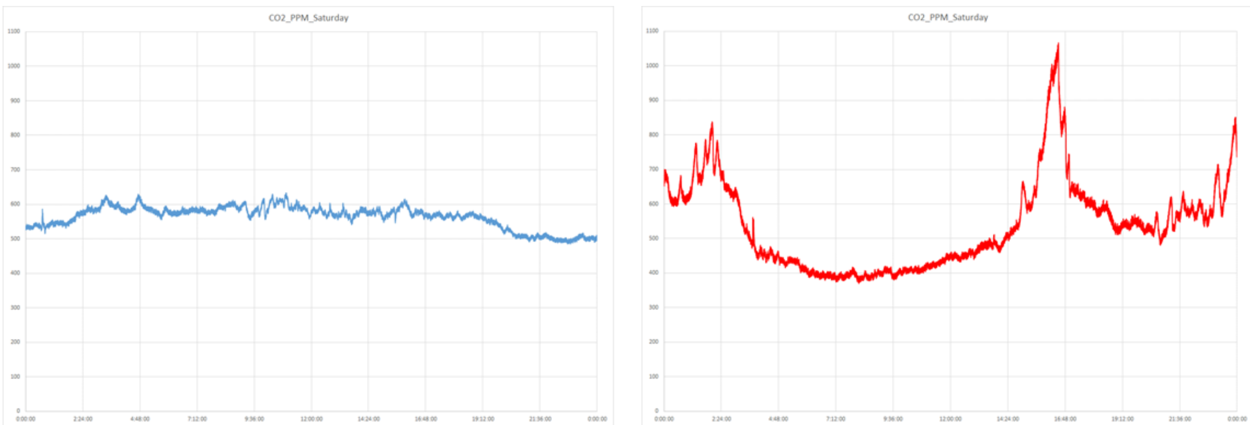
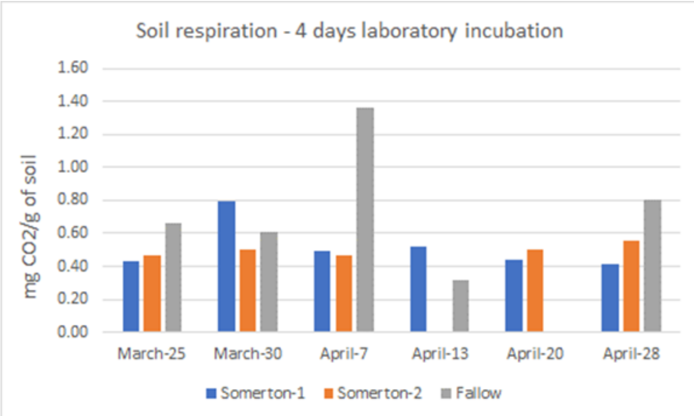


Figure 3. Diurnal cycle dynamics of soil respiration of fallow land (left) and irrigated crop-growing land (right). These data correspond to April 19, 2022. Somerton AZ.

Table 1. Average CO2 flux concentration from soil respiration in selected days during the growing season of durum wheat in Somerton AZ.

	Daily average CO2 concentration flow (ppm)		
Date	Sensor-1 (fallow)	Sensor-2 (low)	Sensor-3 (high)
25-Mar	534	670	805
26-Mar	565	534	558
27-Mar	528	512	486
28-Mar	520	502	493
29-Mar	482	503	501
7-Apr	272	531	593
8-Apr	296	677	753
9-Apr	345	614	667
10-Apr	329	565	602
11-Apr	314	560	556
12-Apr	290	516	522
21-Apr	298	528	587
22-Apr	286	473	432
23-Apr	275	545	496
24-Apr	264	555	473
25-Apr	254	609	555
26-Apr	330	653	646



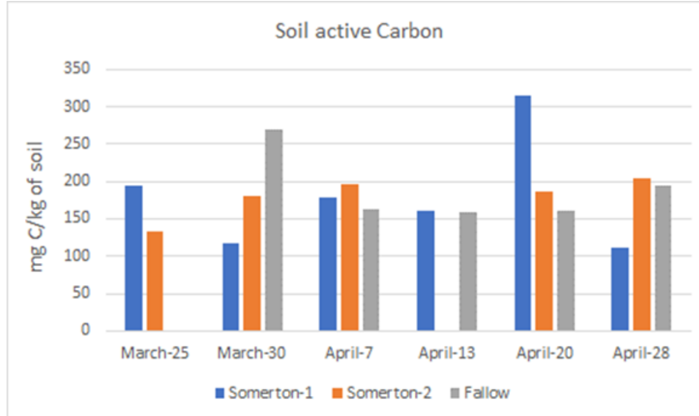


Figure 4. Comparisons in lab-based soil respiration and soil active carbon from samples taken five times with 7-day intervals. 2022 durum wheat season, Somerton AZ.

Conclusions

Soil respiration data obtained in the field is clearly differentiated in regards to crop grown vs fallow. These differences are visually evident, but the high fluctuations in the daily dynamics present a challenge for conventional statistical methods. Advanced statistical methods are required to analyze these time-series data. Laboratory observations display trends consistent with field observations, but they contain significant variation due to the bias introduced by the scale and insufficient spatial resolution of a single soil sample. In all, the data collected during this project show the major effect of land use on the microbial dynamics and subsequent soil quality affecting productivity. A more detailed study is being carried out in the 2023 growing season to further investigate the potential of soil management to negatively/positively impact the productive capacity of desert soils.