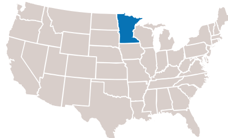
Organic research report

RESEARCH CONDUCTED BY SUSTAINABLE CORN IN 2013 AND 2014

Climate patterns in the central US are expected to become increasingly variable with changes in rainfall intensity, seasonality and available moisture. The economic and social importance of corn makes it a top priority for determining the effects of increasing climate variability on crop production and water requirements. Two Sustainable Corn research hubs exist that are examining these questions, in Coshocton, OH and Lamberton, MN with a paired set of organic experiments designed to quantify water budgets across the individual components, crops (corn, soybean, wheat and cover crops) and weeds, as well as the whole system.

Crop rotation diversification is the most powerful tool that farmers have to reduce economic risk, disrupt pest cycles, increase soil resilience, and improve water quality. Diverse crop rotations have the potential to increase soil organic carbon (SOC) retention and sequestration thereby mitigating the impacts of climate change. Additional potential co-benefits of mitigating climate change through managing soil carbon include increased water and nutrient holding capacity, and improved water use efficiency (WUE) and nutrient use efficiency. The soil water balance plays a key role in the water cycle, affecting the water balance from local up to regional scales and causing feedback between soil, plants and the atmosphere.

The objective of this research was to use direct and indirect methods for quantifying crop water use in short- (two-year) and intermediate-term (three- or four-year) organic and conventional cropping systems. In order to develop a more in-depth understanding of the interactions between water balance components, local soil characteristics, inter-annual weather variability, and their effects on field-scale water budgets, the SWAT model will be used to simulate the cropping systems present at the field sites.



Minnesota site experimentation

The experimental site in Minnesota consisted of 13 plots with dimensions 100 by 180 ft. Treatment comparisons included a two-year conventional rotation of corn following soybean, a four-year conventional and a four-year organic rotation of corn, soybean, oat-alfalfa, alfalfa, a three year organic rotation of corn, soybean, wheat/red clover and a perennial native grass (Figure 1 & 2).

Soil moisture measurements were collected using Time Domain Reflectometry (TDR) probes for measuring soil volumetric water content (5TM, Decagon Devices, Inc. Pullman, WA). These measurements were made at depths of 4, 8, 16, 24, 39 and 78 inches in each plot. The soil water content and weekly change in soil water content were calculated. Weekly volumetric water content for each depth was measured at midnight between Sunday and Monday. The nighttime measurement was selected in order to minimize daytime temperature fluctuations on soil water content, especially near the soil surface. Available soil water content was the product of the difference between the measured soil water

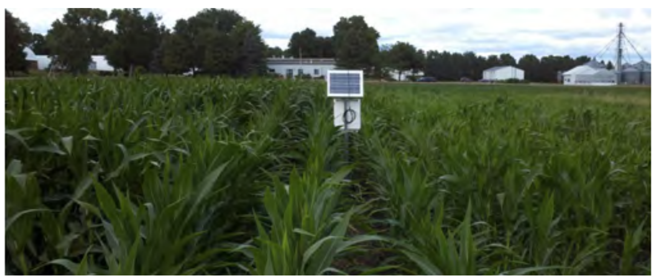


FIGURE 1 | Experimental site in Minnesota

The Ohio State University
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USDA United States Department of Agriculture
National Institute of Food and Agriculture

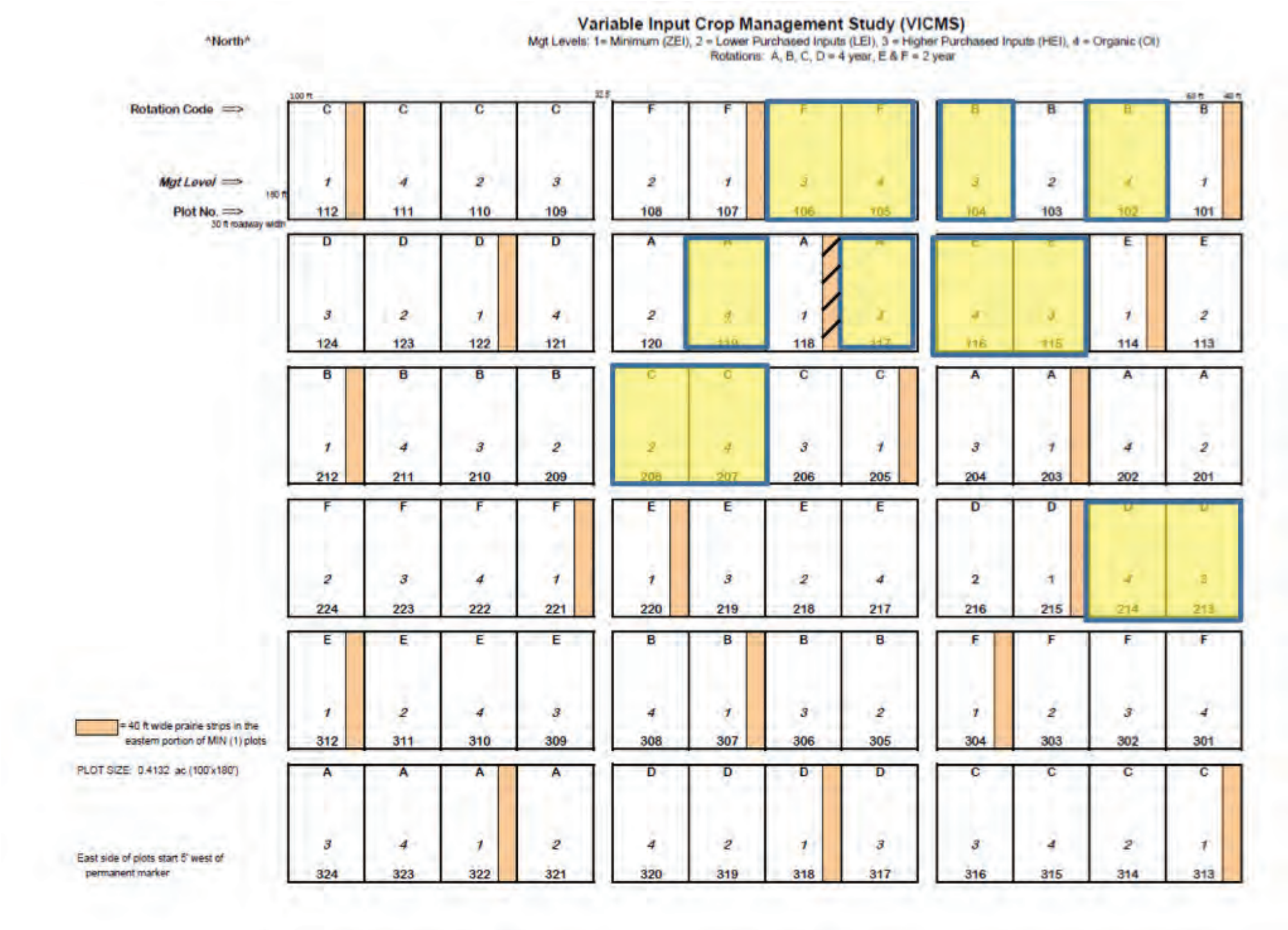

FIGURE 2 | Variable Input Crop Management Study experimental site, Lamberton, MN. Treatment plots are highlighted.

content and the water content measured at a pressure potential of 15 bars and the depth of the soil water content measurement bars. Meteorological data such as temperature and precipitation were collected at a weather station located at the Southwest Research and Outreach Center near Lamberton, MN.

Roots are important in the overall growth processes of plants as well as the uptake of water and nutrients. Knowledge of root systems can provide insights concerning plant susceptibility to water stress, movement of heat and soluble materials in soil, evidence of root depth, extent and development in response to management practices such as tillage, wheel-traffic and/or crop rotation. All root biomass sampling techniques are hampered by high variability, loss of fine root biomass, and high labor requirements. Rooting depths of annual crops range from about 2 ft. to greater than 6 ft. in contrast to perennial root crops such as alfalfa which can reach depths of 18 ft. (Figure 5) after several growing seasons. However, most crops have the majority of the root biomass within the surface 2 ft.

Due to the heterogeneous nature of soil and the non-random and non-uniform distribution of roots a stratified sampling protocol was used to sample corn, soybean, oat, alfalfa and perennial polycultures. Eight to 12 soil cores were collected from each crop using a hydraulic probe. Horizontal root distribution was not uniform; therefore, samples were collected at several horizontal positions relative to the plant between two rows/plants. For example in corn or soybean with 30 inch row spacing, soil samples were collected at three horizontal locations: 0.5-1, 7.5 and 15 inch. Four subplot locations within a plot were sampled. In narrow row crops like oat the horizontal positions would be next to a plant, center of inter-row, next to the next plant and the next inter-row. Soil samples were collected at five depth increments: 0-8, 8-16, 16-24, 24-36, and 36-72 inches. Root sampling does not capture all roots. Roots were collected at boot stage for oat, after second cutting for alfalfa, after flowering for soybean, and at tassel for corn. Roots were washed and collected on sieves and stored for analysis. Root analysis was done using WinRHIZO software (Regent Instruments Inc., Canada).

Minnesota Results

In these studies there were the assumptions that all cropping systems received the same amount of precipitation, similar amounts of runoff have occurred, cropping systems have been exposed to the same evaporative demands, and water extraction by specific crops from all rotations in a given year is the same. There were weekly differences in the change in soil water content for corn likely due to differences in precipitation and the runoff component of the water balance. Air temperature closely followed long-term trends especially during the growing season. Precipitation data were highly variable both seasonally and monthly. During the 2013, growing season precipitation included months of above average and below average precipitation (Figure 3a). Observed data from 2014 were similar. Above average precipitation occurred in June 2014 while July 2014 was below average (data not shown). The difference in average monthly air temperature was small during the growing season during both 2013 and 2014 compared to long-term data from Minnesota (Figure 3b).

It is likely that above average precipitation during June and below average precipitation in 2013 and 2014

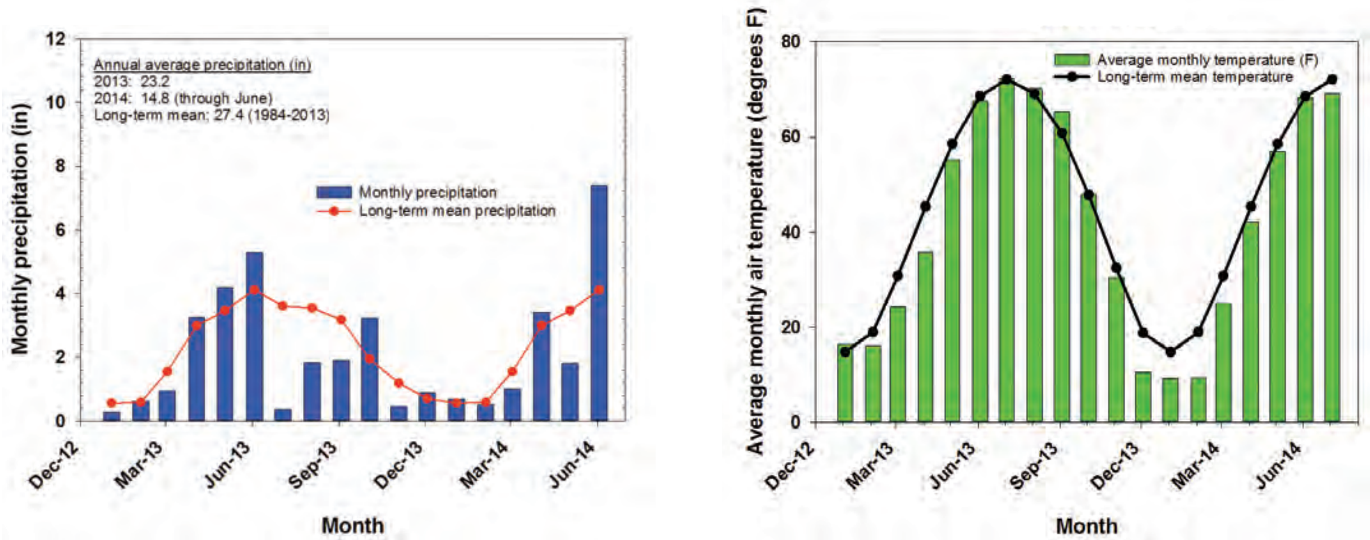

FIGURE 3 | (a) Variation in monthly precipitation from 2013 through June 2014 affected changes in soil water storage and components of the soil water balance (runoff, ET, drainage, etc) at Minnesota sites. (b) Variability in average monthly air temperature during the growing season in both 2013 and 2014 and long-term average data from Minnesota.

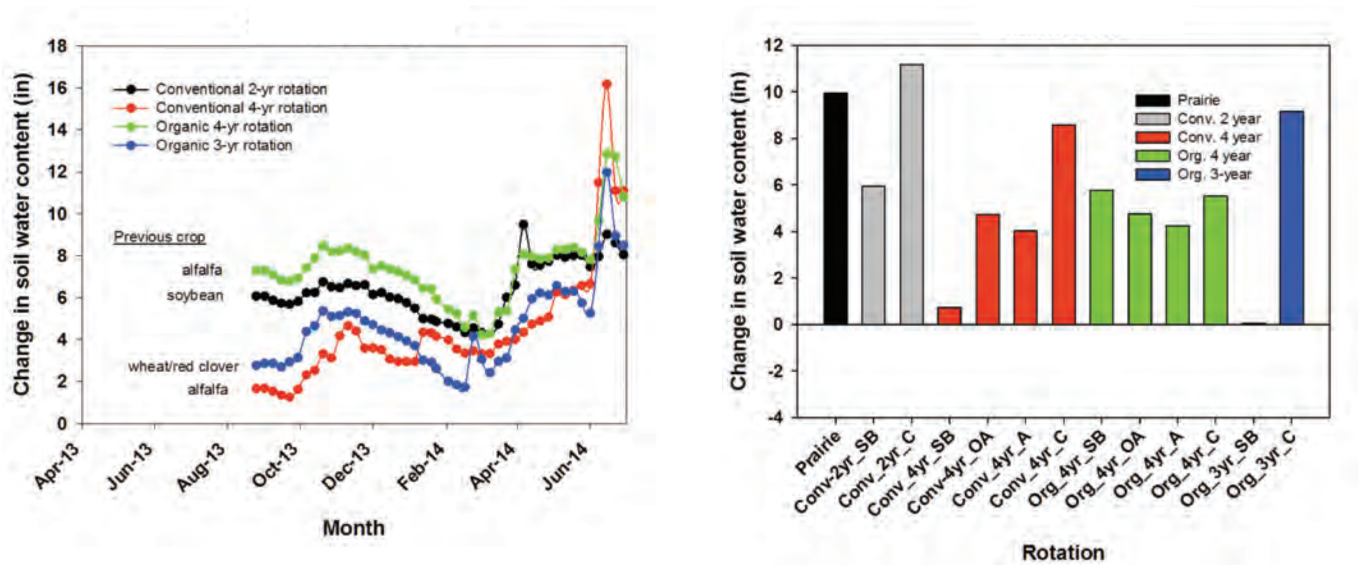

FIGURE 4 | (a) Weekly differences in the change in soil water content for corn. (b) Cumulative difference in soil water content between April 1 and June 30, 2014.

affected crop growth and yield. The landscape at the experimental site in Minnesota is relatively flat (<2% slope) and less prone to runoff compared to the Ohio site. The different rotations exhibited differences in soil water content likely related to previous crop and soil storage capacity. Interestingly, the 3-year rotations at both locations had similar water contents at the start of monitoring following wheat interseeded with red clover. Data indicate differences in soil water content and crop water use among crops and among rotations (Figure 4).

Root length density (RLD) was plotted by depth for each crop by cropping system (Figure 5). Root length density was interpreted cautiously considering differences in plant genetics. Oat and alfalfa seed planted in organic and conventional cropping systems were the same however; corn and soybean varieties between the two cropping systems were different.

It is clear that the perennial mix contained the greatest RLD. In addition, it can be observed that RLD generally decreases with depth. There appear to be differences in RLD between oats for the 4-yr cropping systems but not the alfalfa. Although there were differences in crop genetics between corn and soybean there appear to be some differences in RLD between 2-yr and 4-yr rotations for conventional and organic cropping systems (Figure 5). Generally, the organic systems exhibited lower RLD. There is no clear explanation for these apparent differences at this time, but these differences could impact yield and crop resilience to water and heat stress.

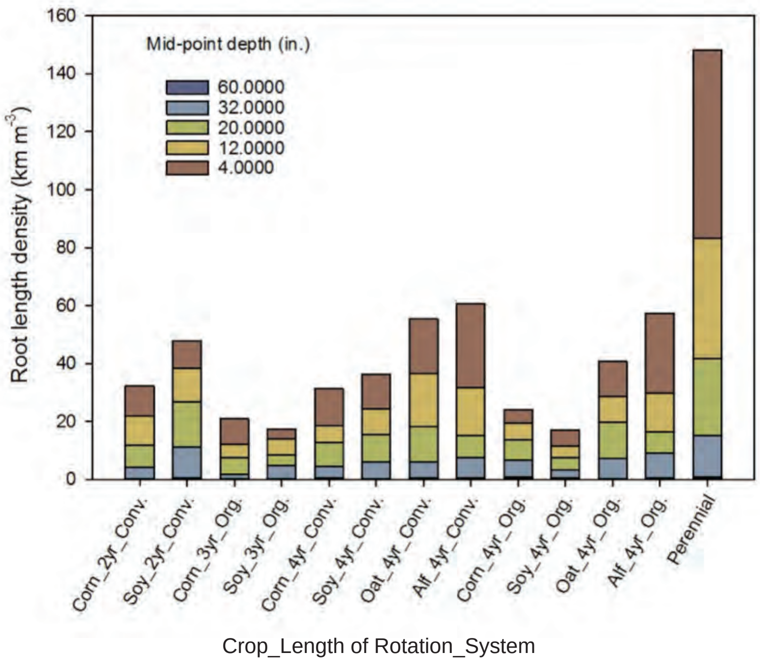

FIGURE 5 | Variation in root length density.

Ohio site experimentation

In Ohio, treatments compared include a conventional no-till system and an organic system. Both systems include cover crops using a corn/cereal rye - soybean/wheat - wheat/(cowpea, oilseed radish, sun hemp) rotation. Experimental units in Ohio, at the North Appalachian Experimental Watershed near Coshocton, OH, consisted of 7 small watersheds and 7 monolith lysimeters (Figure 6 & 7). Three watersheds were managed using the organic system and four others were managed using the nonorganic no-till system to assess the impact of these systems on water balance components. Soil moisture measurements were collected in each watershed using TDR probes for measuring soil volumetric water content (5TM, Decagon Devices, Inc. Pullman, WA). These measurements were made at depths of 4, 8, 16, 24, and 39 inches in each watershed. The same procedure for soil water content calculations used in Minnesota are also used in Ohio. In addition runoff was measured from each small watershed, and runoff and percolate were measured from the lysimeters to aid in calculating water balance.

FIGURE 6 | One experimental site in Ohio

Ohio Results

As discussed in the MN site, assumptions are that all cropping systems received the same amount of precipitation, similar amounts of runoff have occurred, cropping systems have been exposed to the same evaporative demands, and water extraction by specific crops from all rotations in a given year is the same. Preliminary results for 2014 from April 1 through June 30 are included here. The Ohio site was noticeably warmer than the Minnesota location during the observation period (Figure 8; refer to Figure 3 for MN). The landscape at the experimental site in Ohio has greater slope (>12%) and more prone to runoff compare to sites in Minnesota. The different rotations exhibited differences in soil water content likely related to previous crop and soil storage capacity (Figure 9). Interestingly, the 3-year rotations at both locations had similar water content at the start of monitoring following wheat interseeded with red clover. Data indicate differences in soil water storage and crop water use among crops and among rotations at both locations (Figure 9).

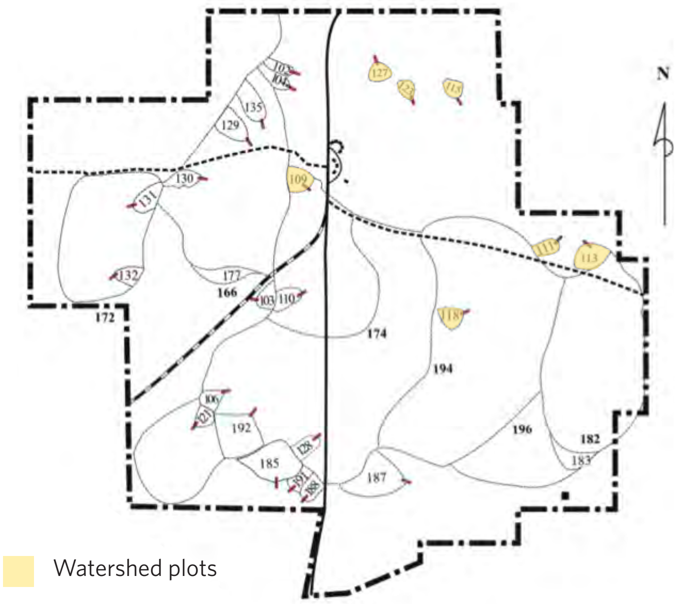

FIGURE 7 | North Appalachian Experimental Watershed experimental site in Coshocton, OH.

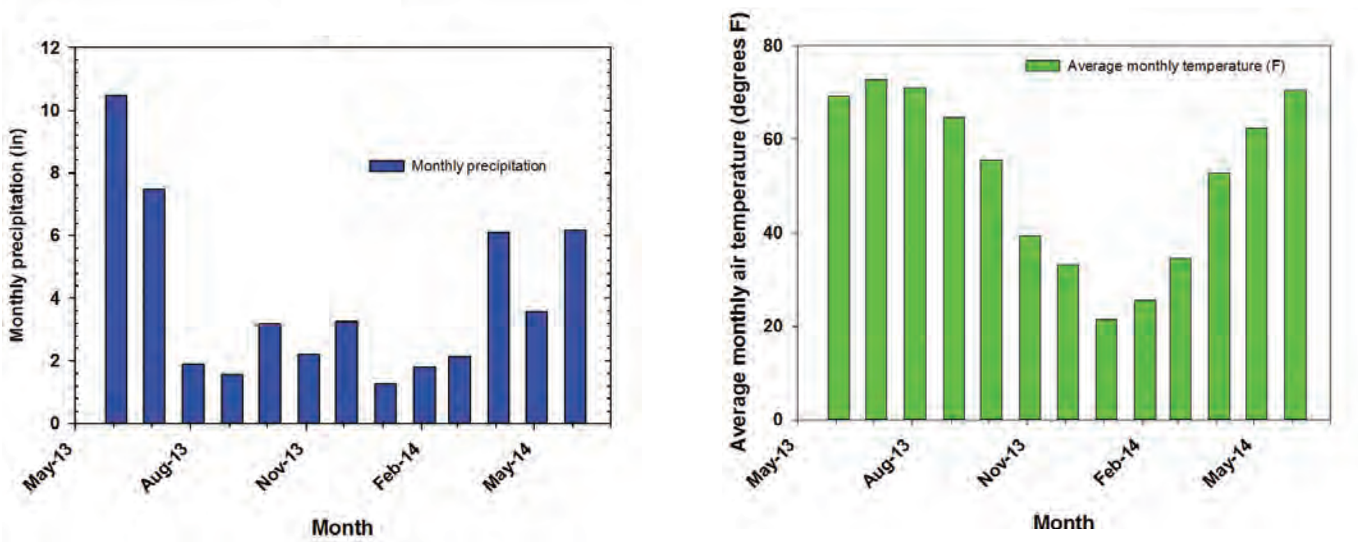

FIGURE 8 | (a) Variation in monthly precipitation from 2013 through June 2014 affected changes in soil water storage and components of the soil water balance (runoff, ET, drainage, etc) at Ohio locations. (b) Variability in average monthly air temperature was small during the growing season during both 2013 and 2014.

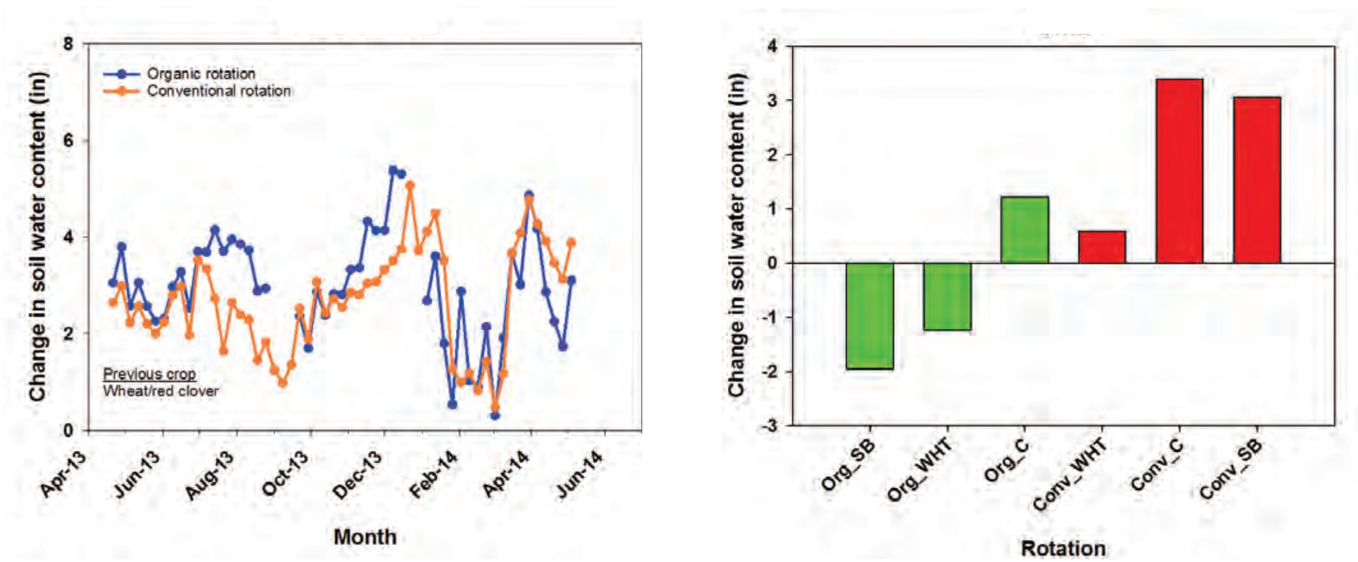

FIGURE 9 | (a) Weekly differences in the change in soil water content for corn. (b) Cumulative difference in soil water content between January 1 and April 30, 2014.

Organic Research Summary

Results from this work will provide information that will allow farmers to design cropping systems in a way that is both effective for production and environmentally responsible. Further, results from this work will also help to provide more detail and insight into the strength of the linkage between field-scale management decisions and watershed-scale hydrologic responses.

- Diversity in the cropping system resulted in much variability in soil water storage between and within the two experimental locations.
- The previous crop affected changes in soil water content and changes in soil water storage for corn.
- Differences in landscape topography likely resulted in differences in the runoff component of the soil water balance.

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