Research to Evaluate Environmental Impacts of Direct Land Application of Uncomposted Green and Woody Wastes on Air and Water Quality

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Table of Contents

Acknowledgments v
Executive Summary 1
Abbreviations, Acronyms, and Glossary of Terms 4
Introduction 6
Part One: Volatile Organic Compounds, Greenhouse Gases and Nutrients from Direct Land Application in the Field and in Laboratory Microcosms 8
Materials and Methods 8
Results and Discussion 16
Part Two: Other Chemical Constituents from Direct Land Application in the Field and from Green Materials Representative of Statewide Sources 50
Materials and Methods 50
Results 51
Discussion 68
Conclusions 69
References (Bibliography) 71
Appendices 73
Appendix A. Daily GHG Fluxes. 73
Appendix A-2. Incubation Data. 83
Appendix B. Green Waste Characterization Raw Data. 91
Appendix C. Data for Soil Solution Samples. 95
Appendix C-2. Reports from Commercial Testing Lab. 100
Appendix C-3. Reports from Commercial Testing Lab for Lysimeter (Soil Solution) Water 115
Appendix C-4. Data for Water-Filled Pore Space, Soil Water, and Temperature. 117
Appendix C-5. Data for Soil Nutrients, DOC, and Nitrate After Irrigation. 136

Table of Tables

Table 1. Average soil water content over the one-year field experiment. 16
Table 2. Soil characteristics at the end of the one-year field experiment. 19
Table A-1-1. Daily N_2O fluxes, N_2O-N (g/d-ha). 74
Table A-1-2. Daily CO_2 fluxes, CO_2-C (in kg/d-ha). 77
Table A-1-3. Daily CH fluxes, CO_2-C (in kg/d-ha). 80
Table A-2-1. CH_4, CO_2, and N_2O concentration in the headspace of the incubation vials over time.. 83
Table A-2-2. Mean O_2 concentration over time in closed vials in the silt loam soil. 87
Table A-2-3. Mean O2 concentration over time in closed vials in the sandy soil. 89
Table A-2-4. Dynamics of NH4+ concentration in the incubation soils.. 89
Table A-2-5. Dynamics of NO3- concentration in the incubation soils.. 90
Table A-2-6. Dynamics of DOC concentration in the incubation soils. 90
Table B-1. Raw data for determination of green waste (GW) density. (density = mass / volume) 91
Table B-2. Results from commercial green waste (GW) testing lab analysis. 92
Table B-3. Fraction of criteria metals in green waste (GW) samples (in mg/kg-dry weight)..... 93
Table B-4. Fraction of other metals in green waste (GW) samples (in mg/kg dry weight) – Part 1. 94
Table B-5. Fraction of other metals in green waste (GW) samples (in mg/kg dry weight) – Part 1. 94
Table C-1-1. Concentration of metals in soil solution water collected by lysimeters – February through March. 95
Table C-1-2. Concentration of metals in soil water collected by lysimeters – June through September.. 98
Table C-4-1. Soil water-filled pore space, % 117
Table C-4-2. Soil volumetric water content 0~15 cm soil depth..... 120
Table C-4-3. Soil temperature ^{o}C 0-15 cm layer. 124
Table C-5-1. Soil NH_4^+-N content (µg N/g). 136
Table C-5-2. Soil NO_3^--N content (µg N/g)..... 137
Table C-5-3. Soil DOC content..... 138
Table C-5-4. Nitrate concentration in the soil solution at 30 cm depth after three irrigation events..... 139

Table of Graphics

Graphic 1. Field layout of treatment plots. 9
Graphic 2. Xia Zhu sampling GHGs from the flux chamber..... 11
Graphic 3. Peter Green taking samples of VOCs. 11

Table of Figures

Figure 1. Water inputs and air temperature at the field experiment site from October 2013 to October 2014..... 10
Figure 2. Soil water content during the one-year field experiment. 17
Figure 3. Soil water-filled pore space during the one-year field experiment. 18
Figure 4. Mean daily temperatures during the one-year field experiment. 20
Figure 5. Mean daily VOC fluxes during the one-year experiment. 21
Figure 6. Mean cumulative VOC fluxes from the one-year experiment. 22
Figure 7. Speciation of VOC emissions from the samples collected from the flux chambers during the 60 sampling events for each of the 15 treatment plots. 23
Figure 8. Mean daily N_2O fluxes for the one-year field experiment. 24
Figure 9. Mean cumulative N_2O fluxes for the one-year field experiment..... 25
Figure 10. Mean N_2O concentration in the middle of the 30 cm high GW pile and N_2O flux..... 26
Figure 11. Mean daily CO_2 fluxes during the one-year field experiment..... 27
Figure 12. Mean cumulative CO2 fluxes during the one-year field experiment. 28
Figure 13. Mean daily CH_4 fluxes during the one-year field experiment. 29
Figure 14. Mean cumulative CH_4 fluxes for the one-year field experiment. 29
Figure 15. Daily methane pile concentrations and fluxes. 30
Figure 16. Mean annual GWP of N_2O and CH_4..... 31
Figure 17. Mean NH_4^+ concentrations in the GW piles during the one-year experiment. 32
Figure 18. Mean NO_3^- concentrations in the GW piles during the one-year experiment. 33
Figure 19. Mean NH_4+ concentrations in the soil during the one-year experiment..... 34
Figure 20. Mean NO_3^- concentrations in the soil during the one-year experiment..... 34
Figure 21. Mean DOC concentrations in the GW piles during the one-year experiment. 35
Figure 22. Mean DOC concentrations in the soil during the one-year experiment. 36
Figure 23. Mean soil solution nitrate concentrations after irrigation. 37
Figure 24. Mean O_2 concentration over time in closed vials in the silty loam soil..... 38
Figure 25. Dynamics of N_2O concentration in the headspace of the incubation vials over time for the silty loam soil. 39
Figure 26. Dynamics of CO_2 concentration in the headspace of the incubation vials over time for the silty loam soil. 40
Figure 27. Dynamics of CH_4 concentration in the headspace of the incubation vials over time for the silty loam soil. 41
Figure 28. Dynamics of NH_4^+ concentration for the silty loam soil..... 41
Figure 29. Dynamics of NO_3^- concentration for the silty loam soil. 42
Figure 30. Dynamics of DOC concentrations for the silty loam soil. 42
Figure 31. Mean O_2 concentration over time in closed vials for the sandy soil..... 43
Figure 32. Dynamics of N_2O concentration for the sandy soil. 43
Figure 33, Dynamics of CO_2 concentration for the sandy soil. 44
Figure 34. Dynamics of CH_4 concentration for the sandy soil. 44

Figure 35. Dynamics of NH_4^+ concentration for the sandy soil. 45
Figure 36. Dynamics of NO_3^- concentration for the sandy soil..... 45
Figure 37. Dynamics of DOC concentration for the sandy soil. 46
Figure 38. Mean O_2 concentration for the clay soil..... 46
Figure 39. Dynamics of N_2O concentration for the clay soil. 47
Figure 40. Dynamics of CO_2 concentration for the clay soil. 48
Figure 41. Dynamics of CH_4 concentration for the clay soil..... 48
Figure 42. Dynamics of NH_4^+ concentration for the clay soil. 48
Figure 43. Dynamics of NO_3^- concentration for the clay soil..... 49
Figure 44. Dynamics of DOC concentration for the clay soil. 49
Figure 45. Density of GW samples from seven sources..... 51
Figure 46. E. coli measured in the GW samples from seven sources. 52
Figure 47. Total coliform in soil solution water using composite samples. 53
Figure 48. Total coliform in soil solution water. 53
Figure 49. Ratio of carbon to nitrogen in the GW samples from seven sources..... 54
Figure 50. Fraction of arsenic in the GW samples from seven sources. 55
Figure 51. Fraction of copper in the GW samples from seven sources. 56
Figure 52. Fraction of lead (Pb) in the GW samples from seven sources. 57
Figure 53. Fraction of zinc in the GW samples from seven sources..... 58
Figure 54. Fraction of sodium in the GW samples from seven sources. 59
Figure 55. Fraction of potassium in the GW samples from seven sources..... 60
Figure 56. Fraction of calcium in the GW samples from seven sources..... 61
Figure 57. Concentration of calcium in the soil solutions collected from the 15 lysimeters located under the plots. 62
Figure 58. Concentration of potassium in the soil solutions collected from the 15 lysimeters located under the plots. 63
Figure 59. Concentration of iron in the soil solutions collected from the 15 lysimeters located under the plots. 64
Figure 60. Concentration of arsenic in the soil solutions collected from the 15 lysimeters located under the plots. 65
Figure 61. Concentration of iron in the soil solutions collected from the 15 lysimeters located under the plots. 66
Figure 62. Concentration of calcium in the soil solutions collected from the 15 lysimeters located under the plots. 67

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Executive Summary

The direct land application (DLA) of chipped or ground but uncomposted green materials, commonly called green waste (GW), may be an increasingly common practice in California. The potential impact of this practice on air quality has not previously been studied. By contrast, the air emissions impact of green waste composting has been previously characterized in many studies used to create the California Air Resources Board's (ARB) compost emission reduction factor (CERF; ARB, 2011) and the United States Environmental Protection Agency's (U.S. EPA's) Waste Reduction Model (WARM; U.S. EPA, 2014).

This study was comprised of three main parts: a year-long field study, a laboratory study, and a statewide green waste characterization. In the field study, we characterized air emissions, and potential soil and soil water (shallow water in the ground, closer to the surface than to groundwater) contamination from the application of green waste. We applied material from a local Northern California GW processing facility to University of California, Davis farmland directly using three different treatments:

- Surface application of a height of six inches (15 cm) of material,
- Surface application of a height of 12 inches (30 cm) of material, and
- A six-inch (15 cm) height of material tilled into the soil.

We measured for the following air emissions and soil/soil water contaminants:

- Air emissions: VOCs and the greenhouse gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)
- Soil/soil water (at a 12-inch depth) contaminants: nutrient nitrogen, soil carbon, and subsurface delivery of metals and pesticides.

The same material that was applied to the farmland was also used in a series of controlled laboratory studies in order to expand the study results to different soil types and soil moisture conditions, and to better understand the mechanisms by which direct land application of green material impacts greenhouse gas emissions from soil.

To better understand the nature of these materials being spread on land, CalRecycle staff gathered additional green waste samples from six other facilities located in both Northern and Southern California. These samples, plus the one used in the field and lab studies, were analyzed in the laboratory for nutrient, bacteria, metal, and pesticide content.

VOCs were greatly reduced by soil incorporation compared to surface application. Cumulative VOCs showed a significant difference between the pair of surface-applied green waste treatment plots and the tilled-in green waste and control plots. The composition of VOC emissions was similar to that seen from compost piles during the composting process, but shifted more toward monoterpenes, representing about 50 percent of VOC emissions (which are more reactive toward formation of ozone), and

away from methanol, representing about 30 percent of emissions (which is less reactive toward formation of ozone). Emissions from compost piles average 10 percent monoterpenes and 70 percent methanol (Kumar et al., 2011). This shift may be associated with a less moisture-controlled environment, since a compost pile typically maintains about a 45 percent moisture content versus the moisture content in the land-applied green waste piles of 20 to 30 percent during the early autumn months when most of the VOC emissions occurred.

The greenhouse gases N_2O and CO_2 were also greatly reduced by soil incorporation compared to surface application, even accounting for fossil fuel usage needed to incorporate the green waste into the soil. Surface application of green waste released larger amounts of the greenhouse gas N_2O than the incorporation of green waste. The amount of N_2O-N (approximately 1.1 to 2.7 Mg CO_2 equivalent per hectare) released from the soil amended with green waste was comparable to that of a furrow-irrigated tomato field or flooded irrigated alfalfa cropping system during one year (1.8 to 1.9 Mg CO_2 equivalent per hectare). Emissions of CO_2 were similarly higher in the surface-applied green waste than in the incorporated green waste but are considered neutral in terms of global warming potential (GWP). This is because the carbon in the green waste is non-fossil based, having been previously fixed CO_2 through photosynthesis. While the soil acts as a natural methane sink, the application of green waste reduced this methane sequestration. The extent of this decrease was to a lesser degree in the 6-inch surface-applied treatment.

In terms of global warming potential, N_2O was the driving factor in the direct land application of green waste, with surface application contributing significantly more N_2O emissions to the atmosphere, with average annual emissions of 2 +/- 0.1 and 2.7 +/- 0.1 Mg CO_2 equivalent per hectare in the six-inch (15 cm) and 12-inch (30 cm) surface treatments, respectively, in comparison to the N_2O emissions of 1.1 +/- 0.2 Mg CO_2 equivalent per hectare in the six-inch (15 cm) tilled treatment, and 0.8 +/- 0.0-0.2 Mg CO_2 equivalent per hectare in the controlled treatments (tilled and control). Notably, the greenhouse gas emissions from the incorporated green waste were not significantly different from that of the background soil.

The results from the soil/soil water testing in the field study netted relatively little in terms of contaminant migration from the green waste. While all three green waste treatments were associated with an increase in nitrates in the soil, nitrate leaching into the soil water was only significantly different from the control treatments in the final irrigation event. In this event, the researchers saturated the soil with close to 100 mm (four inches) of irrigated water. No other impacts were observed to be of concern, though differences were seen with soil incorporation in a few cases. Specifically, calcium and potassium in soil water were increased modestly after winter rains in samples beneath the green waste treatments (whether incorporated or not). This nutrient increase was less prominent after the summer irrigations. The surface-applied green waste played a role in keeping more moisture in the 12 inches of soil underneath the waste than in that of the bare soil that did not have the surface-applied material. Thus, water-filled pore space in the soil beneath the surface-applied treatments was

greater than 60 percent during most of the year. This likely contributed to the higher N_2O emissions in those treatments.

In terms of pathogen presence, E. coli was not detected in the soil water, but total coliform was found in a number of the soil water samples. Here it only exceeded the 1000 MPN/100 mL (most probable number per 100 milliliter) standard (EPA, 2002) in the 12-inch (30 cm) surface application. Notably, it also exceeded the standard in the soil water under the tilled control plots, which is not unusual as coliform bacteria are normally found in natural soil environments (Ferguson and Signoretto, 2011).

In the laboratory, green waste was applied to three types of soils: silty loam, sandy, and clay. The lab incubations demonstrated the effects of green waste as a carbon source in depleting O_2 and stimulating N_2O production similar to what was observed in the field study.

In order to determine representivity of the sample of green waste used in the field and laboratory studies, we characterized six other samples from around the state. The composition results from the two sampling events of chipped and ground green waste taken from all seven facilities between San Diego and the Sacramento area in autumn 2013 and spring 2014, in general, showed similarity for the material statewide. As pathogens are often a concern, it is important to note that salmonella was undetectable in all of the green waste samples. E. coli, on the other hand, was detected in nearly all samples, with eight of the 14 samples exceeding the 1000 MPN/g DW (most probable number per dry weight gram) standard (EPA, 2002). Tests for a number of elements of concern, including arsenic, copper, lead, and zinc, were not found in higher concentrations than background soil levels. This characterization confirmed that the samples used in the field and laboratory studies were not significantly different from other samples and were fairly representative of the chipped and ground green waste in other areas of California.

From a climate change perspective, accounting for varied types of soil and the possibility of soil water contamination, these results indicate that to reduce the environmental impact of green waste application, it should be incorporated into soil. In comparison to compost, land application of uncomposted materials may have higher risk of delivering pests, weed seeds, and pathogens. It would be useful to extend this research and conduct further experiments over a longer period to investigate the potential of direct land application of green waste to cause greenhouse gas emissions and nitrate leaching, especially under different cover crop systems, and water use savings due to the mulching effect. Meanwhile, the greenhouse gas emissions results in this report need to be compared with that from managed composting (including mitigations) and the importance of uncomposted weed seeds, pests, and pathogens when considering direct land application.

Abbreviations, Acronyms, and Glossary of Terms

- ANOVA analysis of variance
- BD bulk density
- C carbon
- °C degrees Celsius
- CH_4 methane
- cm centimeter
- CO_2 carbon dioxide
- CS_2 carbon disulfide
- d day
- DLA direct land application
- DOC dissolved organic carbon
- DW dry weight
- ECD electron capture detector
- eV electron volt
- EPA Environmental Protection Agency
- °F degrees Fahrenheit
- FID flame ionization detector
- g gram
- GC-MS gas chromatograph coupled to a mass spectrometer
- GHG greenhouse gas
- GW green waste
- GWP global warming potential
- h hour
- ha hectare (10,000 square meters)
- ICP-MS inductively coupled plasma mass spectrometer
- KCl potassium chloride
- kg kilogram
- kPa kilopascal
- L liter
- lysimeter gas-tight tube which, with suction, draws soil moisture in through a ceramic fitted, bulb-shaped, tip at the downhill end
- m meter
- mg milligram
- mL milliliter
- mm millimeter
- Mg megagram (1000 kg, 1 metric ton)
- MPN most probable number
- N nitrogen
- NH_4 ammonium ion (NH_4^+)

- NIOSH National Institutes of Occupational Safety and Health
- NO_3 nitrate ion
- N_2O nitrous oxide
- O_2 oxygen
- SSAT soil solution access tube
- TCD thermal conductivity detector
- TMECC test methods for evaluation of compost and composting
- TOC total organic carbon
- ug microgram
- uL microliter
- UV ultraviolet
- VOC volatile organic compound
- WFPS water-filled pore space
- WHC water holding capacity
- yr year

Introduction

Organic compostable materials comprise the largest category of disposed solid waste in California, accounting for about 32 percent of California's estimated 35 million tons of solid waste disposed annually (California Integrated Waste Management Board, 2009). Organic compostable materials include residential and commercial yard and landscaping wastes—often referred to as green materials—as well as food, soiled paper, and related materials.

Two alternatives to disposing of green materials (referred to as green waste or GW in this document) in landfills are composting and direct land application (DLA), (CalRecycle 2010). Depending on the processing technology, degradation of green materials can produce greenhouse gases (GHGs) such as methane (CH_4) and nitrous oxide (N_2O) as well as volatile organic compounds (VOCs, a precursor to the formation of ground-level ozone, a U.S. Clean Air Act criteria pollutant). GHG and VOC emissions from actively composting piles of GW have been fairly well characterized (Zhu et al 2013a, Kumar et al 2011, CIWMB 2007, CalRecycle 2010, ARB, 2011, USEPA, 2014). To date, GHG and criteria pollutant emissions from DLA of uncomposted GW, which includes surface placement and incorporation of GW into soil, have not been quantified.

Direct land application of uncomposted green materials is particularly attractive to farmers with fallow land that may suffer from low organic matter. DLA provides slow release of organic matter and protection from sun, wind, and rain for exposed soils. It also provides an outlet for municipally collected GW in areas where composting capacity is not adequate. DLA is extremely price-attractive to land owners; it is much less expensive than compost and may sometimes be obtained for the cost of delivery and spreading alone.

But DLA may also pose serious challenges for regulators and for public safety and the environment. Because it tends to occur infrequently and on many remote sites, it is difficult to regulate and to ensure it has minimal physical contaminants (i.e., glass, plastic, and metal) and is applied correctly. Once the materials have been spread, they can be difficult to remove. At any given time, dozens of areas within California are under quarantine for invasive pests with the potential to damage aspects of California's $42 billion agriculture industry (USDA 2013). For this reason, we used a local source of GW, rather than transporting a truck-load of GW from elsewhere in California. DLA also has the potential to spread other types of pathogens typically found in GW and destroyed by composting, such as coliform bacteria or salmonella.

The proliferation of commercial composting has been slowed by requirements to reduce fugitive emissions of VOCs and to protect groundwater. GHGs are also a consideration. The questions to be answered in this study were:

- What are the VOC and GHG emissions from DLA of GW?
- What are the potential water quality implications of DLA of GW?

Application of GW to soils could potentially decrease N_2O emissions due to the high carbon (C) availability in GW. This would be possible because dissolved organic C (DOC) that is abundant in decomposing plant material stimulates microbial immobilization of inorganic nitrogen (N), the substrate for nitrification and denitrification (Wright *et al.*, 2007; Dalal *et al.*, 2010). However, the availability of mineralizable C and microbial activity also promotes oxygen (O_2) consumption, and O_2 limitation stimulates N_2O production (Firestone and Davidson, 1989; Zhu et al 2013b). In soil, diffusion of O_2 from the atmosphere into the soil is limited at high soil water content (Balaine *et al.*, 2013). For many soils, N_2O emissions occur when water-filled pore space (WFPS) exceeds 60 percent (Linn and Doran, 1984). The surface-applied green waste played a role in keeping more moisture in the soil underneath the green waste than near the surface of the bare soil. Thus WFPS in the surface green waste applications was greater than 60 percent during most of the entire year, and this contributed to the higher N_2O emissions in those treatments. In addition to denitrification, which uses nitrate (NO_3^-) as a substrate, N_2O is also produced during nitrification, especially under low O_2 availability (Bremner and Blackmer, 1978; Wrage *et al.*, 2001; Zhu *et al.*, 2013). Green waste applications have the potential to generate N_2O because both carbon and inorganic nitrogen availability can be expected to be high. Moisture and temperature can be expected to also regulate the magnitude of the emissions.

Part One: Volatile Organic Compounds, Greenhouse Gases, and Nutrients from Direct Land Application in the Field and in Laboratory Microcosms

Materials and Methods

Field site and experimental design

The field experiment was carried out at the Campbell tract research site at UC Davis (38°32'6"N, 121°46'35"W). The soil is classified as Yolo silt loam, a fine-silty, mixed, non-acid, thermic Typic Xerorthent. The field had been fallow in the summer before the start of the experiment; processing tomatoes (tomatoes used to produce canned tomato paste, as opposed to tomatoes for sale as intact vegetables) had been grown on the site in the preceding year (2012).

Green waste (i.e., residential yard trimmings), collected two weeks earlier and processed to pass through a 13-centimeter (five-inch) screen at a local composting facility (Northern Recycling, Zamora, Calif.), was applied at the field site on October 14, 2013.

The following treatments were imposed in three by three meter plots in a randomized complete block design (see Graphic 1) with three replications per treatment: (1) GW applied on the soil surface to an initial height of 15 cm (six inches); (2) GW applied on the soil surface to an initial height of 30 cm (12 inches); (3) GW applied 15 cm (six inches) high, followed by incorporation of the GW with three passes of a disk to a depth of 15–20 cm (six to eight inches); (4) untilled control; and (5) tilled control with three passes of the disk to a depth of 15–20 cm. Although tilling required operation of a diesel-fueled tractor, in the future this task could be accomplished with non-fossil fuel derived energy.

Complete block design with three replications per treatment:

Plot:	Treatment:	
1	12" GW	**start of block 1**
2	Control	block 1
3	6" GW, tilled	block 1
4	Control, tilled	block 1
5	6" GW	**end of block 1**
6	Control	**start of block 2**
7	6" GW	block 2
8	12" GW	block 2
9	Control, tilled	block 2
10	6" GW, tilled	**end of block 2**
11	Control, tilled	**start of block 3**
12	6" GW, tilled	block 3
13	Control	block 3
14	12" GW	block 3
15	6" GW	**end of block 3**

Graphic 1. Field layout of treatment plots.

During the one-year period of the study, 232 millimeters (mm) of rainfall was recorded at the nearby weather station (California Irrigation Management Information System), and a total of 430 mm of water was applied with sprinklers during irrigation events in January, June, and September (Figure 1).

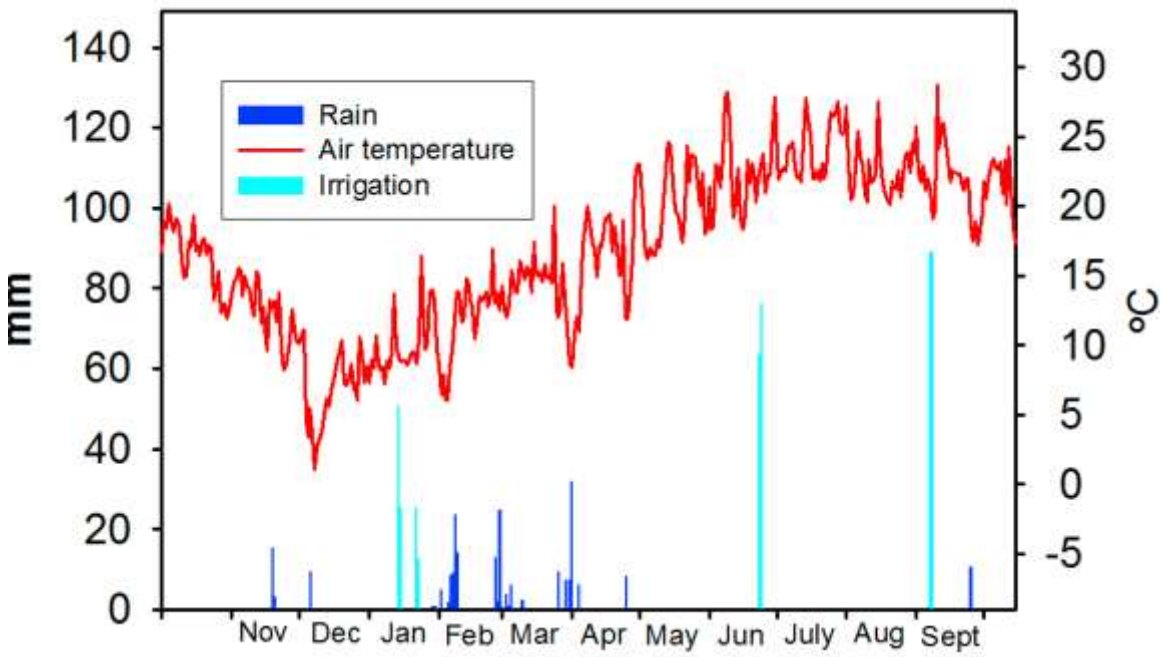

Figure 1. Water inputs and air temperature at the field experiment site from October 2013 to October 2014. Irrigation (light blue) was applied 4 times: twice in mid-January, and once each (for multi-day periods) in June and early September. All other water input was rain (dark blue). (Air temperature is for reference only.)

Gas flux chamber measurements

Emissions of VOCs (precursors of criteria pollutant ozone), and of N_2O, CH_4, and carbon dioxide (CO_2) were measured during the entire year. After each irrigation or significant rainfall event (>10 mm), gas fluxes were measured intensively, i.e. daily or every other day, to capture the peak of the emissions and subsequent decline to ambient levels. During the time in between these events, when soils were relatively dry, the gas fluxes were measured weekly.

Bases for static chambers to measure fluxes were installed approximately in the center of each treatment plot. Round (24.5 cm diameter) polyvinyl chloride rings were inserted eight cm deep into the soil. As such, the chamber bases extended through the GW and therefore varied in length (in order to reach below the material, where present) among the treatments. The bases were left in place for the entire duration of the field experiment. During sampling, the vented tubes (4.8 mm in diameter, ten cm long) and insulated chambers were fitted onto the bases. Headspace air was removed from a sampling port containing a butyl rubber septa via syringe and needle 20, 40, and 60 minutes after deploying the chamber tops onto the bases. To collect a gas sample from the chamber, headspace air was removed by inserting the needle of a polypropylene syringe (Monoject) through the septum of the sampling port and by slowly withdrawing 20 mL gas. The average ambient concentration of the gases (sample size (n) equals five) was used as the time zero measurement. The gas in the syringes was immediately

transferred into evacuated 12-mL glass vials with grey butyl rubber septa (Exetainer, Labco Ltd., Buckinghamsire, UK).

For VOCs, sampling from the flux chambers (immediately after each final GHG sampling; Graphics 2 and 3) was conducted with a 1 L gas-tight Hamilton syringe, followed immediately by immobilization onto charcoal sorbent tubes with later elution and analysis by GC-MS, according to NIOSH methods 1500, 1501, and 1552.

Graphic 2. Xia Zhu sampling GHGs from the flux chamber (photo by Crystal Reul-Chen, July 23, 2014).

Graphic 3. Peter Green taking samples of VOCs (photo by: Crystal Reul-Chen, July 23, 2014).

VOC samples were collected using activated coconut charcoal tubes (Orbo 32, Sigma-Aldrich, St. Louis, MO). Charcoal tubes containing 400 mg and 200 mg of activated carbon in two successive sections were used for sample collection and breakthrough determination, respectively. The sampling was performed at the flow rate of 0.5 L per minute for one minute. Tubes were capped immediately after sampling and transferred to the laboratory in less than 1 hr. Samples were refrigerated at 4°C until they were processed. Individual sections of each tube were extracted in separate vials using 1.5 mL of carbon disulfide (CS_2) solvent and 15 minutes of sonication. The supernatant phase of the solvent was transferred into another vial and analyzed by GC–MS. Charcoal tubes that were taken into the field but not used for sampling were also extracted in CS_2 to check the blank values (NIOSH, 2003; Kumar and Viden, 2007).

The VOCs in the extracted solvent were analyzed using a gas chromatograph (6890A, Agilent, Santa Clara, CA) coupled with a mass spectrometer (5973N, Agilent). A ZB-624 capillary column (Phenomenex, Torrance, CA) with dimensions 30 m by 0.25 mm by 1.4 µm was used for the separation of analytes with the following temperature program: initial oven temperature at 35°C for five minutes, then raised to 220°C at a rate of 7°C per minutes, and then held for five min. A second ramp of 10°C per minute to 240°C was then applied with a holding time of two minutes. The injector was set at 200°C. Electron ionization conditions were: ion energy 70 eV, scan range from 10 to 300 atomic mass units, at three scans per second.

A calibration standard solution was prepared by mixing a known volume of chromatographic-grade methanol, *n*-hexane, isooctane, 1-hexene, toluene, *m*-xylene, 1,3,5-trimethyl benzene (mesitylene), 1,4-diethylbenzene, limonene, 2-pentanone, hexanal, and 1-hexanol in a vial and diluting it with CS_2. The instrument was calibrated to ensure the linearity of the system. If the response factor varied by more than 10 to 15 percent the GC was recalibrated. Carbon disulfide was also analyzed to ensure that it was free of contamination.

The GHG gas samples were analyzed on a Shimadzu gas chromatograph (GC) (Model GC-2014) with a ^{63}Ni electron capture detector (ECD) for N_2O, a flame ionization detector (FID) for CH_4, and a thermal conductivity detector (TCD) for CO_2 linked to a Shimadzu auto sampler (Model AOC-5000). The autosampler uses a gas-tight syringe to remove 2 mL gas from the sample vials and injects it into the GC port. The GC uses as carrier gas a mixture of helium and P5 (mixture of 95 percent argon and five percent CH_4). The CO_2 and N_2O are separated by a Haysep Q column at 80°C. The ECD is set at 320°C, the FID at 250°C, and the TCD at 100°C. The pressure of the carrier gas is 60 kilopascals (kPa). After the acquisition of the sample, the autosampler's syringe and the GC's sample loop are purged with helium to back flush water and other slow chromatically resolved analytes.

The GC system was calibrated daily using analytical grade standards (Airgas Inc., Sacramento, Calif.). Quality assurance of the values generated by the GC and its software was obtained by processing standards in Exetainers after taking them to the field and treating them the same way as field samples. Samples were analyzed within

two weeks of collection, and their quality was ensured by ascertaining that the field N_2O standards were not compromised as a result of extended storage.

Gas fluxes were calculated from the rate of change in chamber concentration, chamber volume, and soil surface area (Hutchinson and Mosier, 1981). Chamber gas concentrations determined by the GC (volumetric parts per million) were converted to mass per volume units assuming ideal gas relations using chamber air temperature values, which were measured by a thermocouple thermometer during each sampling event. The gas fluxes were calculated by linear regression or a least squares regression procedure fitting a quadratic equation to the concentration vs. time data (Wagner *et al.*, 1997) using the LINEST function in Excel (Venterea *et al.*, 2009; Parkin and Venterea, 2010). The algorithm using the quadratic equation was developed for curvilinear concentration data with time (Wagner *et al.*, 1997), e.g. when N_2O concentration in the chamber increases at a decreasing rate. The linear flux (F_{N2O}) was calculated as follows:

$$F_{N2O} = V / A * d[N_2O]/dt \qquad \text{(Eq. 1)}$$

where V = chamber volume, A = area covered by the chamber, t = time.

Briefly, Wagner et al. (1997) used the following quadratic model

$$[N_2O] = a + bt + ct^2 \qquad \text{(Eq. 2)}$$

where a, b, and c were derived from parameter estimates of a least squares multiple linear regression with one dependent variable $[N_2O]$ and two independent variables (t and t^2). The term ct^2 was termed the “observer effect” and a + bt the linear process. The parameters a, b, and c were calculated by the Excel LINEST function for each chamber flux measurement. Differentiating Eq. 2 with respect to time yielded the following equation:

$$d[N_2O]/d(t) = b + 2ct \qquad \text{(Eq. 3)}$$

and setting t = 0 yields the instantaneous N_2O flux b at time t0 without the “observer effect” (i.e. the effect of the chamber diminishing the N_2O flux from the soil surface to the atmosphere). In other words, the flux is computed as the first derivative of the quadratic function at t0 (Parkin and Venterea, 2010).

Linear regression was used if the coefficient of determination (r^2) was >0.90. For the remainder of the fluxes, the slope of the quadratic equation was used if r^2>0.80, or, if the latter criterion was not met, the slope of a linear regression model that included three time points where r^2 >0.80. The minimum detectable change in chamber N_2O concentration by this GC system is 0.02 microliters per liter (µL/L), corresponding to a field N_2O flux of 2.5 micrograms (µg) N_2O-nitrogen (N) per square meter-hour (m/h).

Cumulative emissions of VOCs, CH_4, and N2O

The (cumulative) annual VOC, CH_4, and N_2O emissions were calculated by trapezoidal integration of daily fluxes (mean of flux at sampling date and flux at next sampling date, multiplied by the number of days) under the assumption that the measured fluxes represented mean daily fluxes, and that mean daily fluxes changed linearly between measurements (Venterea *et al.*, 2005).

$$\text{Cumulative } E_{N2O,\ CH4,\ VOC} = (t2 - t1) * (F_{day1} + F_{day2})/2 \qquad \text{(Eq. 4)}$$

where F_{day1}, F_{day2} are the daily fluxes on date 1 and date 2.

Conversion of N_2O and CH_4 annual emissions into CO_2 equivalents was carried out using a conversion factor of 310 for N_2O (310 kg CO_2 per kg N_2O) and 21 for CH_4 (21 kg CO_2 per kg CH_4) (IPCC, 2007). For fuel usage to incorporate the green waste, a conversion factor of 22.23 lbs CO_2 per gallon diesel fuel was assumed (USEPA 2011). Fuel use was estimated based on measurements of fuel use by a John Deere 8300 tractor for stubble disking in Yolo silt loam soil (1.9 gallons per pass per acre). Differences in time-integrated annual N_2O, CH_4, and CO_2 emissions between treatments were assessed using analysis of variance (ANOVA) and standard mean separation procedures. Appropriate transformation of the N_2O emissions data was carried out for the statistical analysis whenever the data were not normally distributed.

Temperature and moisture measurements

During each sampling event, in addition to chamber air temperatures, ambient air temperatures were measured. The temperature was continuously (hourly) monitored by HOBO temperature loggers (Onset Computer Corp., Bourne, MA) in the middle of the GW (i.e., at 15 cm and 7.5 cm depth in the 30 cm and 15 cm high GW piles), and at five cm depth in the soil of all treatments (two probes for each plot). Gravimetric soil moisture in the 0–15 cm layer was determined at each gas sampling event. Gravimetric soil moisture was calculated by comparing the field-moist and oven-dry (105ºC) mass of soil collected in the 0–15 cm layer using a 1.83-cm diameter steel corer. Volumetric soil moisture in the soil under the GW piles was measured by in-situ calibrated soil moisture sensors (EC-5, Decagon Inc., Pullman, WA). The bulk density (BD) was measured by collecting 10 cm diameter × 7 cm long cores in the 5–15 cm layer of soil, followed by drying of the cores at 105ºC (one sample per replication). The gravimetric soil moisture (W) values were converted to water-filled pore space (WFPS) values by the following equation using the measured BD values (Paul & Clark, 1996):

$$WFPS = (W*BD)/ [(1- (BD/2.65)] \qquad \text{(Eq. 5)}$$

Soil characterization and inorganic N concentrations

Inorganic N (NO_3^- and ammonium (NH_4^+)) and DOC in the 0–15 cm layer was measured before and after the irrigation events and approximately monthly during the remainder of the time by extracting 15 g of well-mixed soil from four borings with a 1.83-cm diameter steel corer with 80 mL of 0.5 M potassium sulfate solution, and by analyzing the extracts colorimetrically for ammonium (NH_4^+) and nitrate (NO_3^-) by a Shimadzu

spectrophotometer (Model UV-Mini 1240). For determining NH_4^+, the phenate (indophenol blue) method was employed (Forster, 1995). Nitrate in the extracts was reduced to nitrite (NO_2^-) with vanadium chloride, and the NO_2^- was analyzed by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl)ethylenediamine-dihydrochloride (Doane and Horwath, 2003). Dissolved organic carbon was measured with a total organic carbon (TOC) ultra-violet (UV)-persulfate oxidation analyzer (Model Phoenix 8000, Teledyne Tekmar, Mason, OH). The total carbon and nitrogen in soil of the 0–15 cm layer was measured by a carbon and nitrogen analyzer (Costech Analytical Technologies Inc., Valencia, CA) by the dry combustion method (Dumas, 1848) after grinding air-dried representative soil samples to a fine powder. The pH in the 0-15 cm layer of soil was measured in the supernatant of a soil slurry (soil/1 M KCl ratio 1:1) with a pH meter (Model 220, Denver Instrument Co., Arvada, CO). Soil texture was determined by a modified pipet method.

Laboratory incubation

To study the effects of GW addition to soil on the dynamics of O_2 consumption and N_2O, CH_4, and CO_2 production, three soil types of varying texture were amended with fresh (two weeks old) GW material at two soil moisture levels and incubated in closed vials. The following three soil types were used: (1) the soil from the field experiment site (Yolo silt loam), (2) Stockton clay, classified as fine, smectitic thermic, Xeric Epiaquerts, and (3) Tujunga loamy sand, classified as mixed thermic Typic Xeropsamments. The GW was delivered new from the same facility as the one used in the field experiment. The GW and the soils were air dried, crushed and passed through a four mm sieve. The soils were pre-incubated at 40 percent water-holding capacity (WHC) for seven days. The purpose of the pre-incubation was to avoid the pulse of respiration associated with wetting dry soils (Kieft et al., 1987).

The treatments of the lab incubation included two moisture levels (50 percent or 100 percent of soil WHC), three soil types, and either GW plus soil, GW only, or soil without amendment (control). There were a total of 14 treatments (three soil types plus GW at 50 or 100 percent of WHC, GW at the two moisture levels, and three unamended soils at the two moisture levels), replicated four times, set up in a completely randomized design. For each microcosm, 30 grams (g) dry weight pre-incubated soil was placed into 160 mL serum vials (Supelco, Bellefonte, PA). The GW treatments additionally received 9 g dry weight GW, corresponding to the 15 cm height GW addition incorporated in the field experiment. Deionized water was sprayed onto the surface of the soil by using a syringe with a fine-tipped needle to achieve a soil moisture content of 50 percent or 100 percent WHC with uniform distribution. The WHC was empirically determined for each soil type prior to the incubation experiment. The incubations were conducted at 22°C. Oxygen levels in the vials were monitored via optical O_2 sensors (PreSens Precision Sensing, Regensburg, Germany) attached to the bottom of vials underneath the soil layer. Headspace gas samples (3 mL) were removed at four and nine hours, one, seven, 14, 21, and 28 days after the start of the incubation and analyzed for N_2O, CH_4, and CO_2 concentration by GC. Ammonium and NO_3^- concentrations in the soil were

measured weekly in separate microcosms, following the same protocols as in the field experiment.

Results and Discussion

Soil and green waste moisture and temperature

The total water inputs during this one-year experiment were comparable to precipitation typical for this region. Additionally, N_2O responses to two summer irrigations were investigated. Between the application of the green waste in October and the end of April, a total of 333 mm of water entered the experimental plots with two irrigations and rainfall, whereas the 30-year average annual rainfall in this region has amounted to 432 mm. The two summer irrigations totaled another 331 mm.

The volumetric soil water content, expressed in cm for the 0–15 cm layer, was on average highest underneath the two surface GW treatments (Table 1), although the average water content in the control treatments did not statistically differ from the 15 cm high surface application treatment. The average water content in the control and the 30 cm high surface application treatments did not statistically differ either. However, the average water content of the GW incorporated treatment was significantly lower than that of the surface treatments.

Table 1. Average soil water content over the one-year field experiment. Averages and standard errors in the 0–15 cm layer in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments from November 2013–October 2014. Values designated with the same letters are not statistically different ($P<0.05$). $n_{piles} = 3$. Treatments with the same letters $^{(ABC)}$ do not have statistically significantly different average soil water content.

Treatment	cm
12 inch	4.77 ± 0.06^{AB}
Control	4.09 ± 0.20^{ABC}
6 inch + till	3.85 ± 0.17^{C}
Control + till	4.02 ± 0.12^{BC}
6 inch	4.81 ± 0.22^{A}

Although a large amount of organic matter in the form of GW had been added to this soil layer in the GW incorporated treatment, the soil did not hold more water than the control. This unexpected result may have been due to the uncomposted nature of the GW (i.e., the material contained many relatively large, woody pieces that may not have held much water). Another reason could be that due to the recent incorporation of this relatively coarse material, the soil had many large air spaces (macro pores) that facilitated downward drainage of applied water. The greater soil moisture underneath the surface GW treatments was evident during the summer months when the material acted as mulch (Figure 2).

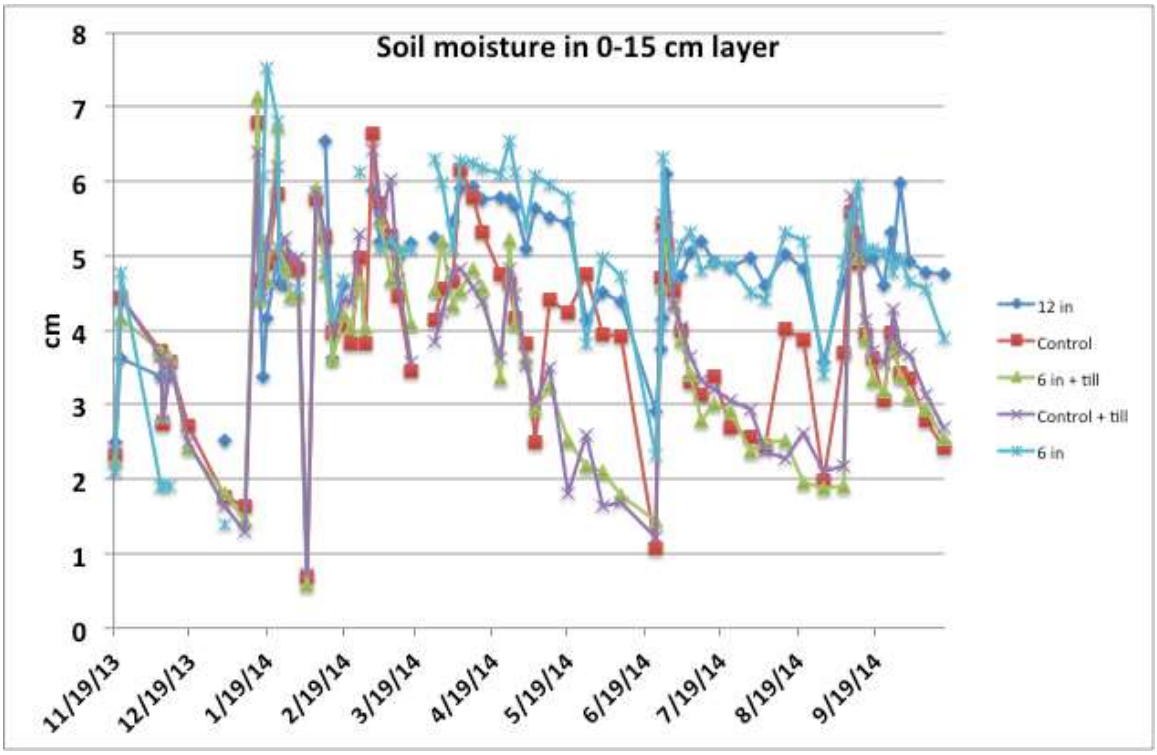

Figure 2. Soil water content during the one-year field experiment. Soil water content (cm) in the 0–15 cm layer in the 30 cm high surface GW application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments from November 2013–October 2014.

The WFPS in the control plots ranged from as high as 80 to 100 percent following irrigation events to about 40 percent during the winter and less than 20 percent during the summer (Figure 3). The application of GW increased soil moisture and WFPS in the underlying soil. With few exceptions, the WFPS underneath the GW remained greater than 60 percent during the entire year. Immediately after the irrigation events WFPS was similar in both the control soils and the GW-covered soils, but the covered soils held their moisture longer than the control or the treatment where GW was tilled into the soil. Furthermore, the incorporation of GW lowered the soil bulk density values (Table 2) and thus, the WFPS tended to be lowest in the GW-incorporated treatment.

Soil moisture is a critical factor regulating the production and release of N_2O to the atmosphere since soil moisture affects the microbial processes of nitrification and denitrification, a soil's O_2 status, and gas exchange between the soil and atmosphere. Field studies have shown that N_2O emissions occur mostly at WFPS greater than 60 to 70 percent (Linn and Doran, 1984; Burger *et al.*, 2005). The surface-applied GW played

a role in keeping more moisture in the soil underneath the material than near the surface of the bare soil. Thus, WFPS in the surface GW applications was greater than 60 percent during most of the entire year. This contributed to the higher N_2O emissions in those treatments. Conversely, the application of the GW lowered the BD of the soil in the GW incorporated treatment, thereby increasing the pore space in this treatment. This resulted in lower WFPS in this treatment compared to that in the control treatments.

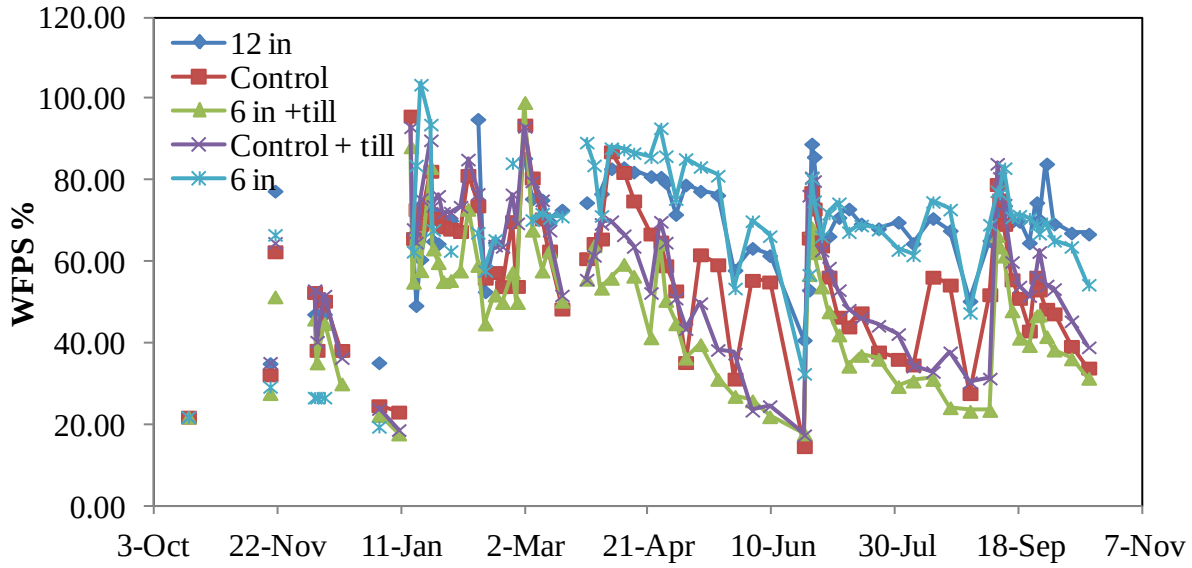

Figure 3. Soil water-filled pore space during the one-year field experiment. Soil water-filled pore space in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments from October 2013 to October 2014.

Table 2. Soil characteristics at the end of the one-year field experiment. WFPS = average water-filled pore space during one year. Values designated with the same letters within the same column are not significantly different P <0.05). n = 3.

Treatment type	Bulk density g/cm^3	Total C, g/kg	Total N, g/kg	Soil pH (KCl)	WFPS %
12 in	1.39 ±0.02^{A}	1.45 ±0.12^{C}	0.18 ±0.05^{A}	6.33 ±0.14^{A}	67.8 ±3.8^{A}
Control	1.39 ±0.06^{A}	1.35 ±0.03^{C}	0.11 ±0.00^{A}	6.00 ±0.05^{A}	57.8 ±6.6^{AB}
6 in + Till	1.22 ±0.02^{B}	2.30 ±0.29^{A}	0.16 ±0.01^{A}	6.10 ±0.08^{A}	47.7 ±3.8^{B}
Cont. + Till	1.43 ±0.03^{A}	1.30 ±0.07^{C}	0.11 ±0.00^{A}	6.10 ±0.05^{A}	57.4 ±5.0^{AB}
6 in	1.39 ±0.02^{A}	1.87 ±0.04^{B}	0.15 ±0.01^{A}	6.20 ±0.05^{A}	68.2 ±5.7^{A}

The temperature within the 30 cm high GW pile exceeded 55°C (131°F) for two days (October 25–26, 2014), immediately following the GW application in the field (Figure 4). This may have briefly produced some pathogen reduction (CalRecycle, 2014). Temperature then declined to nearly the same levels as in the soil although the temperature within this GW pile and in the soil underneath it remained a few degrees Celsius higher than in the control soils until April 2014. In the 15 cm (6 inches) high GW pile, temperatures never reached 30° C, but the temperature tended to be slightly higher in the GW material and soil underneath it than in the control soil until February 2014. Higher soil temperature, in general, increases the rate of microbially mediated transformations, such as soil mineralization, nitrification, and denitrification, and therefore, GHG production (Avrahami and Bohannan, 2007).

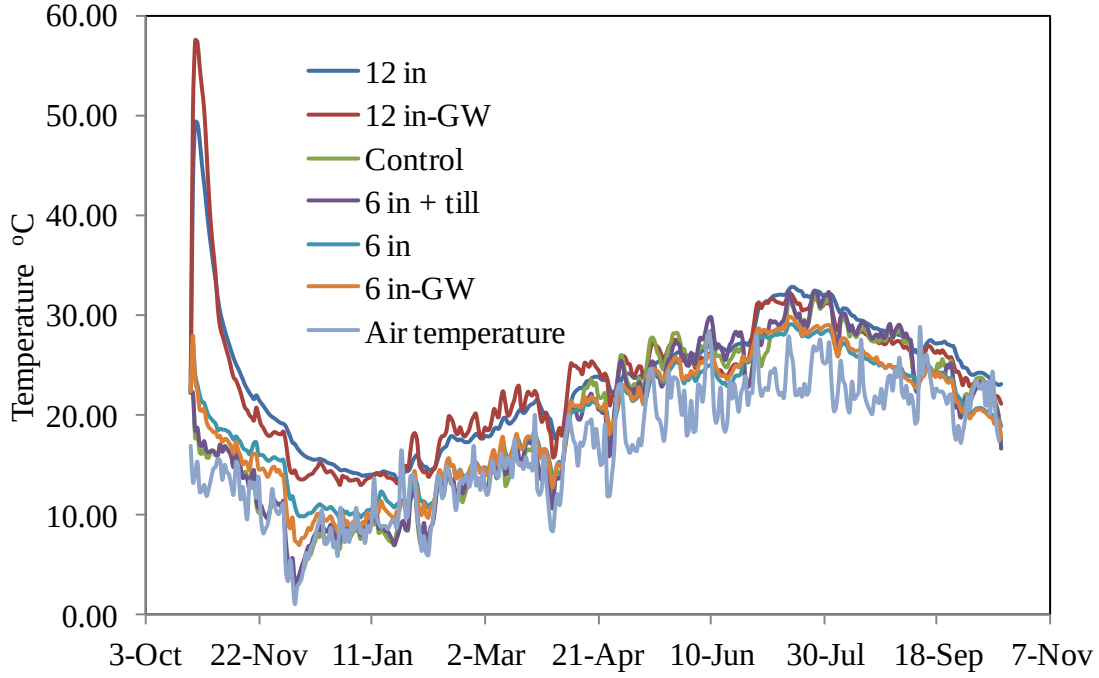

Figure 4. Mean daily temperatures during the one-year field experiment. Mean daily temperatures in the soil underneath the 30 cm high surface GW application (12 in-Soil), within the 30 cm high GW material (12 in-GW), the control soil (Control), the soil of the incorporated GW treatment (6 in + till), the soil underneath the 15 cm high surface GW application (6 in-Soil), within the 15 cm high GW material, and the daily average air temperature from October 2013 to October 2014.

VOC emissions

VOC emissions were strong from the surface-applied GW during the first month or two, before declining to background (Figure 5). Since VOCs are measured against the ambient background, emissions were only detectable for the first few months of the 12-month study. (After that time, the background VOCs were as high as the samples, due to emissions from the surrounding weeds, nearby agricultural fields, and regional plant growth with winter beginning to turn into spring.)

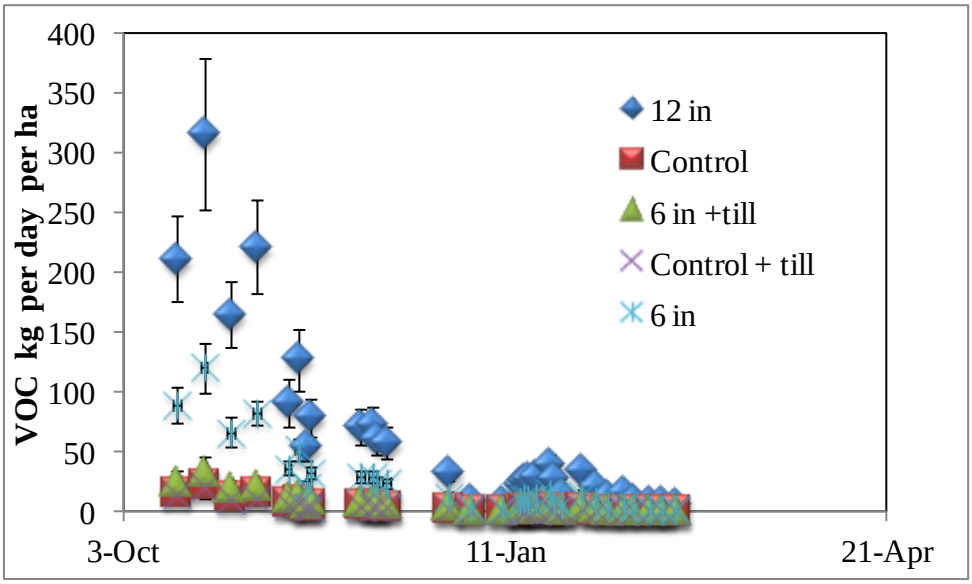

Figure 5. Mean daily VOC fluxes during the one-year experiment. Mean (n_{piles}=3) daily VOC fluxes in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments from October 2013 to October 2014. Standard errors are shown as line bars.

Cumulative VOCs showed a significant difference between the pair of applied GW treatment plots and the controls (Figure 6). The tilled 15 cm GW plots were not distinguishable from the controls.

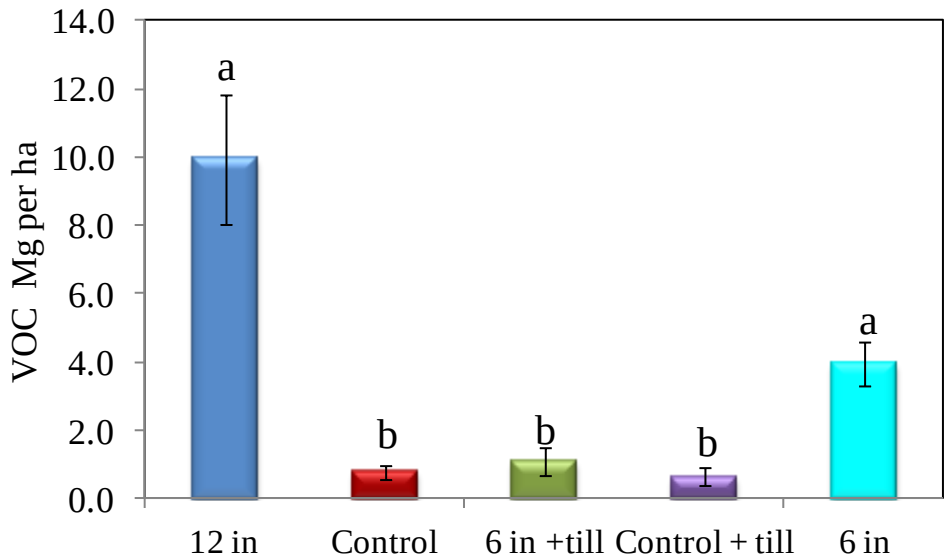

Figure 6. Mean cumulative VOC fluxes from the one-year experiment. Mean (n_{piles} = 3) cumulative VOC emissions during one year in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments. Standard errors are shown as line bars. Bars designated with same letters aren't significantly different (P <0.05).

The composition of VOCs (Figure 7) was similar to that seen from compost piles (Kumar et al, 2011) but shifted more toward monoterpenes (which are more reactive toward formation of ozone) and away from methanol (which is less reactive toward formation of ozone). Plausibly, the moisture-managed composting operations lead to predominance of methanol in the VOC profile, compared to the relatively dry green waste, which releases more monoterpenes.

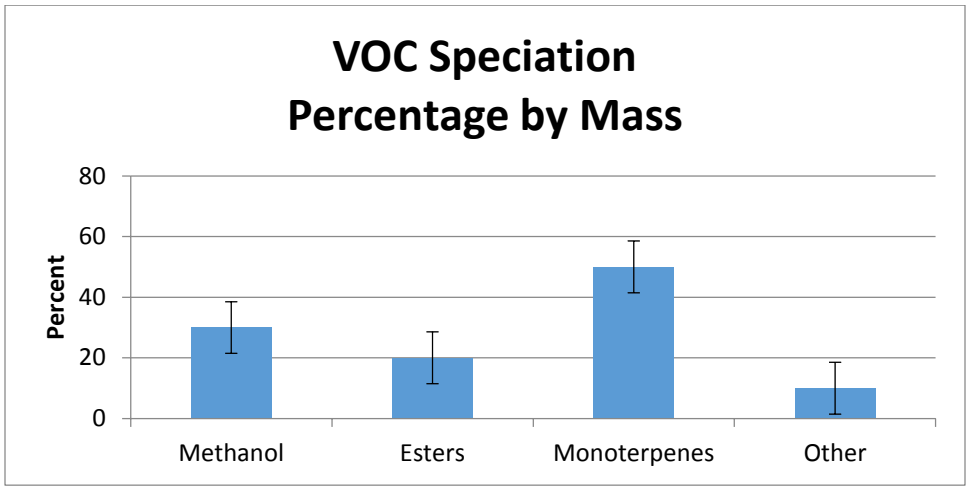

Figure 7. Speciation of VOC emissions from the samples collected from the flux chambers during the 60 sampling events for each of the 15 treatment plots.

N_2O emissions

The highest daily N_2O fluxes were measured following the irrigation events, especially those in June and September (Figure 8). The peaks of N_2O emissions in the incorporated GW and control treatments were similar in magnitude immediately following these events as in the two surface applications of GW treatments. However, the decrease in daily flux values was slower in the latter treatments, and daily fluxes were somewhat elevated in these treatments for extended periods.

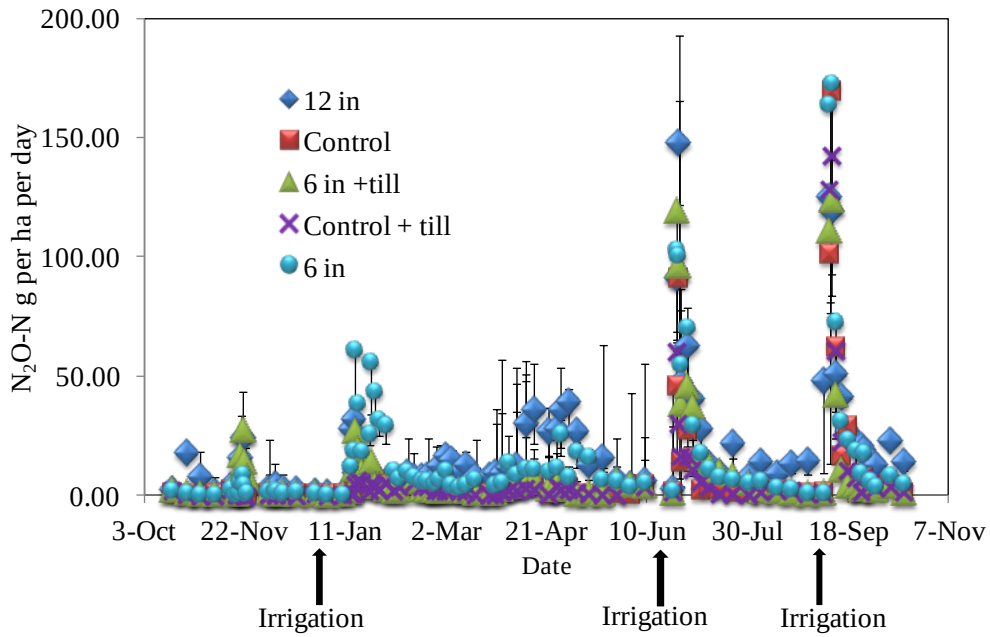

Figure 8. Mean daily N_2O fluxes for the one-year field experiment. Mean (n_{piles}=3) daily N_2O fluxes in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments from October 2013 to October 2014. Standard errors are shown as line bars.

The cumulative annual N_2O emissions were 5.5 (± 0.14) kg N_2O-N/ha in the 30 cm high surface GW application treatment and significantly higher than in the 15 cm high surface GW application treatment with total emissions of 4.2 (± 0.2) kg N_2O-N/ha, whereas those in the two control and the incorporated GW treatments were similar and significantly lower than in the former treatments, ranging from 1.6 (± 0.3) to 1.9 (± 0.4) kg N_2O-N ha^{-1} ($P < 0.05$) (Figure 9).

Surface application of GW released larger amounts of the GHG N_2O to the atmosphere than incorporation of the material (Figures 8 and 9). The cumulative annual N_2O emissions were more than twice as large from surface application than from incorporation of GW applied 15 cm high (equivalent to 540 Mg dry weight GW/ha).

Incorporation (by tilling) of this amount of green waste into the soil did not result in a significant increase in N_2O emissions compared to (tilled or untilled) control treatments. The annual N_2O emissions in the 30 cm high green waste (12 inches application rate, or to 1080 Mg dry weight/ha) treatment were 3.4 times greater than in the unamended control treatments.

The amount of N_2O-N released from the soil amended with GW is comparable to that of a furrow irrigated tomato field, or flood irrigated alfalfa cropping system during one year (Burger and Horwath, 2012; Kennedy *et al.*, 2013). It should be noted that in the present GW experiment, crops were absent. A recent study (Horwath, for CalRecycle) has quantified the release of N_2O-N Mg^{-1} of green waste during composting, but those results are not yet finalized for comparison.

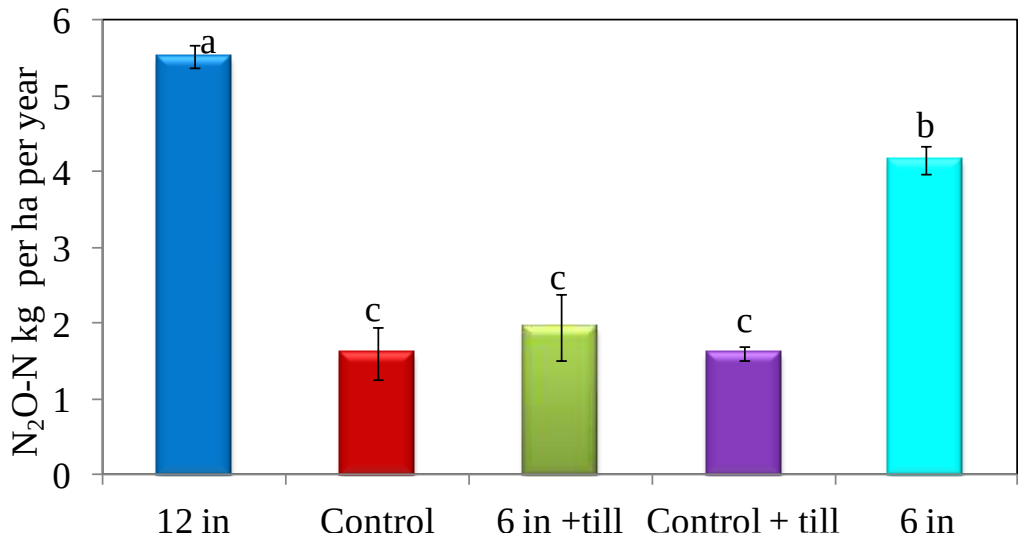

Figure 9. Mean cumulative N_2O fluxes for the one-year field experiment. Mean (n_{piles} = 3) cumulative N_2O emissions during one year in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments. Standard errors are shown as line bars. Bars designated with the same letters are not significantly different ($P < 0.05$).

Although GW provides the substrate for N_2O emissions and an abundance of mineralizable C that could be expected to lead to O_2 consumption, it is not entirely clear whether the higher emissions of N_2O from the surface GW applications were due to production of N_2O within the piles or due to the fact that the WFPS underneath the GW piles was elevated throughout most of the experimental period. The lab incubation provided ample evidence that GW C quickly depletes O_2 levels both in GW-amended soil and in GW alone although diffusion of atmospheric O_2 into the piles was probably relatively unimpeded. Gas samples taken within the 30 cm high GW piles in the field experiment suggested rapid transport of gases through the piles since spikes of high N_2O concentrations in the piles coincided with elevated N_2O fluxes (Figure 10). Replenishment of O_2 in the GW piles could have kept N_2O production within the piles

relatively low. The chamber bases extended through the piles into the soil, so the source of the N_2O in the chambers could be from within the pile, the soil, or both locations.

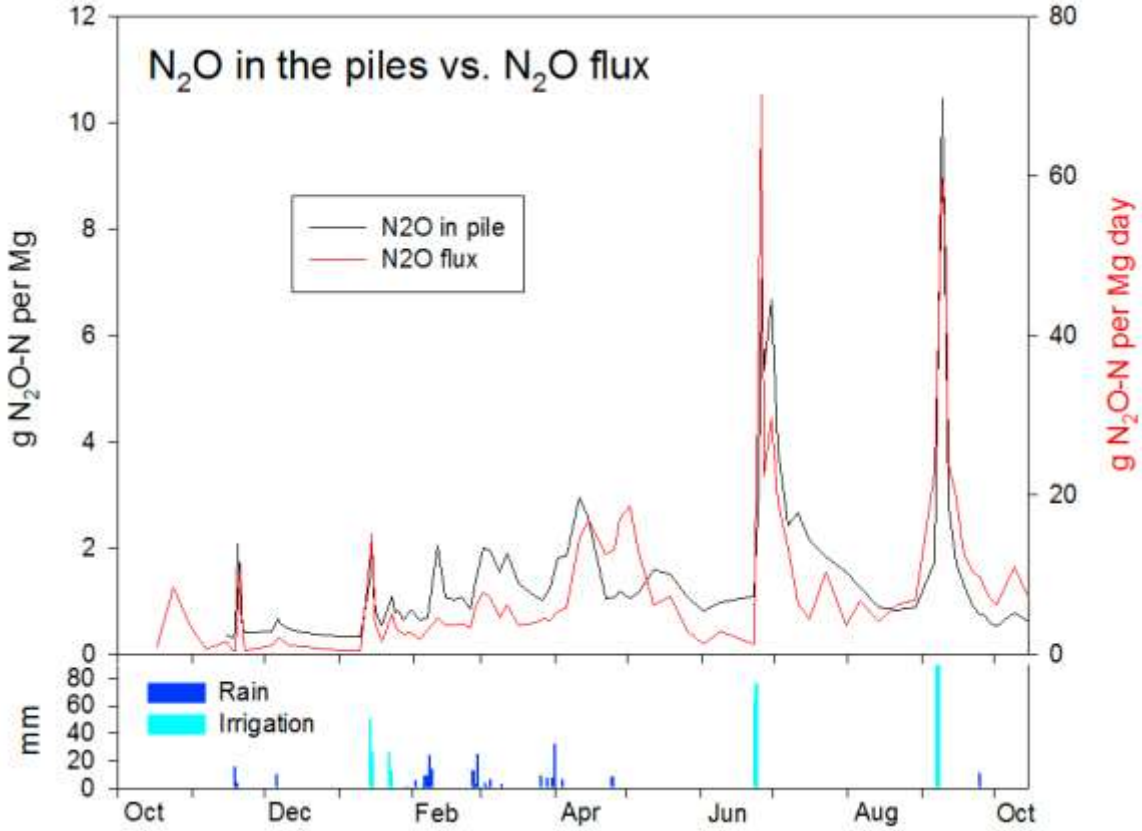

Figure 10. Mean N_2O concentration in the middle of the 30 cm high GW pile and N_2O flux. Mean concentration (n_{piles} = 3) of N_2O in the middle of the 30 cm high GW pile (left axis) and N_2O flux (right axis).

CO_2 emissions

The daily and the cumulative CO_2 emissions were higher in the GW than the control treatments (Figures 11 and 12). After application of the GW in the fall of 2013, the daily fluxes declined, and then, after the irrigations and rainfall events, increased and stayed elevated through early summer (May) before declining and increasing again after the irrigations in June and September. This pattern was observed only in the GW treatments, most strongly in the 30 cm high surface application treatment. In this treatment, the increases in CO_2 fluxes following the irrigation events in June and September were less pronounced than those following irrigation and rainfall during winter and spring (Figure 11).

Cumulative annual CO_2 emissions were 40.6 (± 3.0) Mg CO_2-C/ha in the 30 cm high surface GW application treatment and about 2.4 times greater than in the 15 cm high surface GW application treatment with total emissions of 16.7 (± 2.1) Mg CO_2-C/ha. The CO_2 emissions in the two control and the incorporated GW treatments ranged from 5.3

(± 0.6) to 10.1 (± 0.4) Mg CO_2-C/ha and were significantly lower than the surface application of GW treatments ($P < 0.05$) (Figure 12).

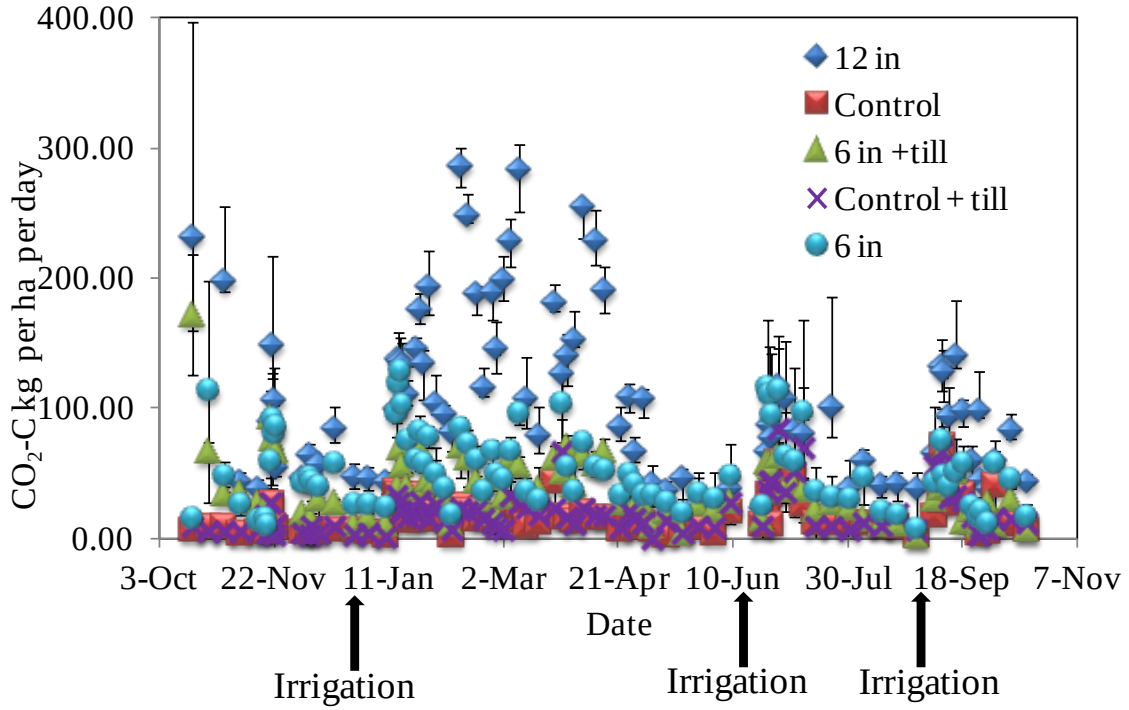

Figure 11. Mean daily CO_2 fluxes during the one-year field experiment. Mean daily CO_2 fluxes in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments from October 2013 to October 2014.

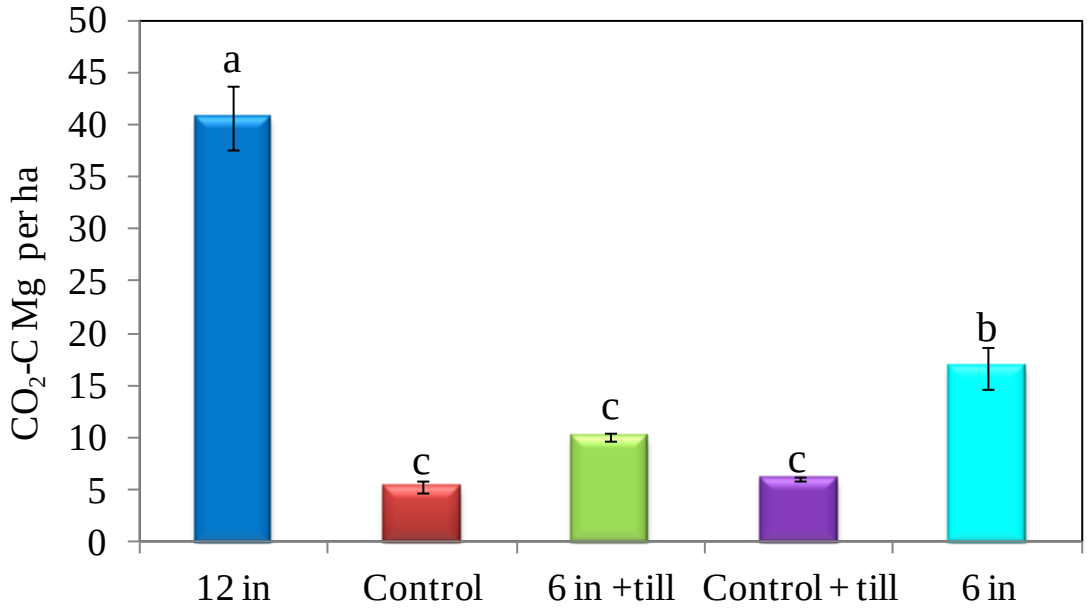

Figure 12. Mean cumulative CO_2 fluxes during the one-year field experiment. Mean (n_{piles} = 3) cumulative CO_2 emissions during one year in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments. Standard errors are shown as line bars. Bars designated with the same letters are not significantly different (P <0.05).

CH_4 emissions

In all of the treatments, cumulative CH_4 emissions were negative (i.e., CH_4 from the atmosphere was consumed by the soil). This cumulative CH_4 consumption accounts for CH_4 that was produced at points throughout the year in the treatments (Figure 13). The CH_4 production led to significantly lower decreased total cumulative CH_4 consumption in the 30 cm (12 inches) high surface GW and the incorporated GW treatments than in the control and 15 cm (6 inches) high treatments (Figure 14).

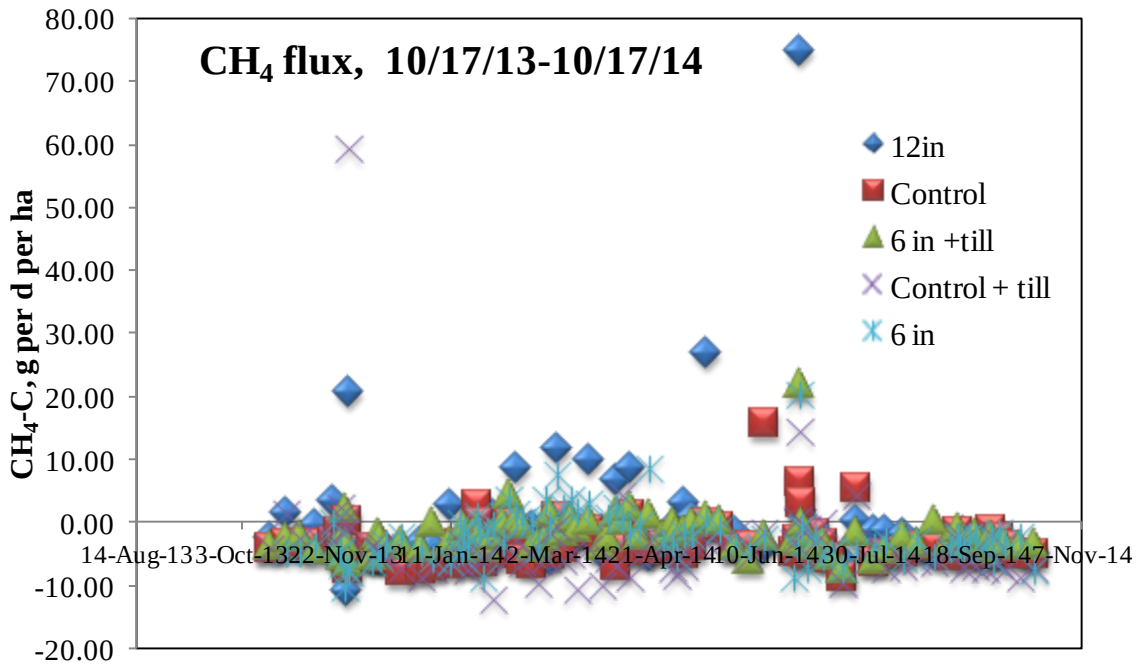

Figure 13. Mean daily CH_4 fluxes during the one-year field experiment. Mean daily CH_4 fluxes in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments from October 2013 to October 2014.

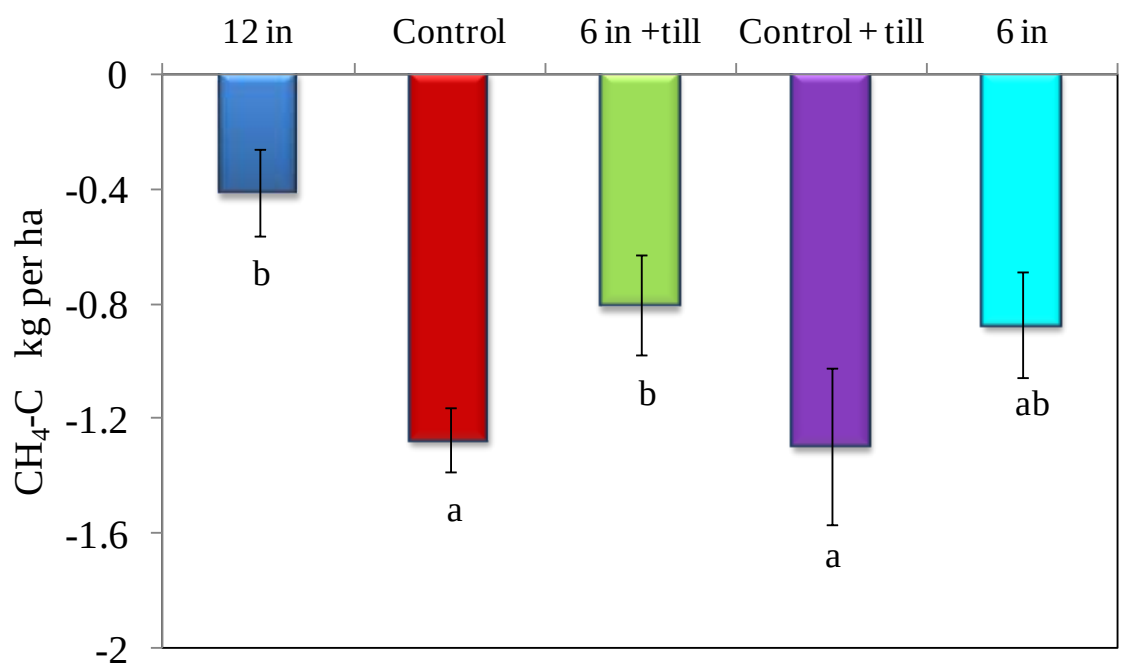

Figure 14. Mean cumulative CH_4 fluxes for the one-year field experiment. Mean (n_{piles} = 3) cumulative annual CH_4 exchange between soil and atmosphere in the 30 cm high surface green waste application (12 in), untilled control (control), incorporated GW treatment (6 in + till), the

disked control (control + till), and the 15 cm high surface GW application (6 in) treatments. Standard errors are shown as line bars. Bars designated with the same letters are not significantly different (P <0.05).

Measurements of CH_4 concentration in the 30 cm high GW piles indicated that CH_4 was continuously produced in those piles while CH_4 was consumed at the surface of the piles (Figure 15). The spikes in CH_4 efflux occurred after wetting events. During those events, consumption of CH_4 at the surface was probably suppressed, while production inside the piles increased, as evidenced by the increase in CH_4 concentration in the piles during those events.

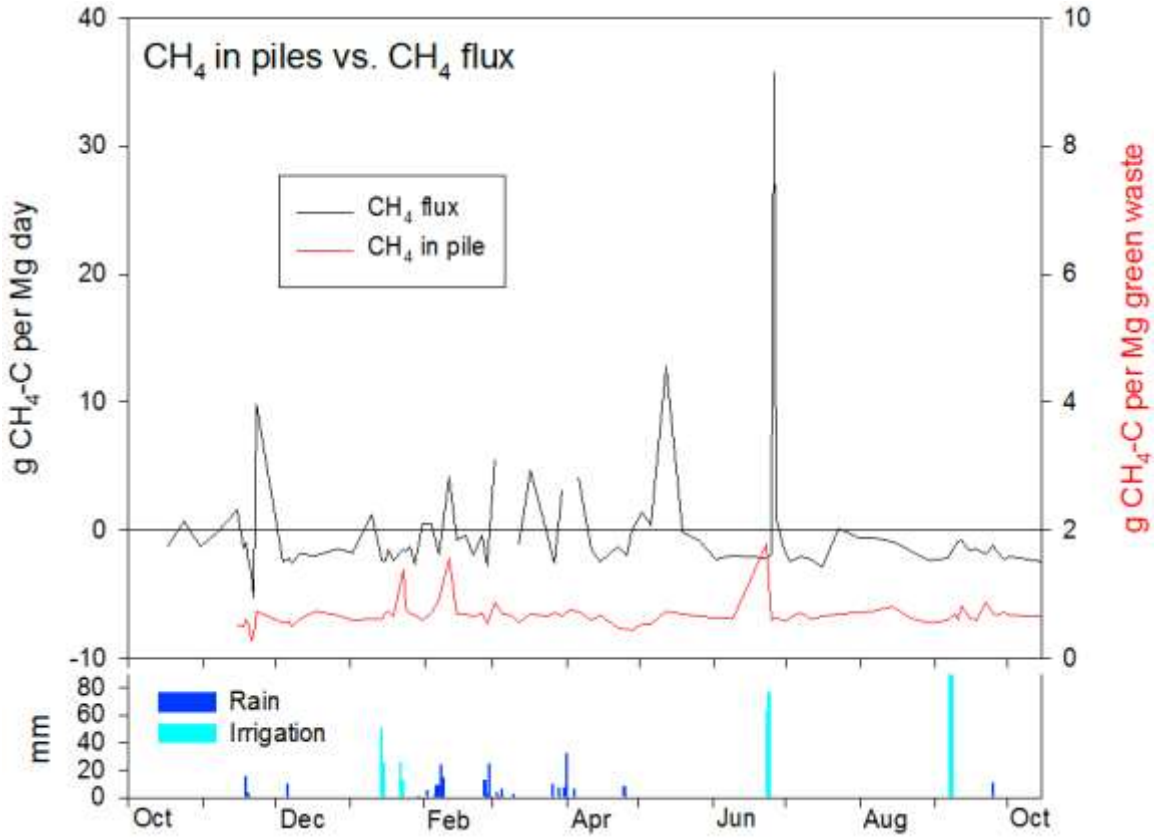

Figure 15. Daily methane pile concentrations and fluxes. Methane (CH_4) concentrations per Mg GW material (right axis) and CH_4 flux per Mg GW per day (left axis).

Comparisons were made among GHG emissions and with usage of fossil fuel during tilling. In terms of global warming potential (GWP) expressed as CO_2 equivalents, the consumption of CH_4 reduced the impact of N_2O emissions by 0.4 percent in the 30 cm high surface GW application, 5.1 percent in the control, 2.8 percent in the incorporated GW, 5.1 percent in the tilled control, and 1.0 percent in the 15 cm high surface GW

application treatments (Figure 16). That is, the N_2O emissions greatly outweigh the slight CH_4 tradeoff.

Fuel use to incorporate the GW with three passes of a disk increased the GWP in the incorporated GW treatment by 0.142 Mg CO_2 equivalents per hectare. This trade-off is less than one-tenth of the benefit obtained from GHG reductions resulting from tilling. (In the future, one might till without use of fossil fuel.)

Carbon dioxide emissions from the plots were considered neutral in terms of GWP because the carbon in the GW is non-fossil based, because the CO_2 was previously fixed through photosynthesis.

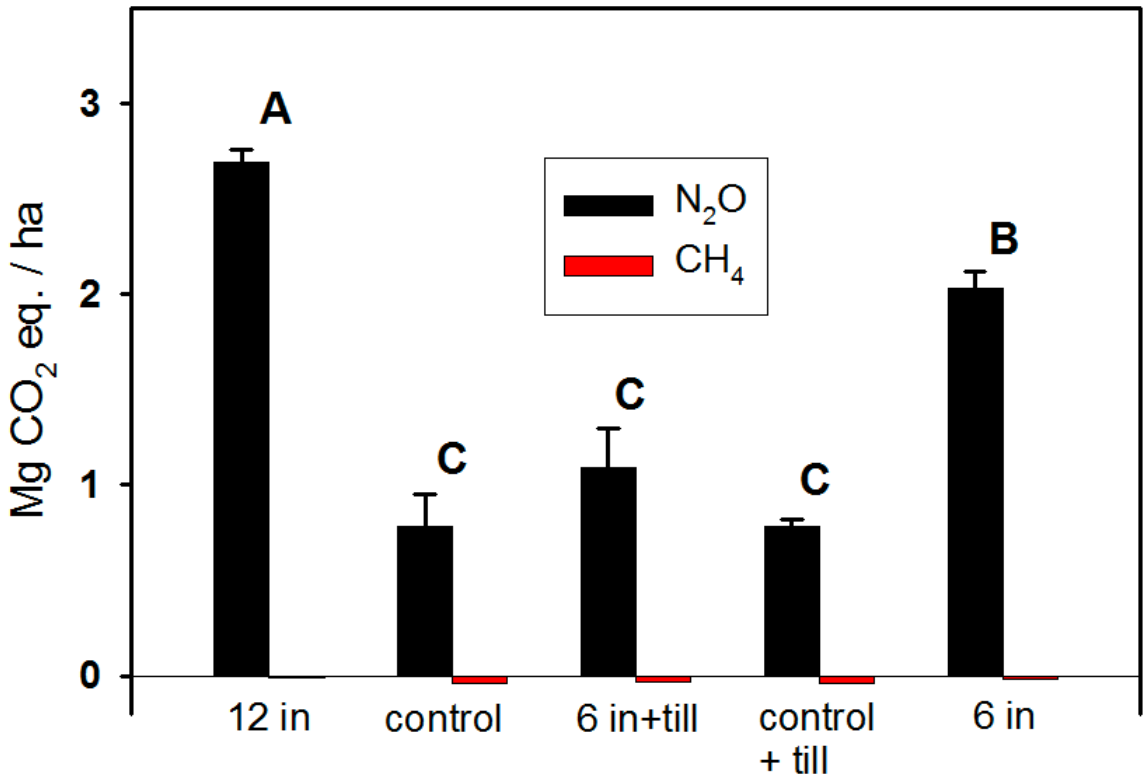

Figure 16. Mean annual GWP of N_2O and CH_4. Mean (n_{piles} = 3) annual emissions of N_2O and CH_4 expressed in CO_2 equivalents in the 30 cm high surface GW application (12 in), untilled control (control), incorporated GW treatment (6 in + till; includes 146 kg CO_2 per ha for fuel use for disking), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments. Standard errors are shown as line bars.

Soil inorganic N

The inorganic N (NH_4^+ and NO_3^-) concentrations in the green waste material fluctuated in the course of the year, with three peaks: in January after the irrigation events, spring/early summer (April/May), and after the irrigation in June (Figures 17 and 18). In general, the NH_4^+ concentrations in the GW material were higher than the NO_3^-

concentrations. Nitrate concentration peaks followed the NH_4^+ peaks without reaching the same magnitude as the NH_4^+ concentrations, except in late summer (August) before the NO_3^- concentrations declined steeply after the September irrigation. In the soil for all the treatments, NH_4^+ concentrations ranged between not detectable and about 10 µg N/g soil, with a small increase occurring in the fall and very low concentrations during summer (Figure 19). Soil NO_3^- concentrations declined from levels of 30-60 µg N/g to <10 µg N/g soil after the irrigation and rainfall events during the winter and increased through the summer before declining again after the last irrigation events (Figure 20). Toward the end of the one-year experiment, soil NO_3^- concentrations tended to be higher underneath the surface GW piles (i.e., in the 30 cm and 15 cm high application treatments).

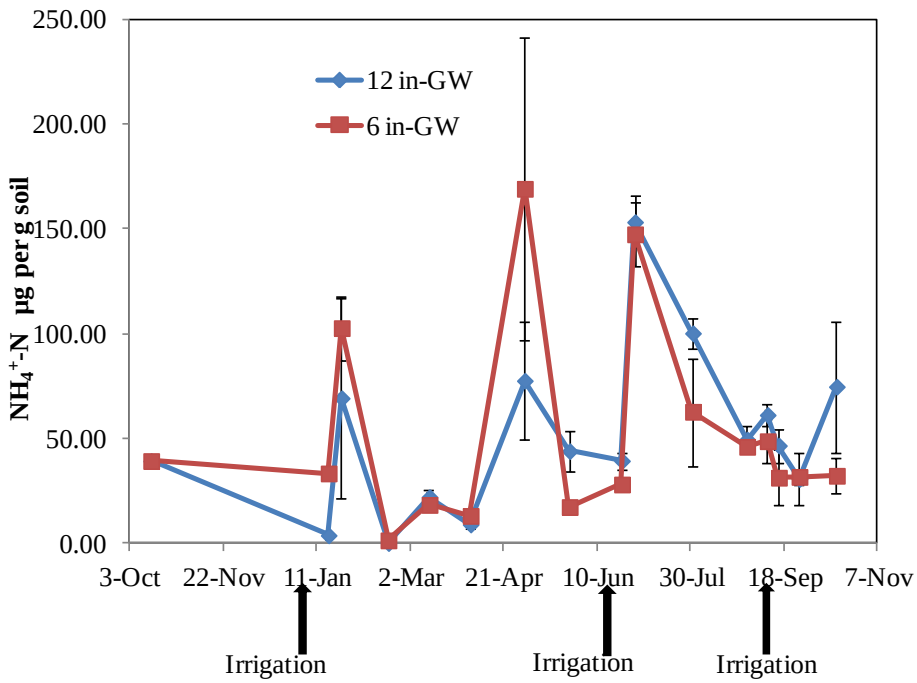

Figure 17. Mean NH_4^+ concentrations in the GW piles during the one-year experiment. Mean (n_{piles} = 3) NH_4^+ concentrations in the 30 cm high GW (12 in GW) and 15 cm high GW (6 in GW) with irrigations in January, June, and early September.

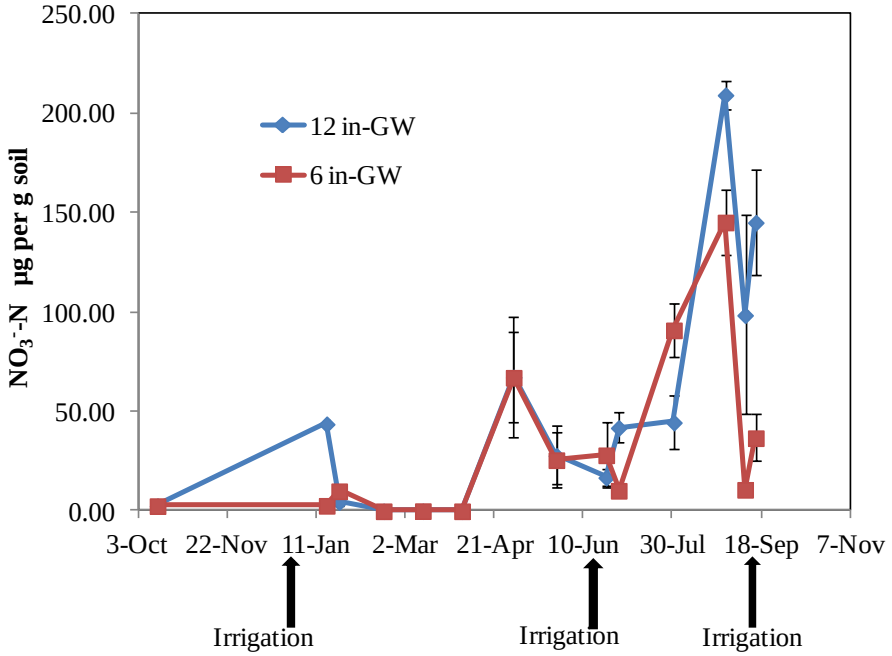

Figure 18. Mean NO_3^- concentrations in the GW piles during the one-year experiment. Mean (n_{piles} = 3) NO_3^- concentrations in the 30 cm high GW (12 in GW) and 15 cm high GW (6 in GW) with irrigations in January, June, and September.

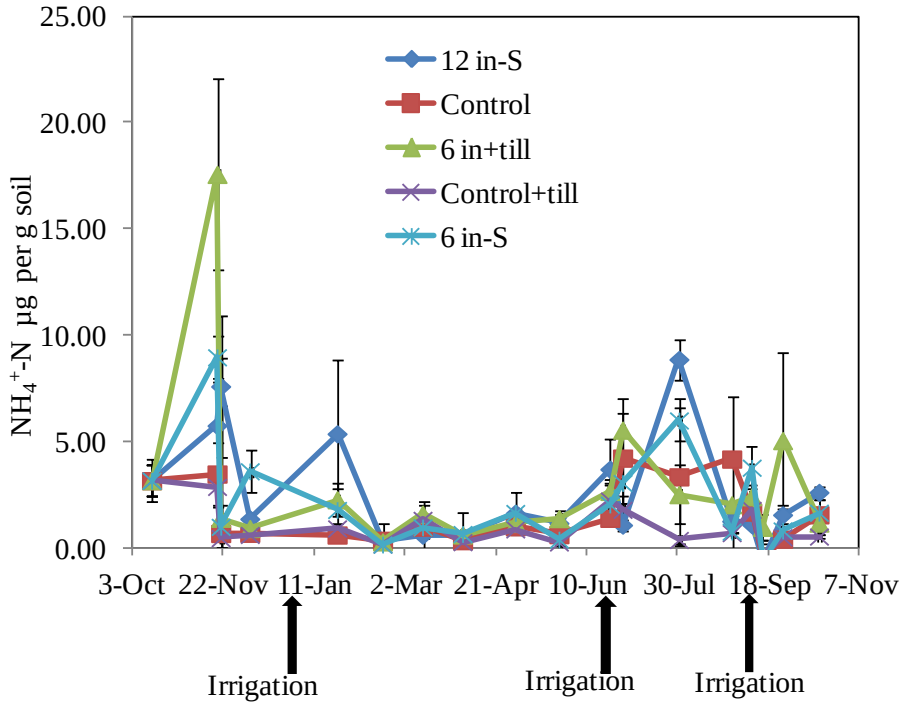

Figure 19. Mean NH_4+ concentrations in the soil during the one-year experiment. Mean NH_4^+ concentrations in the soil of the 30 cm high surface GW application (12 in-S), untilled control (Control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in-S) treatments. Standard errors are shown as line bars.

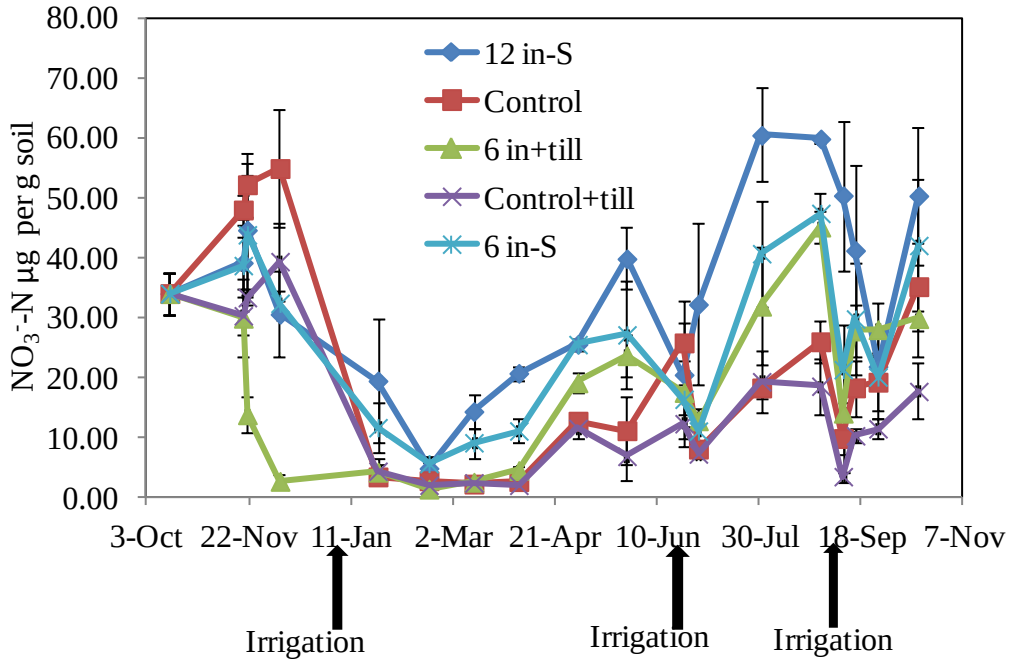

Figure 20. Mean NO_3^- concentrations in the soil during the one-year experiment. Nitrate concentration in the soil of the 30 cm high surface GW application (12 in-S), untilled control (Control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in-S) treatments. Standard errors are shown as line bars.

The concentration of the N substrate for N_2O production was not affected by the GW applications. One reason could be that NO_3^- being produced was leached. However, more NO_3^- leaching from the GW treatments than the control was only evident after the last irrigation in September 2014, when NO_3^- concentrations in the soil solution at 30 cm depth underneath the GW treatments (both surface applied and incorporated) were higher than those in the control treatments (Figures 20 and 23). During this final irrigation almost 100 mm (four inches) of water was applied to the field treatments. This was significantly higher than previous irrigations and rain events (Figure 15). Before the September irrigation, soil NO_3^- levels increased to their highest levels in the soil underneath the surface GW and the incorporated GW treatments and then steeply declined. These data support the soil solution data that indicate nitrate leaching from the GW treatments after significant watering events (both on the surface and incorporated) (Figures 20 and 23).

The concentrations of NH_4^+ and NO_3^- in the GW indicated that this material was a source of inorganic N (Figures 17 and 18), and the fact that NH_4^+ concentrations in the GW piles reached peaks between 100 and 150 µg N/g several times, suggested high rates of mineralization (Figure 17). This mineralization was also evident in the CO_2 emissions data (Figures 11 and 12), the temperature in the 30 cm high GW pile (Figure 7), and much higher release of DOC within the GW piles than in the soil (Figures 21 and 22). The DOC concentrations in the GW material started out at 7600 µg DOC-C/g, then declined to fluctuate between 600 and 450 µg DOC-C/g (Figure 21). In the soil, DOC concentrations fluctuated between 30 and 420 µg DOC-C/g (Figure 22).

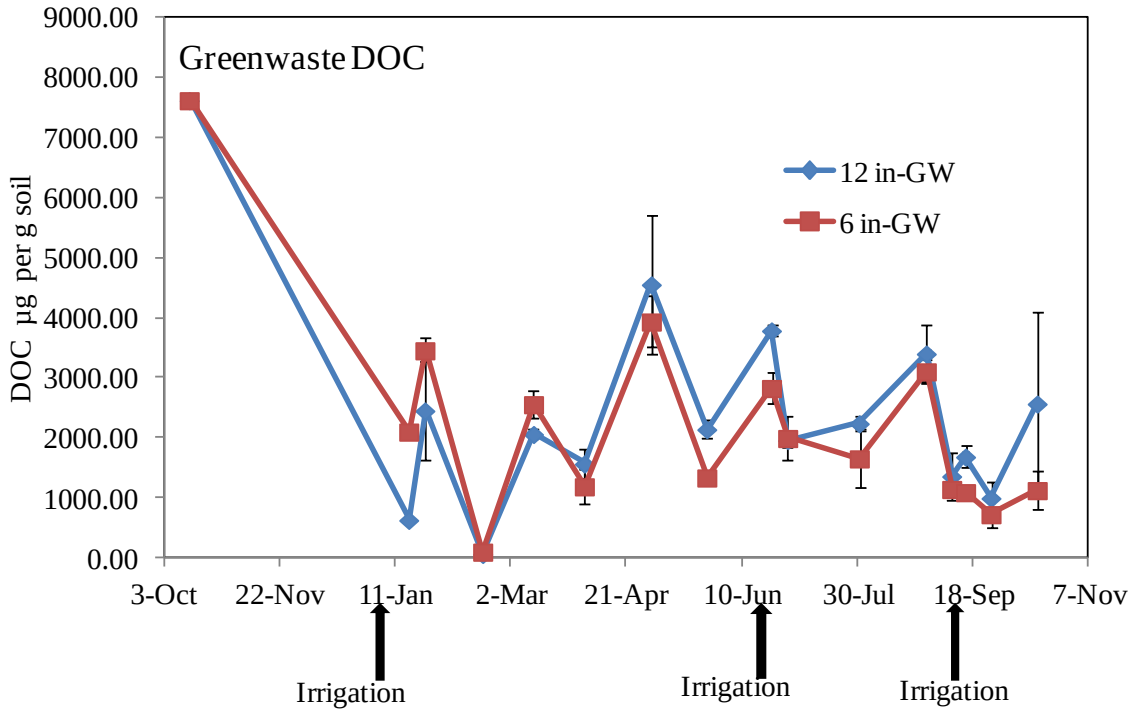

Figure 21. Mean DOC concentrations in the GW piles during the one-year experiment. These concentrations are for the surface-applied 30 cm high (12 in GW) and 15 cm high (6 in GW) GW applications in the field experiment.

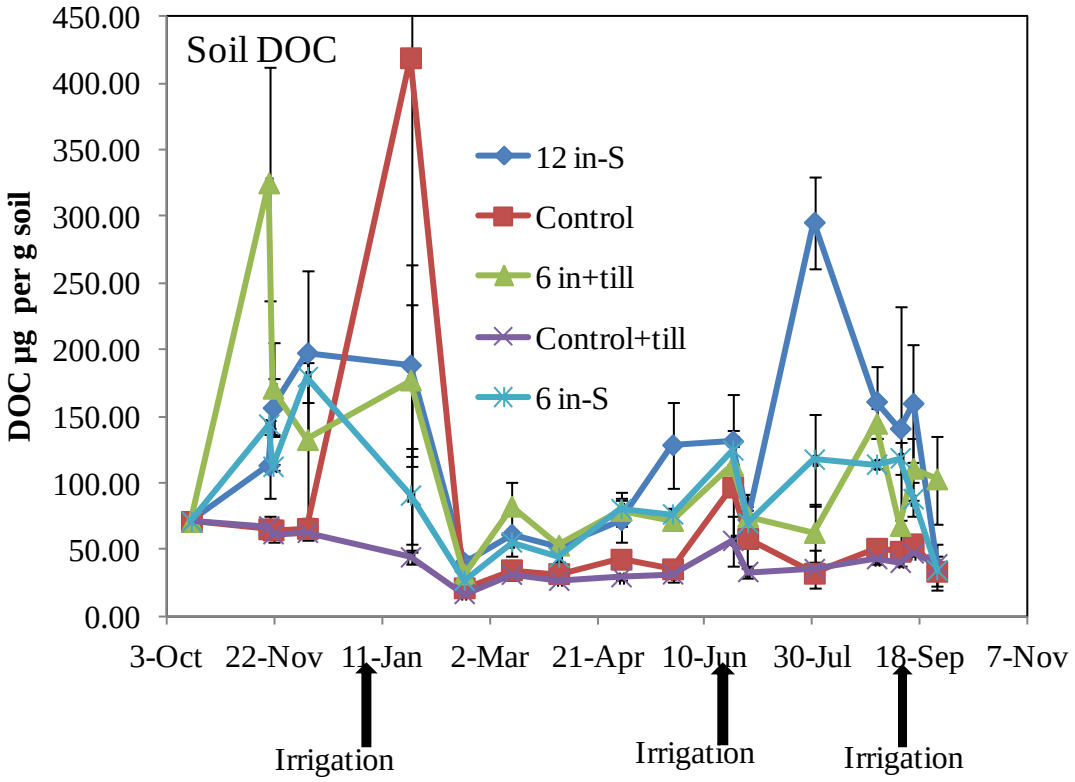

Figure 22. Mean DOC concentrations in the soil during the one-year experiment. These DOC concentrations are for all five of the treatments: the 30 cm high surface GW application (12 in-S), untilled control (Control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in-S) treatments.

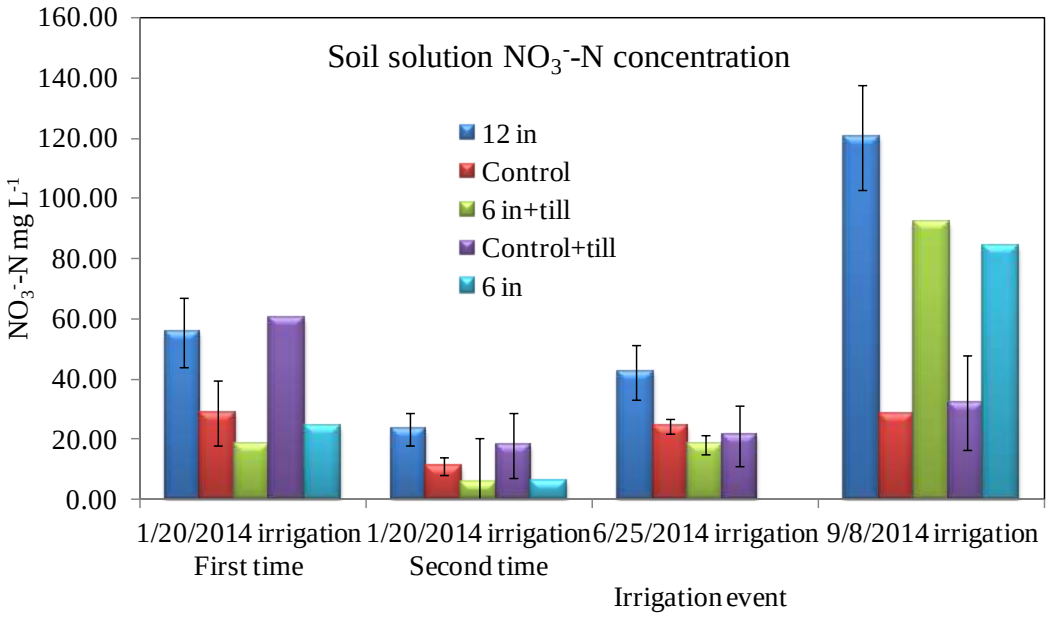

Figure 23. Mean soil solution nitrate concentrations after irrigation. Nitrate concentrations in the soil solution at 30 cm depth after three irrigation events underneath the 30 cm high surface GW application (12 in), untilled control (Control), incorporated GW treatment (6 in + till), the disked control (control + till), and the 15 cm high surface GW application (6 in) treatments.

The incubation experiment is illustrated with seven figures for each of the three types of soil: Figures 24-30 are for silty loam soil, figures 31-37 are for sandy soil, and figures 38-44 are for clay soil.

Within less than three days, the headspace O_2 concentration in the laboratory incubation declined to zero in all but the control silt loam soil at 50 percent of WHC. Within nine hours, practically all the O_2 was consumed in the GW and GW-amended silt loam soils at 100 percent WHC. In the silt loam soil + GW at 50 percent of WHC, the O_2 was completely depleted after 1.2 days, and in the control silt loam soil at 100 percent of WHC, it was completely depleted after 2.7 days (Figure 24). In the control soil at 50 percent WHC, the O_2 did not get depleted most likely because the carbon—relatively limited in the soil alone—was not as accessible to microbes as in the soil at 100 percent WHC, and because O_2 from the headspace of the vials replenished the O_2 that was consumed in the soil. In the incorporated green waste treatments at 50 percent WHC, either the consumption of carbon compounds by microbes must have kept O_2 levels depleted or all the O_2 in the vials was consumed, because of the carbon (GW) addition. We did not measure O_2 concentrations in the headspace. The O_2 dynamics were similar in all three soils although the timing to complete depletion differed somewhat among the soil types.

The N_2O concentration in the headspace of the vials increased sharply in the GW at 100 percent and 50 percent of WHC, and within one day declined to zero (Figure 25). A

similar dynamic was observed in the silt loam soil + GW at 100 percent and 50 percent of WHC, but the peak concentration in silt loam soil + GW at 100 percent of WHC was one percent of the peak N_2O concentration in the green waste at 100 percent of WHC, and even lower in the silt loam soil + GW at 50 percent of WHC. In the silt loam soil at 100 percent of WHC, N_2O was found in the headspace until day 15.

Silt loam soil incubations

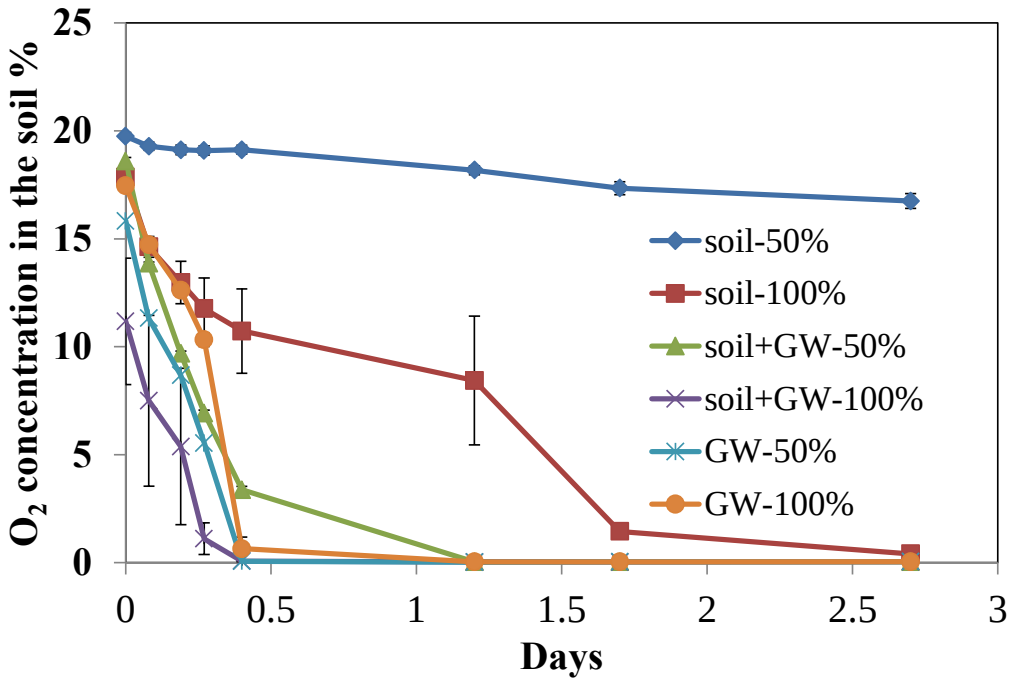

Figure 24. Mean O_2 concentration over time in closed vials in the silty loam soil. Mean O_2 concentration over time in closed vials in the silt loam control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), the GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and in GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC. With limited organic content and unsaturated conditions, oxygen was not completely depleted in the soil-50% vials.

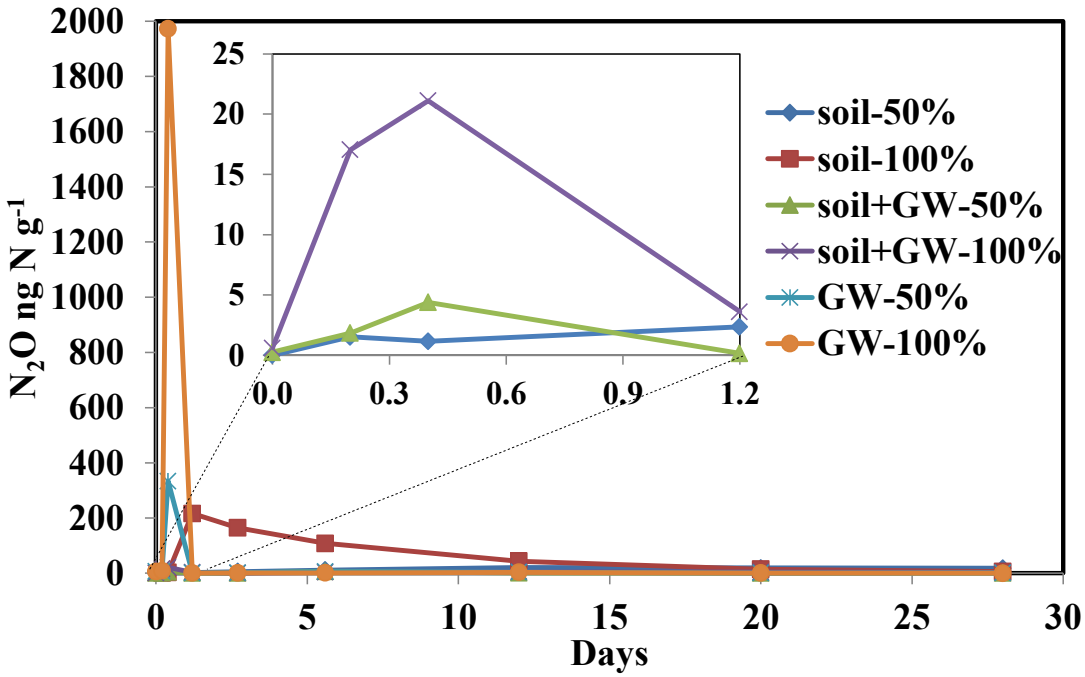

Figure 25. Dynamics of N_2O concentration in the headspace of the incubation vials over time for the silty loam soil. The treatments were silt loam control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

The rapid depletion of O_2 in the soil led to the consumption of the previously produced N_2O and very likely the production of dinitrogen (N_2) (Figures 25, 32, 39) because NO_3^- concentrations declined to zero in all the GW treatments (Figures 29, 36, and 47). Interestingly, mineralization of organic matter and NH_4 production continued under the anaerobic conditions, especially in the GW only treatments (Figures 28, 35, and 42). Mineralization of GW organic matter under anaerobic conditions was also evident from the increasing DOC concentration in GW (Figures 30, 37, and 48). In contrast, in the soil treatments, DOC did not increase (Figures 30, 37, and 48). Increasing DOC concentrations have also been observed after incorporation of crop residues in submerged, anaerobic soil (Ye *et al.*, 2015). Responses in the different soil types were similar, most likely due to the overwhelming effect of the GW on O_2 dynamics in the microcosms. The lab incubations demonstrated the effects of GW as a carbon source in depleting O_2 and stimulating N_2O production. However, in contrast to the microcosms, the GW treatments in the field were exposed to the atmosphere. Replenishment of O_2 from the atmosphere prevented even higher N_2O emissions, while some N_2 have been released in the field during short periods.

Carbon dioxide was produced in the GW treatments, and to a lesser degree in the GW amended treatments, but not in the control soils (Figure 26 for silt loam, Figure 33 for sandy soil, Figure 40 for clay soil). Methane was produced in all the GW and GW + soil

treatments and remained in the headspace for the entire 30 days of the incubation (Figures 27, 34, and 41).

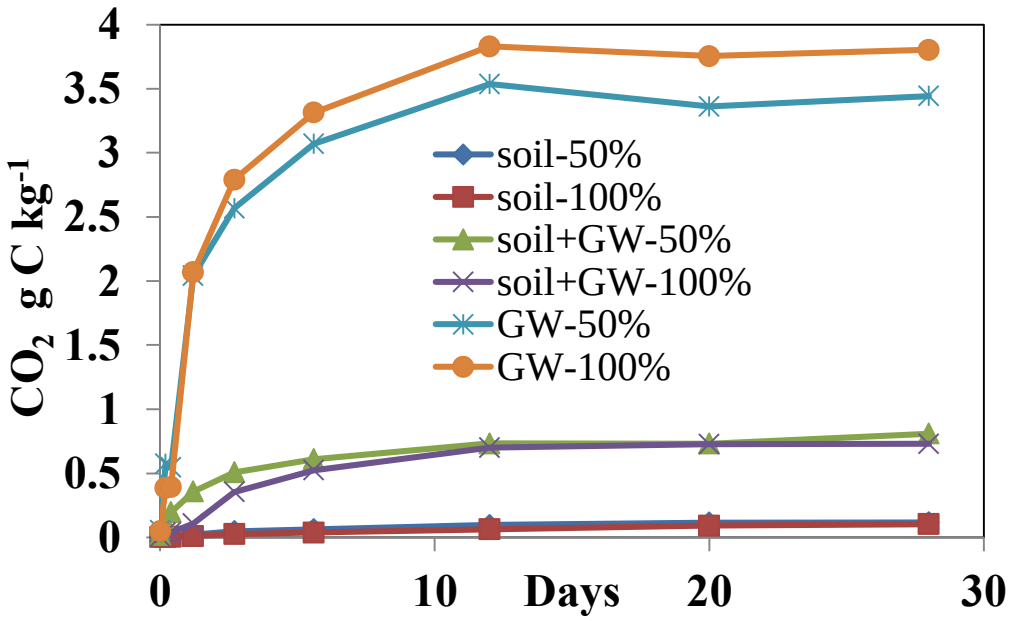

Figure 26. Dynamics of CO_2 concentration in the headspace of the incubation vials over time for the silty loam soil. The treatments were silt loam control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

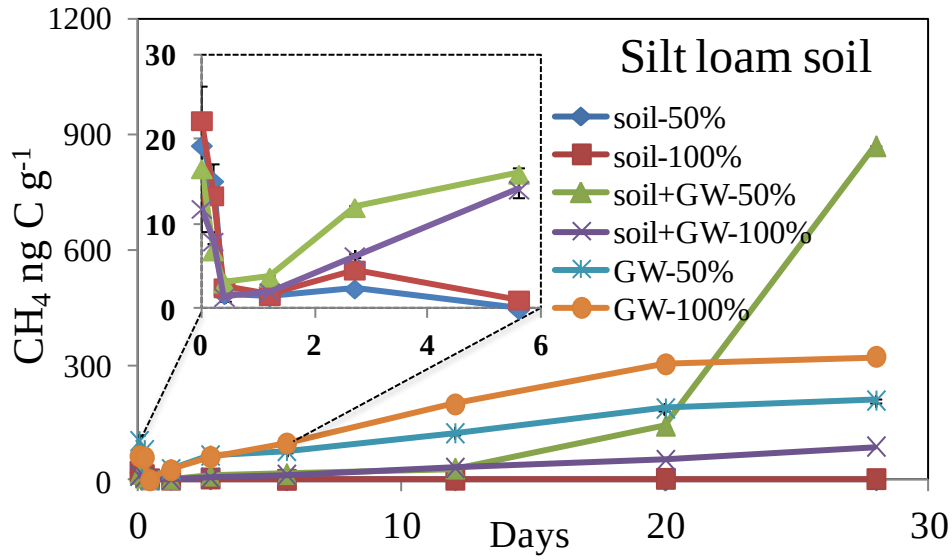

Figure 27. Dynamics of CH_4 concentration in the headspace of the incubation vials over time for the silty loam soil. The treatments were silt loam control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

During the 30-day incubation, NH_4^+ concentrations increased in the GW treatments and in the soil + GW treatment at 50 percent of WHC (Figures 28, 35, and 42). The NO_3^- concentrations declined to zero in the GW treatments and in the soil + GW treatments at 100 percent of WHC (Figures 29, 36, and 43).

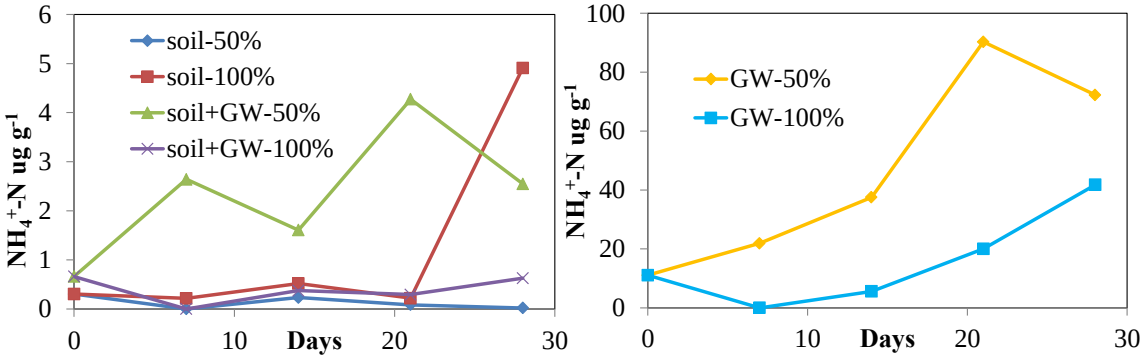

Figure 28. Dynamics of NH_4^+ concentration for the silty loam soil. Dynamics of NH_4^+ concentration in the silt loam control soils and GW-amended soils. The treatments were (in the left panel) soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and (in the right panel) GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

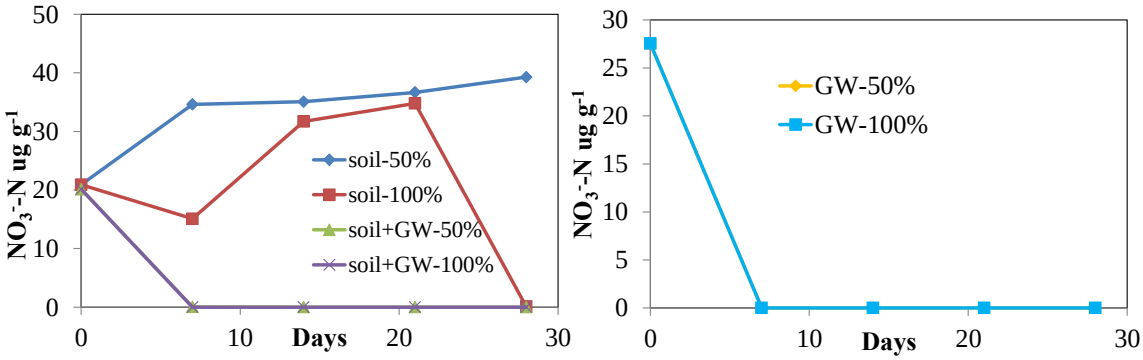

Figure 29. Dynamics of NO_3^- concentration for the silty loam soil. Dynamics of NO_3^- concentration in the silt loam control soils and GW-amended soils. The treatments were (in the left panel) soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and (in the right panel) GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

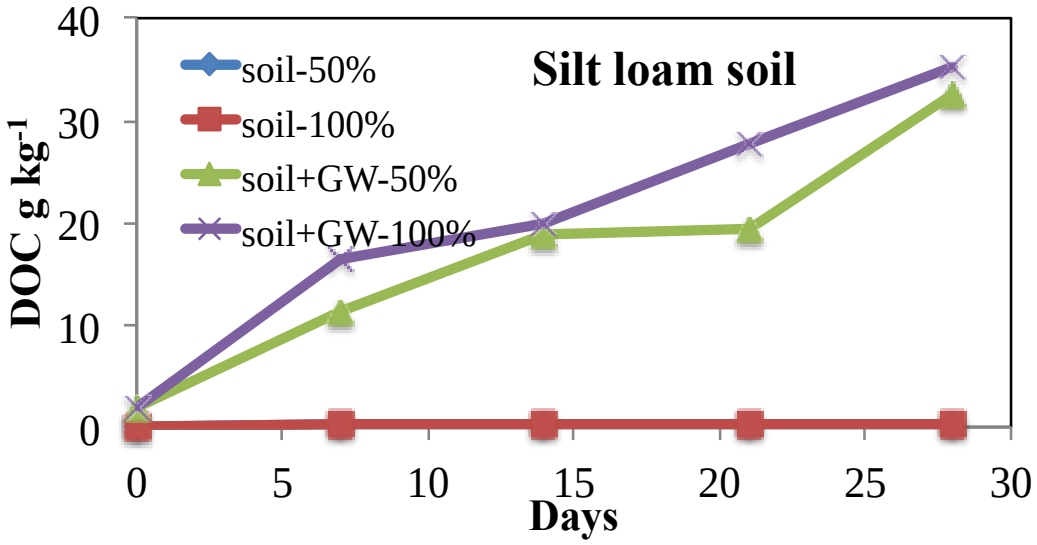

Figure 30. Dynamics of DOC concentrations for the silty loam soil. Dynamics of DOC concentrations in the silt loam control soils and GW-amended soils. The treatments were soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), and GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%).

Sandy soil incubations

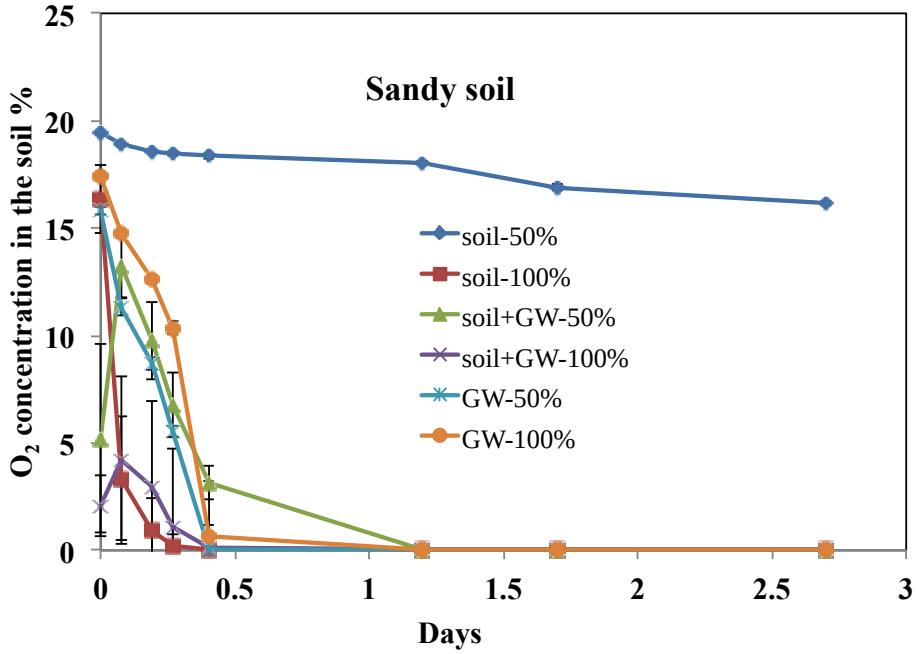

Figure 31. Mean O_2 concentration over time in closed vials for the sandy soil. Mean O_2 concentration over time in closed vials in the sandy control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), the GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and in GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC. With limited organic content, and unsaturated conditions, oxygen was not completely depleted in the soil-50% vials.

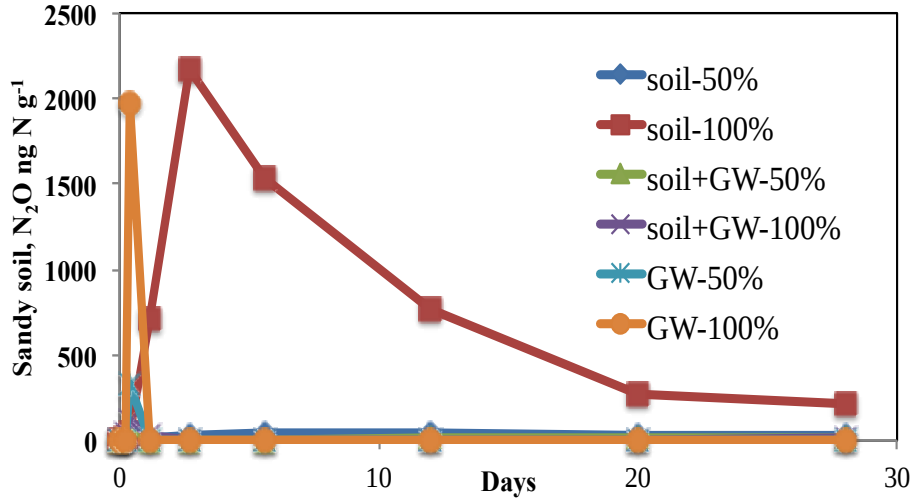

Figure 32. Dynamics of N_2O concentration for the sandy soil. Dynamics of N_2O concentration in the headspace of the incubation vials over time. The treatments were sandy control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

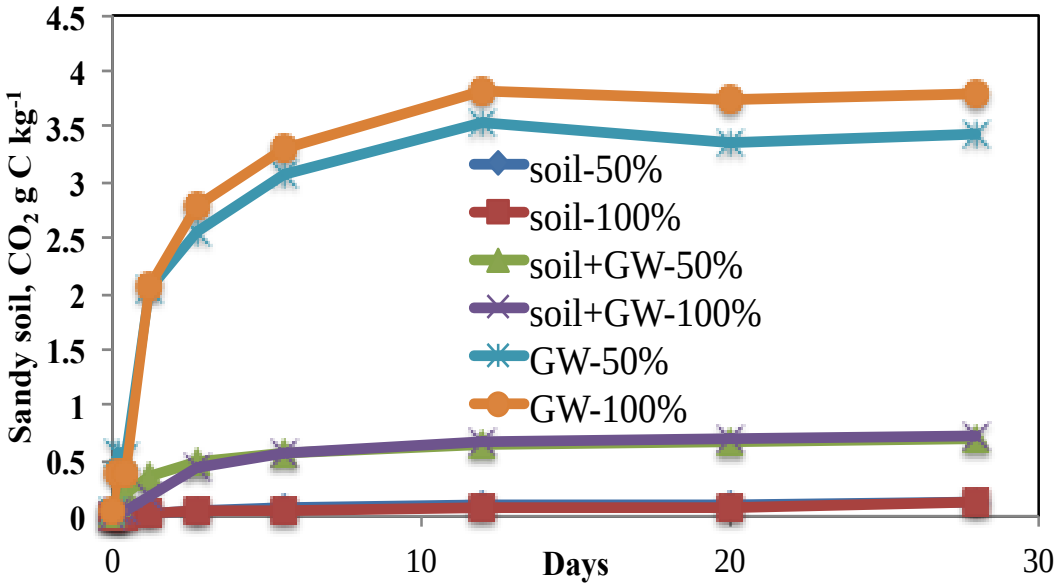

Figure 33, Dynamics of CO_2 concentration for the sandy soil. Dynamics of CO_2 concentration in the headspace of the incubation vials over time. The treatments were sandy control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

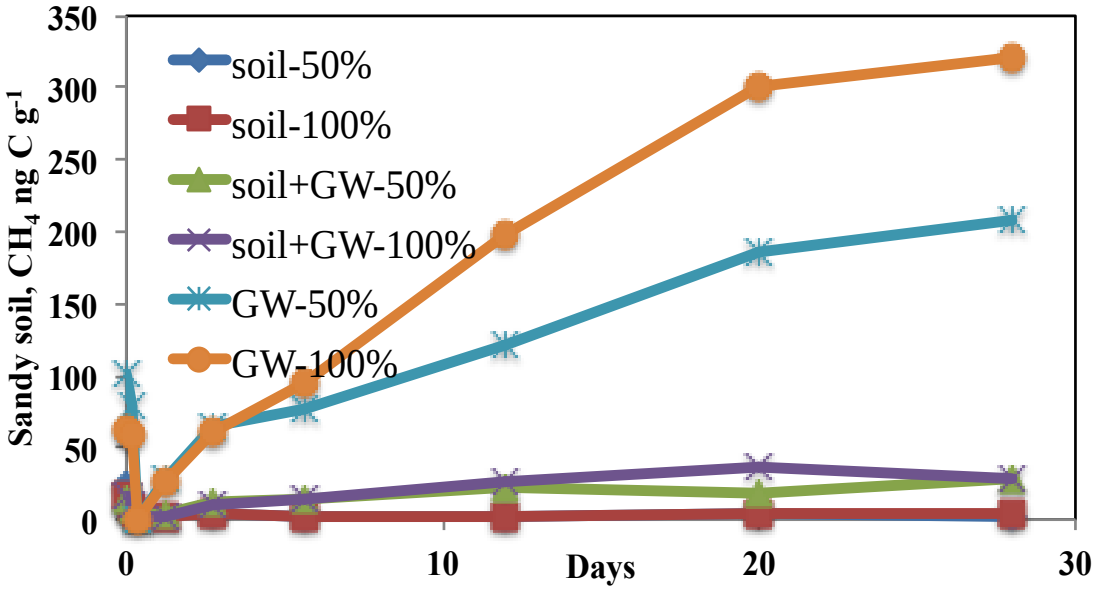

Figure 34. Dynamics of CH_4 concentration for the sandy soil. Dynamics of CH_4 concentration in the headspace of the incubation vials over time. The treatments were sandy control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

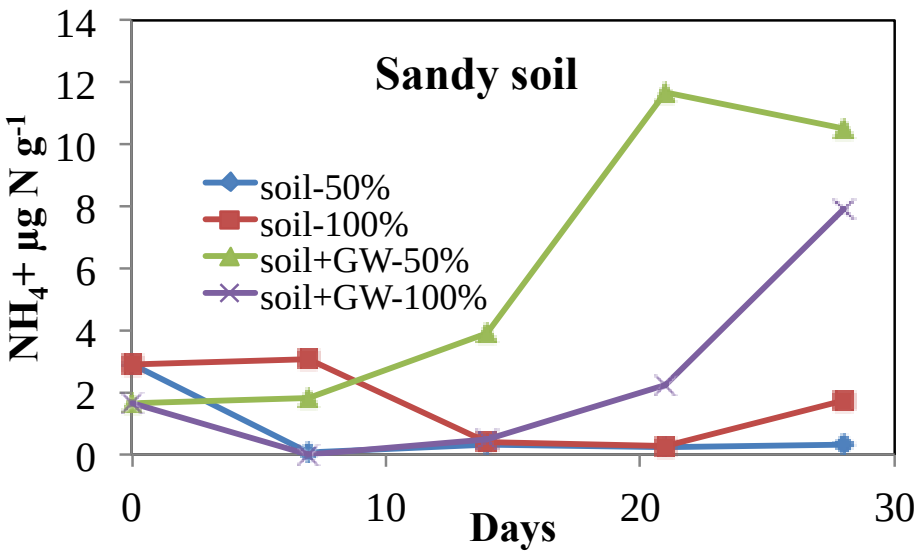

Figure 35. Dynamics of NH_4^+ concentration for the sandy soil. Dynamics of NH_4^+ concentration in the sandy control soils and GW-amended soils. The treatments were soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), and GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%).

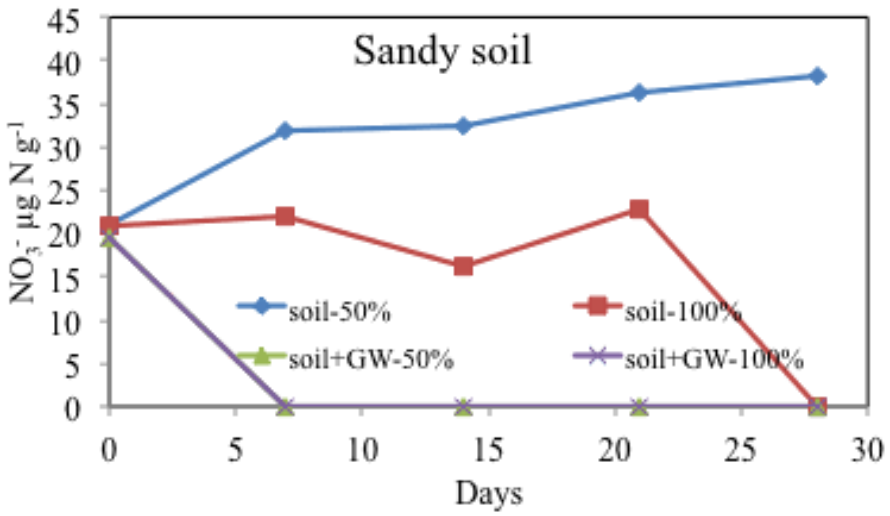

Figure 36. Dynamics of NO_3^- concentration for the sandy soil. Dynamics of NO_3^- concentration in the sandy control soils and GW-amended soils. The treatments were soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), and GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%).

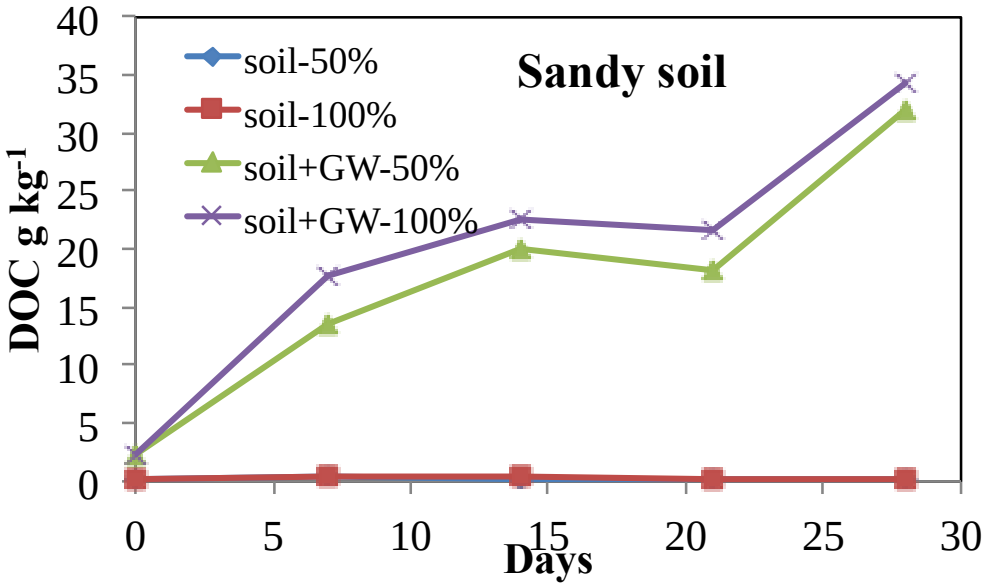

Figure 37. Dynamics of DOC concentration for the sandy soil. Dynamics of DOC concentration in the sandy control soils and GW-amended soils. The treatments were soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), and GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%).

Clay soil incubations

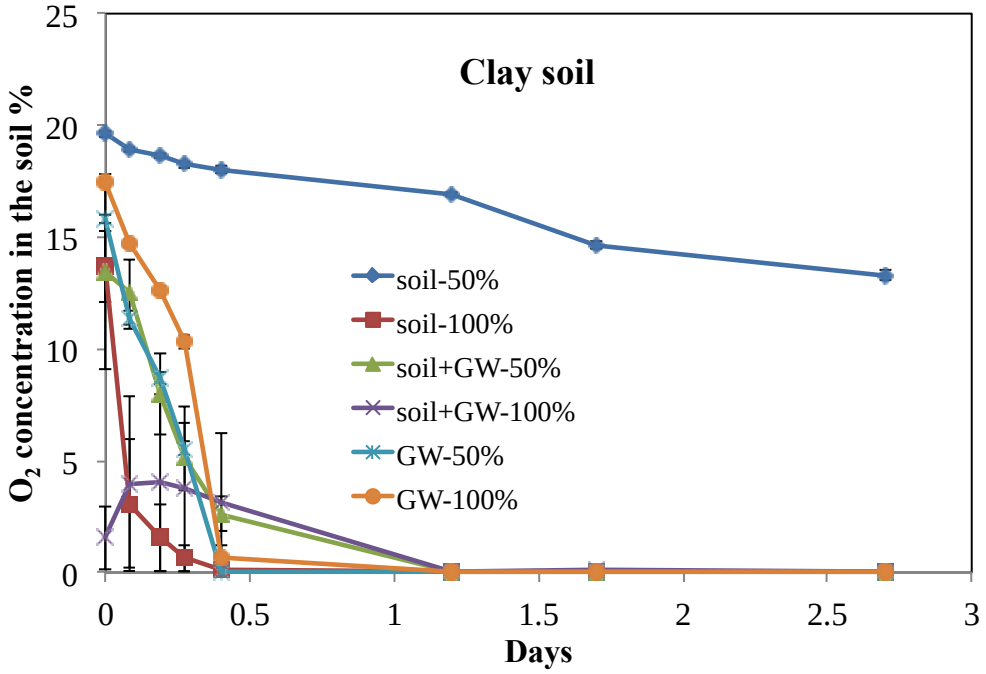

Figure 38. Mean O_2 concentration for the clay soil. Mean O_2 concentration over time in closed vials in the clay control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%),

the GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and in GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC. With limited organic content, and unsaturated conditions, oxygen was not completely depleted in the soil-50% vials.

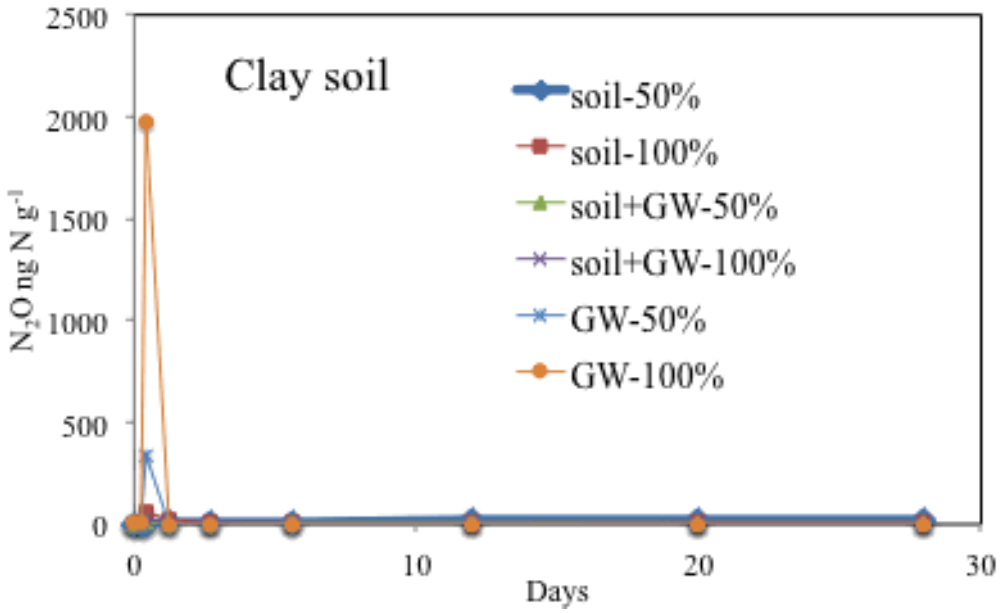

Figure 39. Dynamics of N_2O concentration for the clay soil. Dynamics of N_2O concentration in the headspace of the incubation vials over time. The treatments were clay control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

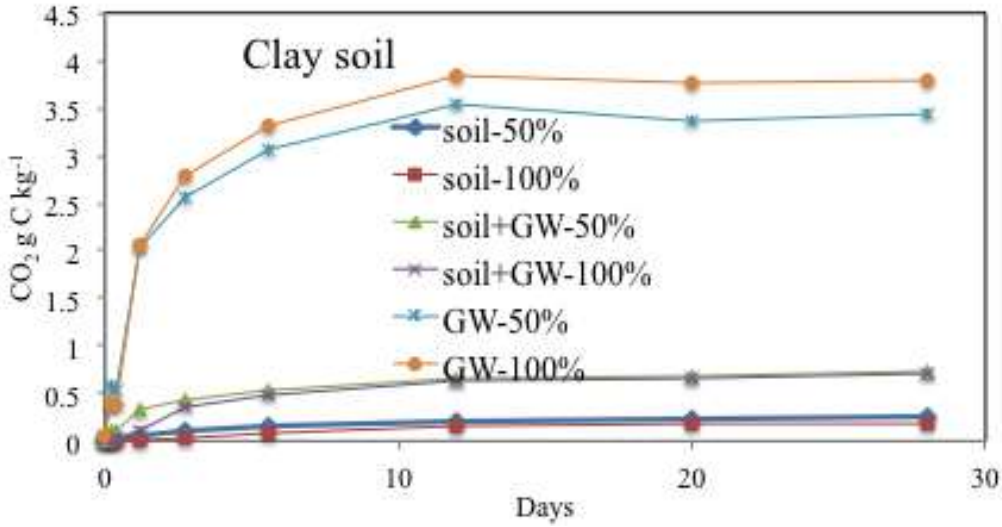

Figure 40. Dynamics of CO_2 concentration for the clay soil. Dynamics of CO_2 concentration in the headspace of the incubation vials over time. The treatments were clay control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

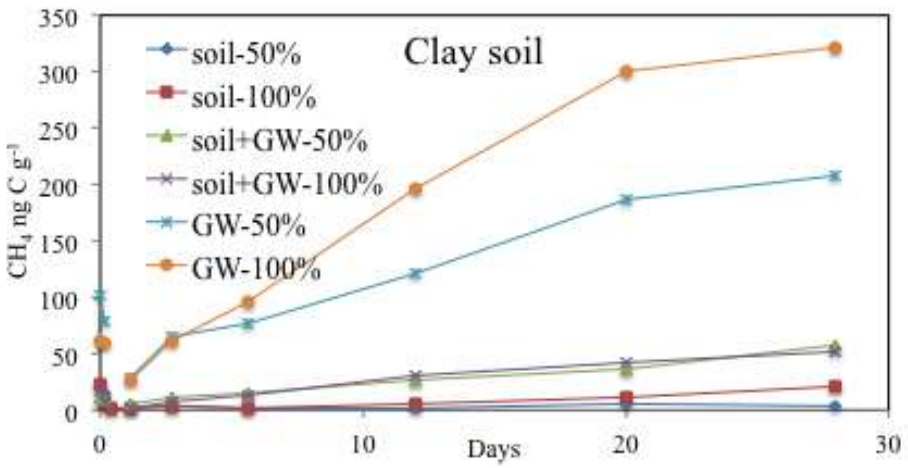

Figure 41. Dynamics of CH_4 concentration for the clay soil. Dynamics of CH_4 concentration in the headspace of the incubation vials over time. The treatments were clay control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

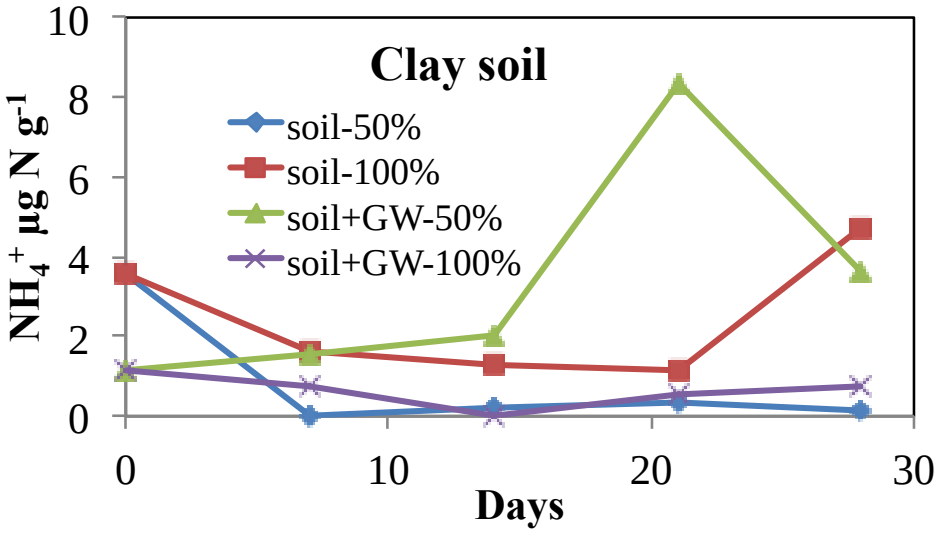

Figure 42. Dynamics of NH_4^+ concentration for the clay soil. Dynamics of NH_4^+ concentration in the clay control soils and GW-amended soils. The treatments were soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), and GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%).

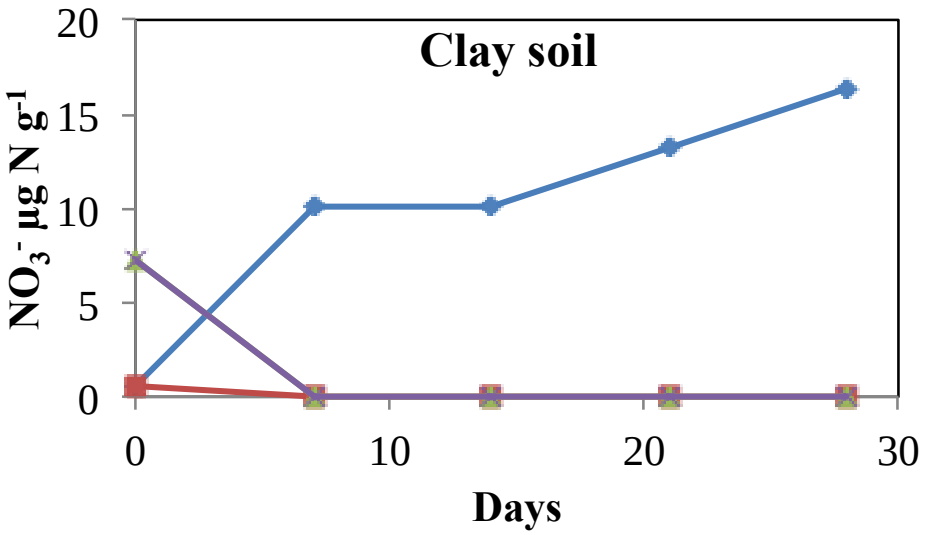

Figure 43. Dynamics of NO_3^- concentration for the clay soil. Dynamics of NO_3^- concentration in the clay control soils and GW-amended soils. The treatments were soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), and GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%).

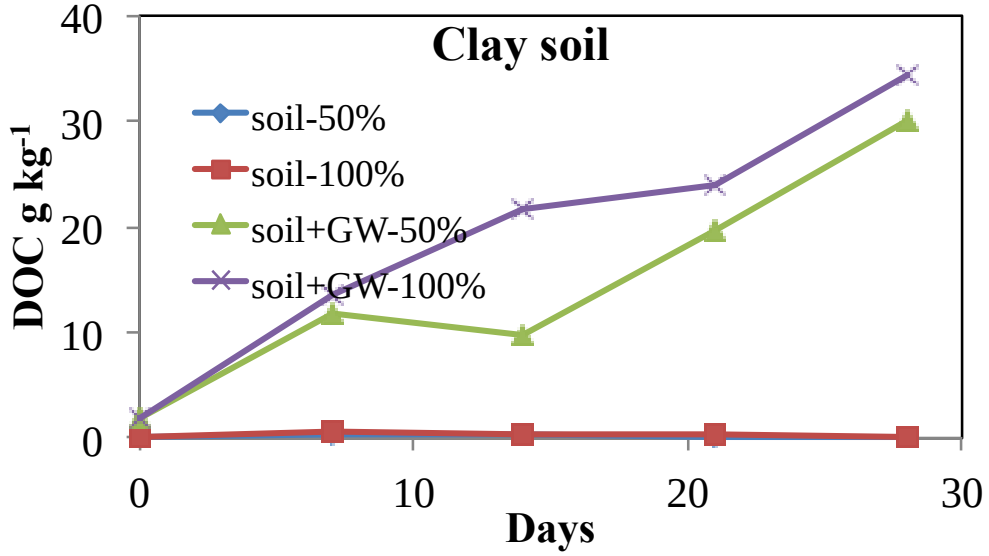

Figure 44. Dynamics of DOC concentration for the clay soil. Dynamics of DOC concentration in the clay control soils and GW-amended soils. The treatments were soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), and GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%).

Part Two: Other Chemical Constituents from Direct Land Application in the Field and from Green Materials Representative of Statewide Sources

To further characterize possible environmental impacts, additional emissions were collected and characterized. From lysimeters, soil solution was collected and analyzed for N-nutrients (described in Part One), metals (both trace heavy metals and major constituents), and pesticides.

In order to provide comparison to statewide sources of GW, a total of seven GW samples were collected (five from Southern California), including the one used in the field study, and characterized for the following: density, moisture content, total C and total N (for C:N ratio), bacteria, metals, and pesticides.

Materials and Methods

We employed standard methodology for collection, extraction, and analysis of samples for characterizing statewide GW and for soil water (soil solution) in the field study.

GW Characterization Methodology

The seven statewide GW samples were collected twice, in autumn 2013 and in spring 2014, with clean plastic zipped bags and shipped in picnic coolers overnight with frozen ice packs. Five of these samples came from Southern California chip and grind facilities, one from the Central Valley, and one from the facility that supplied the GW for the field study. Fresh material for the spring sampling was collected from there again. They were characterized using several of the standard methods from the Test Methods for the Examination of Composting and Compost (TMECC; http://compostingcouncil.org/tmecc/) produced by the U.S. Composting Council. Density was measured by displacement. Bacteria (E. coli, all strains and the Salmonella genus) were measured by TMECC methods 7.01-C and 4.02-A, respectively. Nitrogen was determined by TMECC method 4.02-D. Carbon was measured by TMECC method 4.01. Moisture was determined by TMECC method 3.09. Metals were extracted using TMECC methods 4.12-B and 4.14-A, followed by ICP analysis using EPA methods 3050B and 6010.

Soil Water Methodology

Thirty-six-inch Soil Solution Access Tube (SSAT, Irrometer, Riverside, CA) lysimeters were placed vertically in a hole prepared with a Veihmeyer probe and sealed with fine, field surface soil slurry. The lysimeter access cup was placed 30 cm (12 inches) below the original soil surface level.

Following extraction into hexane, pesticides were identified and quantified using an Agilent (Palo Alto, Calif.) 6890 GC equipped with a J&W DB-5MS capillary column (30

m × 0.25 mm ID, 0.25 μm film thickness) and an Agilent 5793 mass spectrometer (MSD), which was operated in electron ionization (EI, 70 eV) and selected ion monitoring (SIM) mode. The injector temperatures was 290°C. The oven temperature was programmed to start at 50°C with a one-minute hold time and increased to 100°C at 25°C/min, 300°C at 5°C/min, with five minutes of final holding time.

Results

GW Characterization

The GW samples collected from around the state showed, in general, similar overall composition. For some parameters, the change from autumn to spring sampling was similar among nearly all the samples. For other characteristics, individual sources were unique.

Density

Density (Figure 45) ranged from 0.2 to 0.4 g/mL, and was generally more similar within a facility's two seasonal samples than between facilities. Sample 7, which was used for the field study, is near the middle of the range observed, suggesting it is relatively representative of GW statewide.

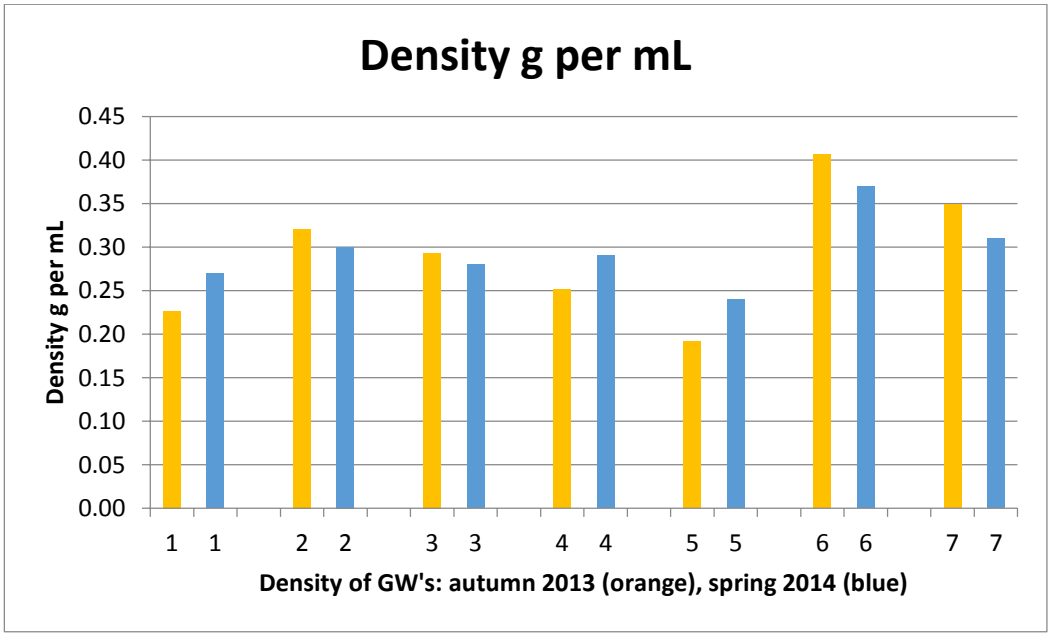

Figure 45. Density of GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7, in the autumn, was used for the field study.

Bacteria

Salmonella was never detected in the GW samples (nor in the soil solution). In the fresh GW, E. coli was detected in nearly all samples (Figure 46). After time, and distance travelled to 30 cm below the surface, only total coliform (a broader category) could be found in the soil solution (Figure 47). The GW used for the field study had the fewest E. coli, based on the average of autumn and spring samples; all the others had one or two samples with more than the 1000 MPN/g DW (most probable number per gram of dry weight) standard (EPA 2002).

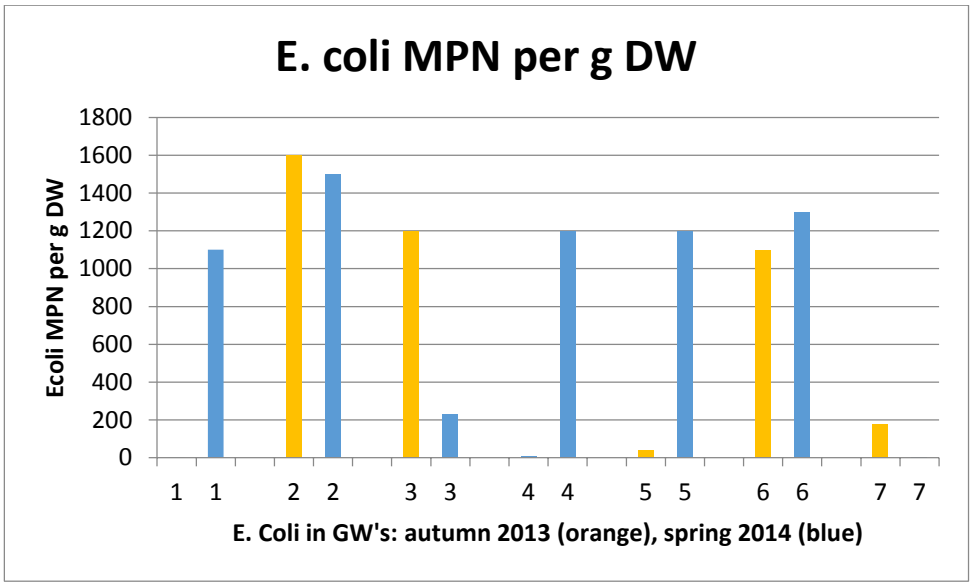

Figure 46. E. coli measured in the GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7 (autumn 2013) was used for the field study.

Soil Solution Characterization

For the water from the lysimeters (soil solution), E. coli was not detectable.

However, total coliform were measurable in several of the soil solutions, but without an apparent trend that might have been related to the overlying GW material.

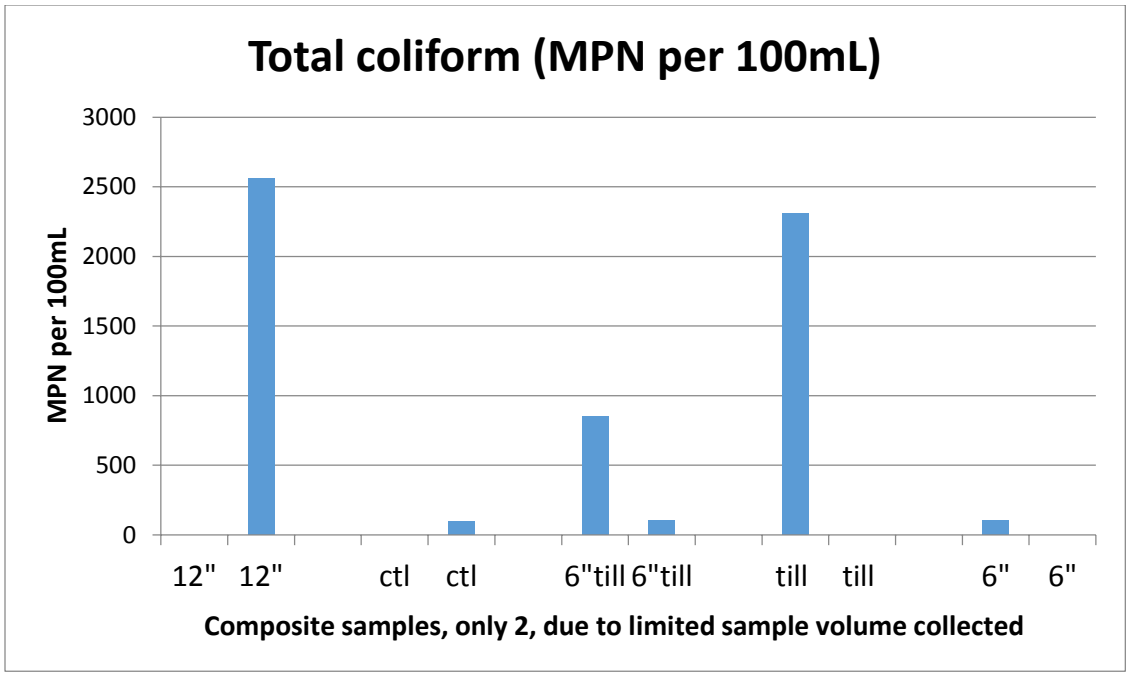

Figure 47. Total coliform in soil solution water using composite samples.

When plotted (Figure 48) as a function of GW thickness, a regression shows the slope is both low and of no statistical significance (P = 0.6).

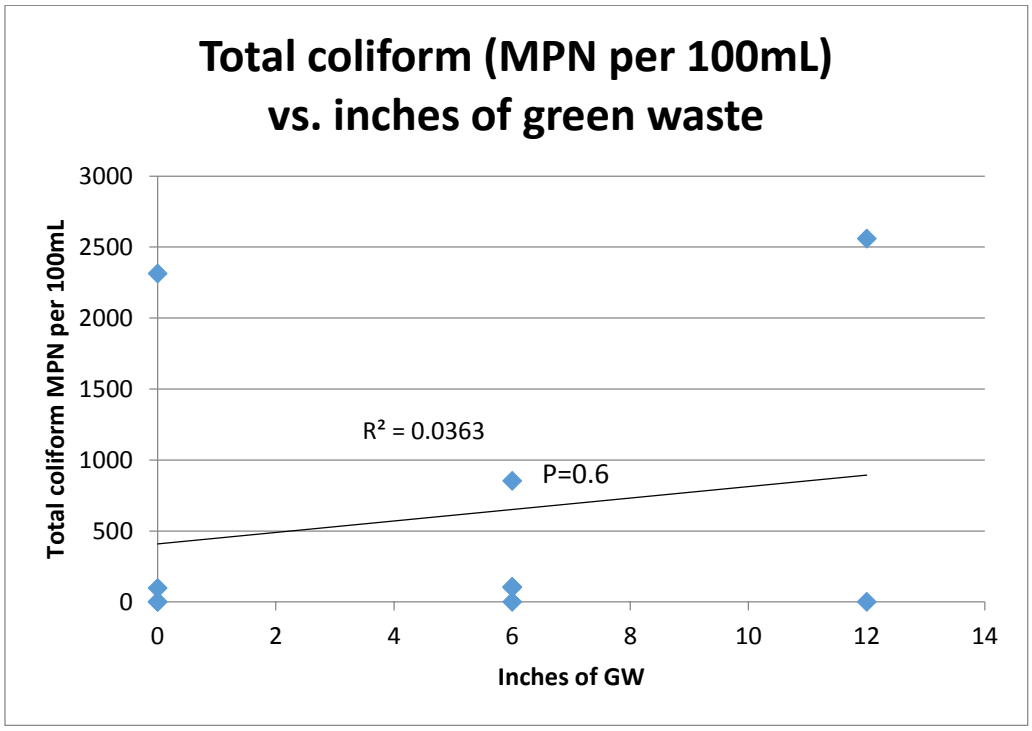

Figure 48. Total coliform in soil solution water. Plotted as a function of GW thickness above each lysimeter location.

As observed for density, the C:N ratio (Figure 49) was generally more similar from the same source than similar during seasons statewide. The source used for the field study was near the middle of the range observed, which was from 20 to 56.

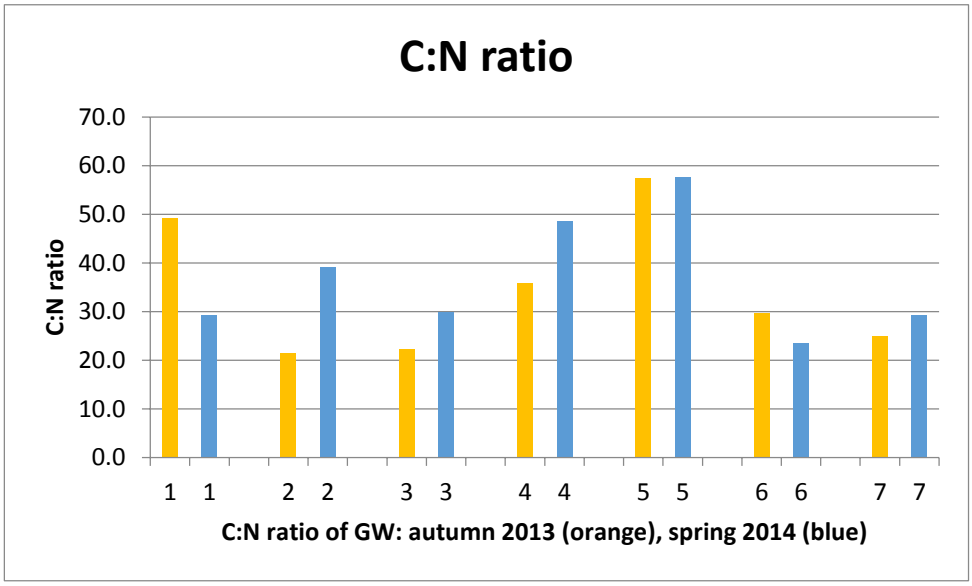

Figure 49. Ratio of carbon to nitrogen in the GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7 (autumn 2013) was used for the field study.

Metals

The GW samples, as well as the soil solution samples from the lysimeters, were analyzed for a wide range of metals and semi-metals, including those of potential environmental concern at trace levels and minor and major constituents. The complete list of elements was: arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, cobalt, lithium, beryllium, sodium, magnesium, aluminum, potassium, calcium, vanadium, manganese, iron, rubidium, strontium, silver, cesium, barium, thallium, uranium, and phosphorus. Several of these were not detectable, namely cadmium, selenium, mercury, silver, cesium and thallium.

Of high concern (particularly for human health) in recent years has been arsenic, which was detected in all samples (Figure 50). The concentrations in GW ranged from 1 to 7 mg/kg DW, with the source for the field study having 3.5 mg/kg at the time of delivery in the autumn. Interestingly, all but one of the seven sources showed higher concentrations in the autumn samples (ranging from 1 to 4 mg/kg) than in the spring samples (which ranged from 3 to 7 mg/kg). However, based on statewide surveys of subsurface, uncontaminated soils, a mean of 3.5 mg/kg (with a range of 0.6 to 11 mg/kg) existed for 50 California soils (Kearney, 1996). So, these samples, and the one used for the field study, were not unusually high.

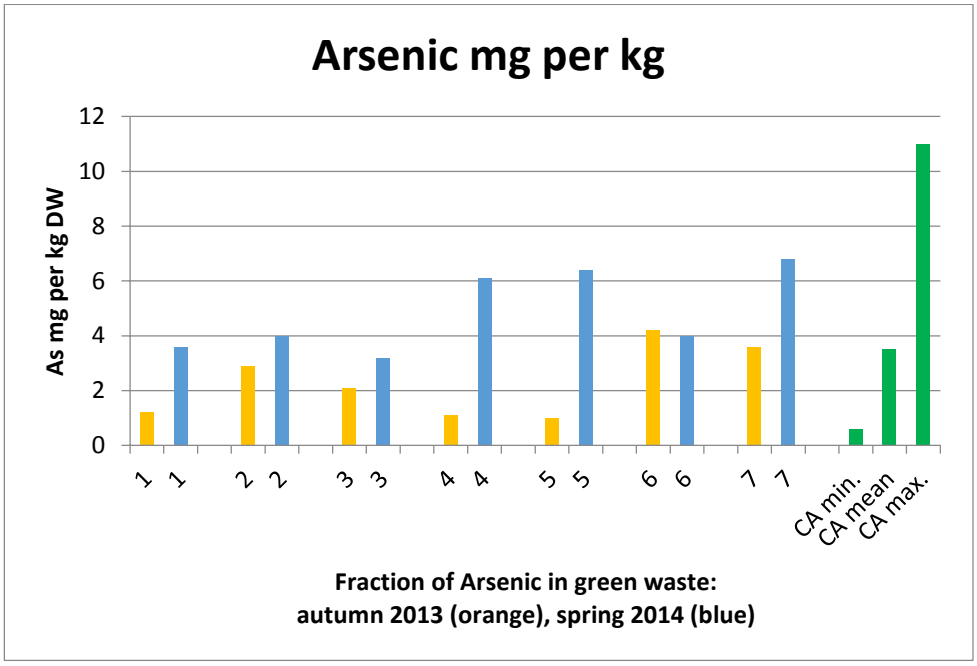

Figure 50. Fraction of arsenic in the GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7 (autumn 2013) was used for the field study. Minimum, mean, and maximum for 50 California soils are shown at the right side of the graph.

An element of considerable concern for aquatic life, and heavily used in agriculture, is copper, which was detected in all the samples (Figure 51). The concentrations in GW ranged from 15 to 100 mg/kg dry weight, with the source for the field study having 42

mg/kg at the time of delivery in the autumn. In contrast to the trend seen with arsenic, four of the seven sources showed higher concentrations in the spring samples (ranging from 35 to 100 mg/kg) than in the autumn samples (which ranged from 15 to 60 mg/kg). However, based on statewide surveys of subsurface, uncontaminated soils, a mean of 29 mg/kg (with a range of 9 to 96 mg/kg) existed in 50 California soils (Kearney, 1996). So, these samples, and the one used for the field study, were not unusually high for California soils.

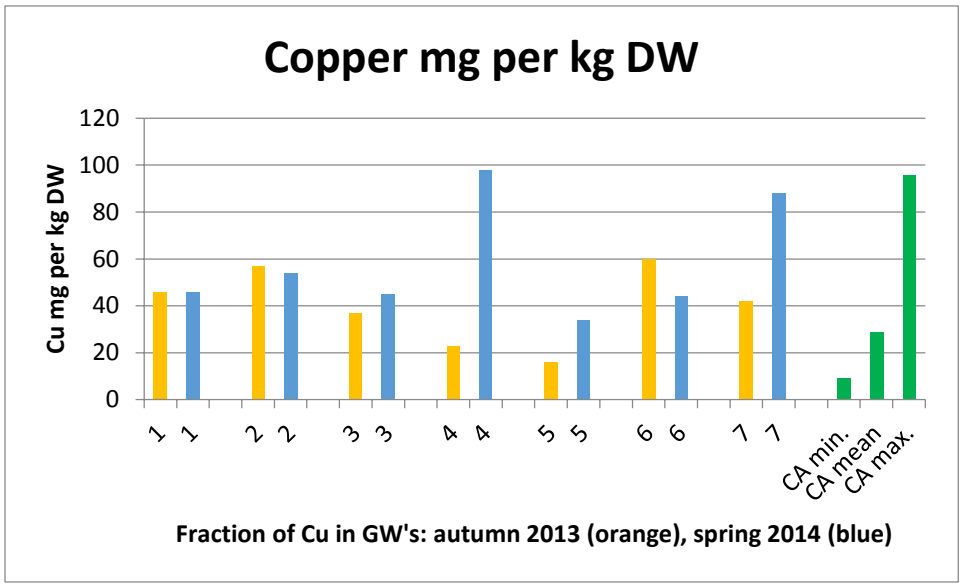

Figure 51. Fraction of copper in the GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7 (autumn 2013) was used for the field study. Minimum, mean, and maximum for 50 California soils are shown at the right side of the graph.

The heavy metal lead (Pb) is another element that was detected in every sample (Figure 52). The concentrations in GW ranged from 4 to 66 mg/kg dry weight, with the source for the field study having 25 mg/kg at the time of delivery in the autumn. In contrast to the trends seen with arsenic and copper, the autumn-to-spring comparison was mixed: Three of the seven sources showed higher concentrations in the autumn samples (ranging from 4 to 66 mg/kg), and three were higher in the spring samples (which ranged from 4 to 27 mg/kg), while one was roughly the same. However, based on statewide surveys of subsurface, uncontaminated soils, a mean of 24 mg/kg (with a range of 12 to 97 mg/kg) existed in 50 California soils (Kearney, 1996). Therefore, these samples, and the one used for the field study, were not unusually high for California soils.

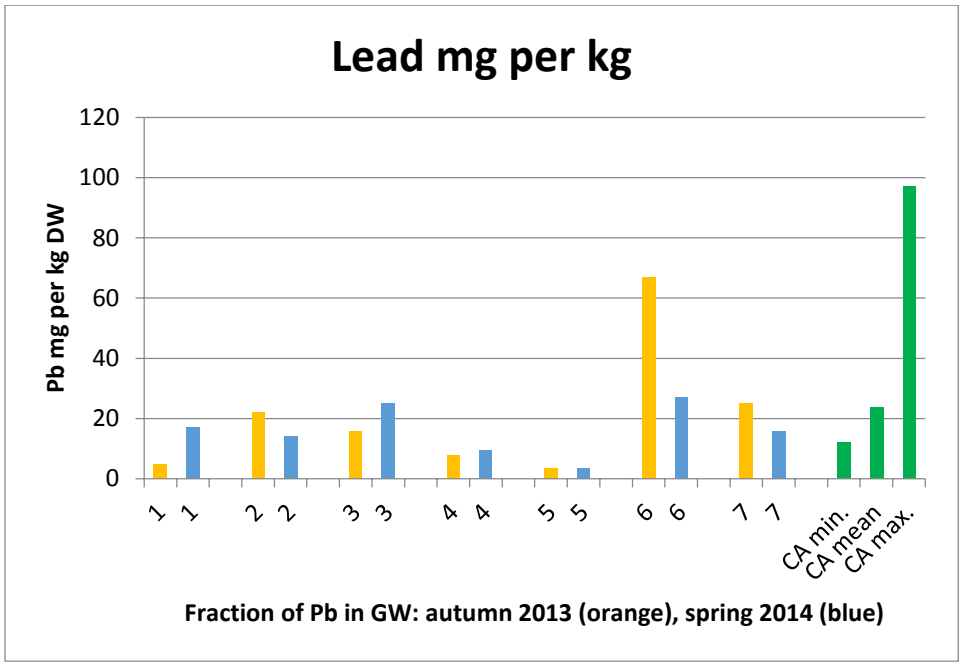

Figure 52. Fraction of lead (Pb) in the GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7 (autumn 2013) was used for the field study. Minimum, mean, and maximum for 50 California soils are shown at right.

The element zinc was also detected in every sample (Figure 53). The concentrations in GW ranged from 40 to 130 mg/kg DW, with the source for the field study having 120 mg/kg at the time of delivery in the autumn. For comparison, five of the seven sources showed higher concentrations in the autumn samples (ranging from 40 to 130 mg/kg), and three were higher in the spring samples (which ranged from 40 to 100 mg/kg). However, based on statewide surveys of subsurface, uncontaminated soils, a mean of 150 mg/kg (with a range of 90 to 240 mg/kg) existed in 50 California soils (Kearney, 1996). So, these samples, and the one used for the field study, were not unusually high for California soils either.

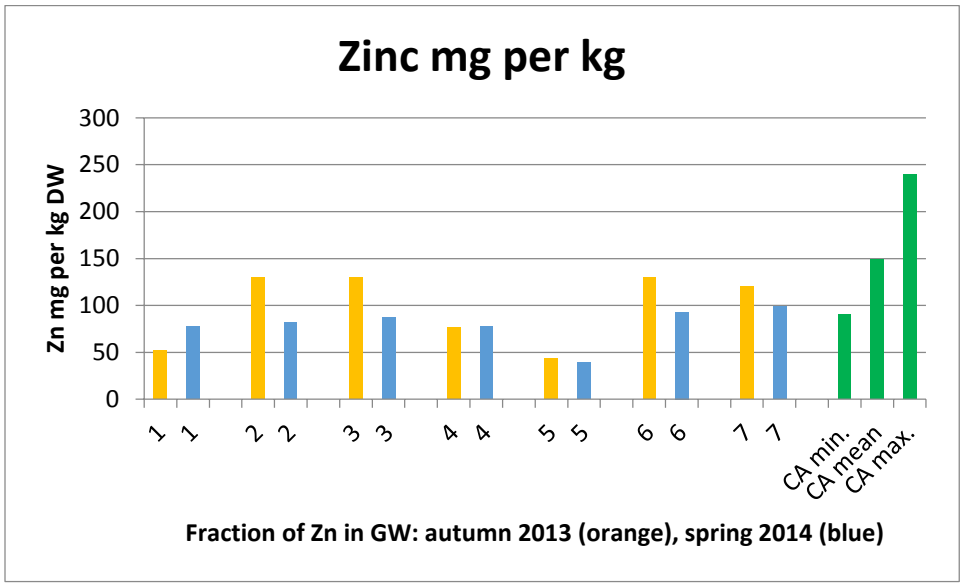

Figure 53. Fraction of zinc in the GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7 (autumn 2013) was used for the field study. Minimum, mean, and maximum for 50 California soils are shown at right.

The metal that is the earth's most common salt, sodium (Na), was measured (Figure 54). The concentrations in green waste ranged from 150 to 2600 mg/kg of dry weight, with the source for the field study having 1550 mg/kg at the time of delivery in the autumn. For comparison, six of the seven sources showed higher concentrations in the autumn samples (ranging from 400 to 2600 mg/kg), while only one was higher in the spring samples (which ranged from 150 to 1750 mg/kg). With drier conditions (after evaporation during summer irrigation) in the autumn, higher sodium is not unexpected.

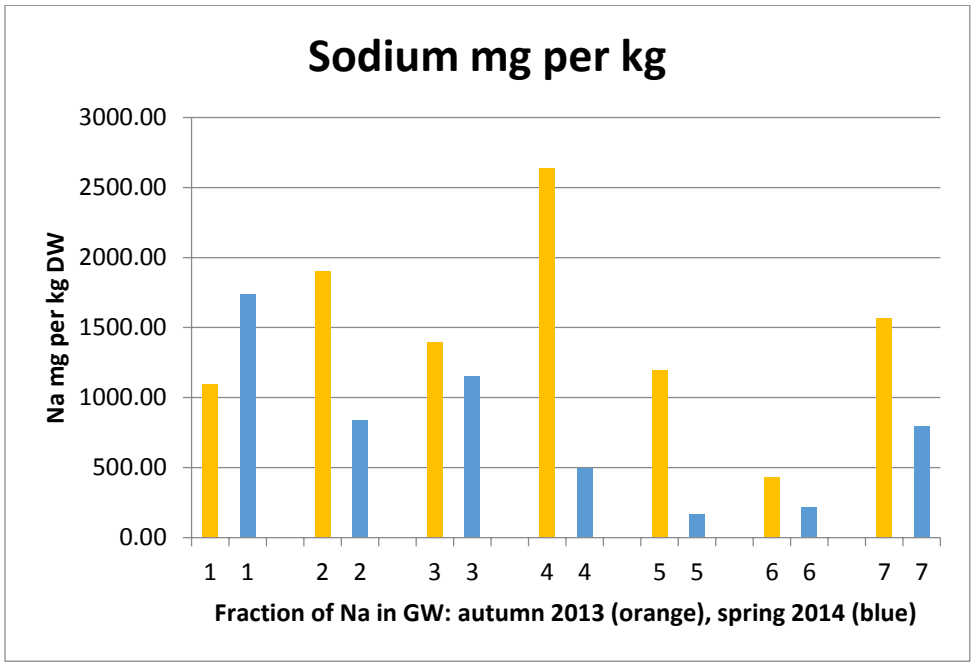

Figure 54. Fraction of sodium in the GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7 (autumn 2013) was used for the field study.

The important plant nutrient potassium (K) was measured (Figure 55). The concentrations in GW ranged from 2,000 to more than 16,000 mg/kg dry weight, with the source for the field study having more than 16,000 mg/kg at the time of delivery in the autumn. For comparison, four of the seven sources showed higher concentrations in the autumn samples (ranging from 2,500 to more than 16,000 mg/kg), while three were higher in the spring samples (which ranged from 2,500 to 12,500 mg/kg).

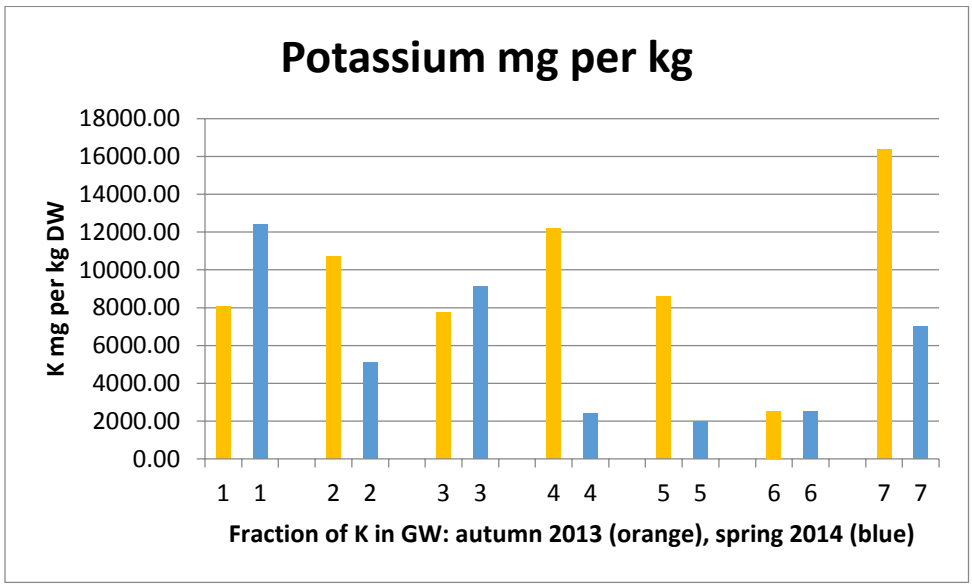

Figure 55. Fraction of potassium in the GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7 (autumn 2013) was used for the field study.

As a final example, calcium (Ca) was measured (Figure 56). The concentrations in GW ranged from 500 to 3,800 mg/kg dry weight, with the source for the field study having 3800 mg/kg at the time of delivery in the autumn. For comparison, five of the seven sources showed higher concentrations in the autumn samples (ranging from 500 to more than 3,800 mg/kg), while two were higher in the spring samples (which ranged from 550 to 2,200 mg/kg).

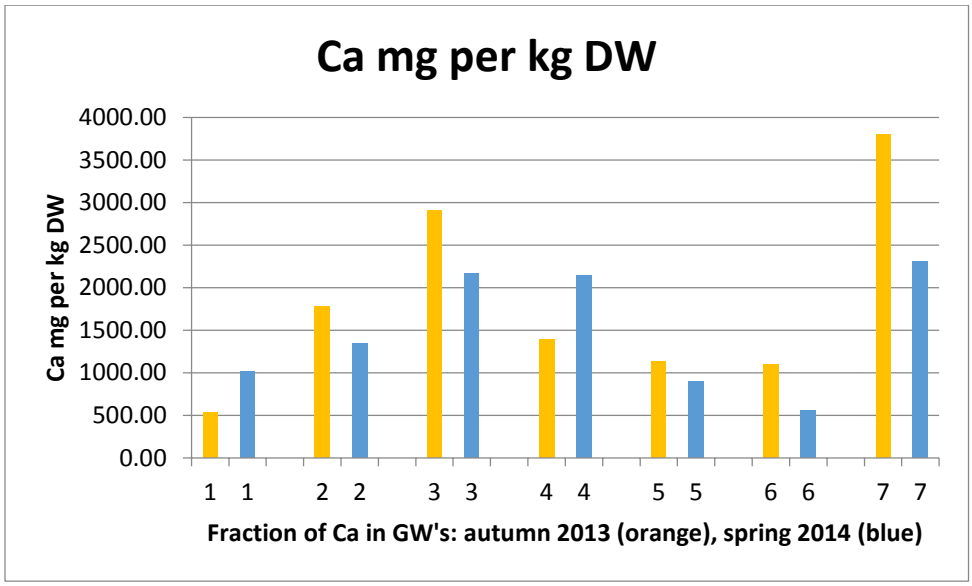

Figure 56. Fraction of calcium in the GW samples from seven sources. Data shown in pairs for the two sampling times: autumn 2013 and spring 2014. Sample 7 (autumn 2013) was used for the field study.

Elements found in soil solutions collected with lysimeters

The complete list of metals were also analyzed from the soil solution samples collected with the lysimeters, with results plotted in groups according to season and field treatment. Not all lysimeters produced water during each sampling. Most metals showed no trend by treatment type. The more interesting ones are described and plotted here.

Calcium showed a strong trend, corresponding with the amount of green waste on top of the plot (Figure 57).

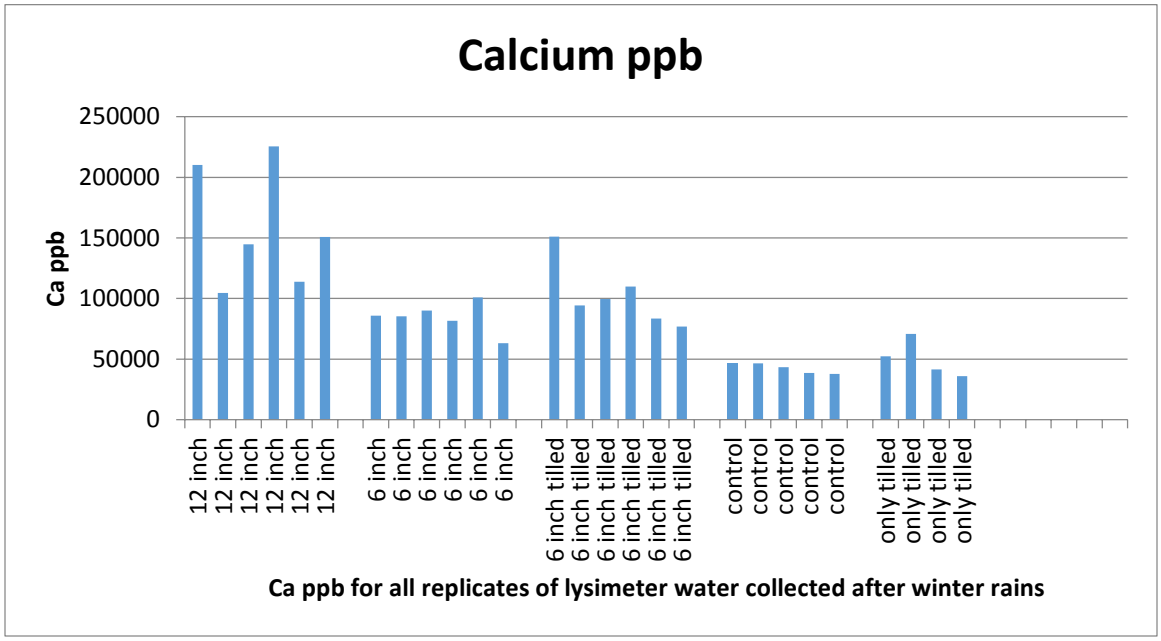

Figure 57. Concentration of calcium in the soil solutions collected from the 15 lysimeters located under the plots. Samples were taken during the rainy periods where samples could successfully be collected in late February and late March.

Potassium showed a modest trend, though with considerable variation, also aligned with the amount of GW on top of the plot (Figure 58).

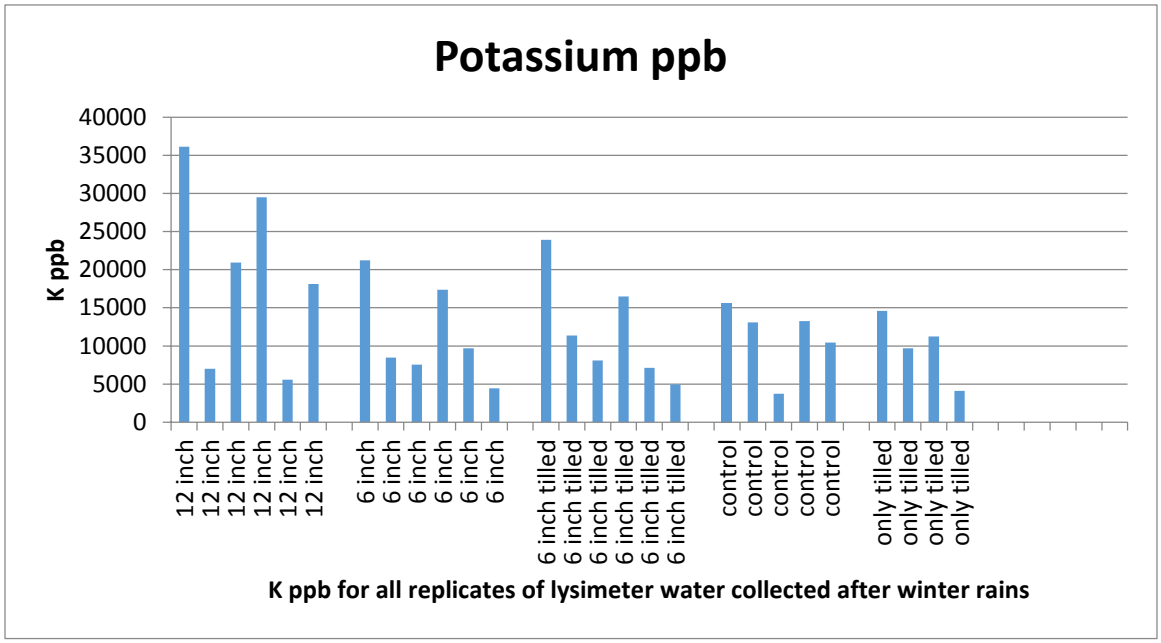

Figure 58. Concentration of potassium in the soil solutions collected from the 15 lysimeters located under the plots. Samples were taken during the rainy periods where samples could successfully be collected in late February and late March.

Iron showed more variation than trend, displayed in order of amount of GW on top of the plot (Figure 59).

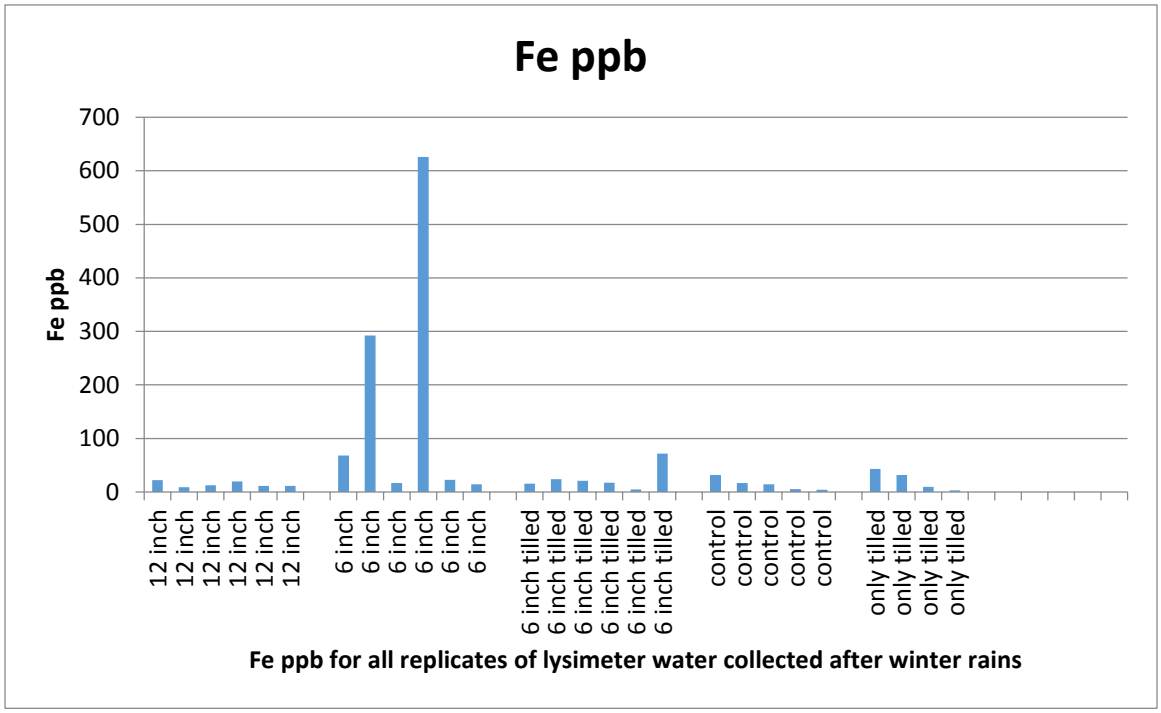

Figure 59. Concentration of iron in the soil solutions collected from the 15 lysimeters located under the plots. Samples were taken during the rainy periods where samples could successfully be collected in late February and late March.

Arsenic showed a weak trend, displayed in Figure 60 in order of the amount of GW atop the plot, with concentrations not unusual for raw groundwater in the Davis area. (http://www.cityofdavis.org/city-hall/public-works/water/water-quality-information/annual-water-quality-report).

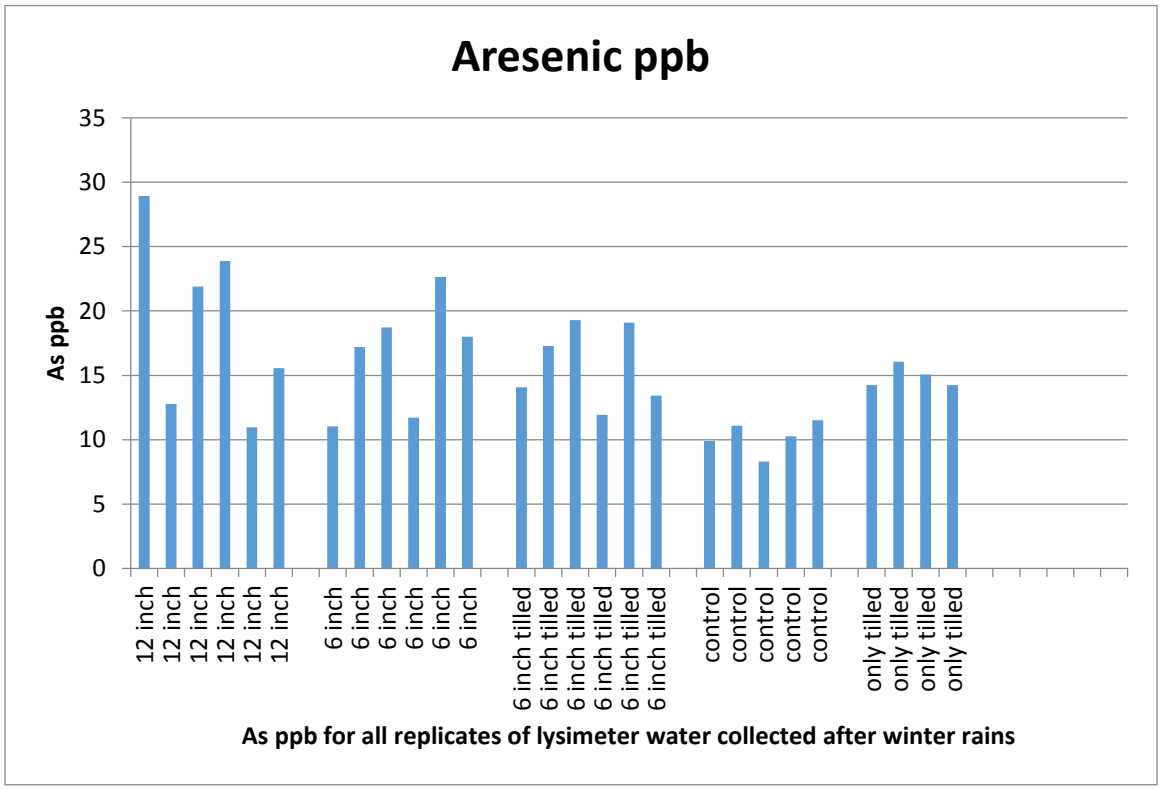

Figure 60. Concentration of arsenic in the soil solutions collected from the 15 lysimeters located under the plots. Samples were taken during the rainy periods where samples could successfully be collected in late February and late March. In the Davis area, wells used for drinking water average 5 ppb. Wells with higher concentrations have been retired from potable use in recent years (http://www.cityofdavis.org/city-hall/public-works/water/water-quality-information/annual-water-quality-report).

Iron showed little trend, displayed in order of amount of green waste atop the plot, with concentrations lower than in the irrigation water applied (Figure 61).

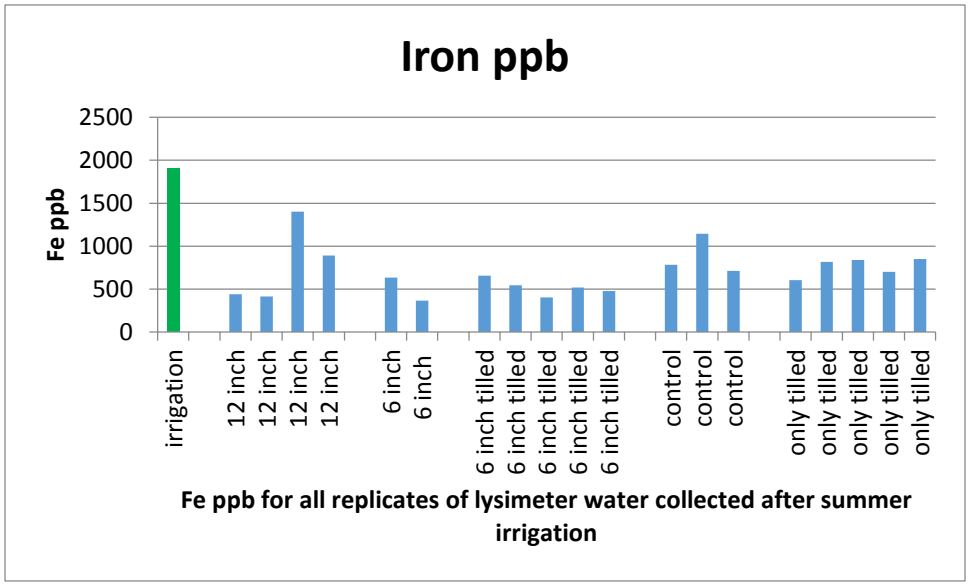

Figure 61. Concentration of iron in the soil solutions collected from the 15 lysimeters located under the plots. Samples were taken during the irrigation periods where samples could successfully be collected in June and September.

Calcium showed little trend, displayed in order of the amount of GW atop the plot, with concentrations higher than in the irrigation water applied (Figure 62).

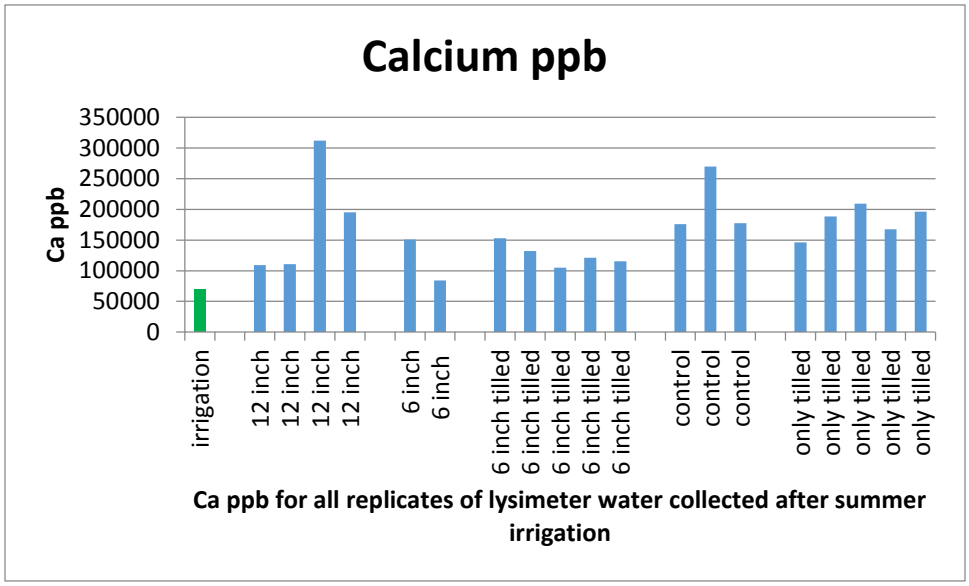

Figure 62. Concentration of calcium in the soil solutions collected from the 15 lysimeters located under the plots. Samples were taken during the irrigation periods where samples could successfully be collected in June and September.

Due to the small volume of water that could be collected by the lysimeters, pesticides could not be detected using the methods described in the work plan. Despite using GC-MS in scan mode, then moving to the more sensitive SIM mode, supplemented by chemical ionization (which is more sensitive for pyrethroids), no pesticides were detectable, even with a detection limit of 20 ng/mL for scans, and 0.2 ng/mL with SIM. Additional effort was conducted by LC-MS, detecting various non-pesticides, though none with correlation to treatment vs. control. The LC-MS detection limit was 0.2 ng/mL.

Briefly, when the lysimeters had a sample at all, it was generally between 20 and 50mL. Needing 5mL for metals analysis, and 5mL for nutrient analysis, about 10 to 40mL was available for pesticide analysis. For larger-volume samples, the excess was used as a composite for bacterial analysis, where 100mL is the preferred volume. If it had been possible to collect hundreds of milliliters, the detection limits for GC-MS would have been ten-fold lower.

Discussion

In addition to the VOCs, greenhouse gases, and N-nutrients described in Part One, many additional chemical constituents were measured from the field treatments, the soil solution water collected from beneath them, and from a statewide selection of GW. The characterization of statewide selected GW showed that the sample used for the field study was generally typical of what was available for delivery around California in terms of density, C:N ratio, bacteria content, trace metals, and major constituents.

For water collected from underneath the GW treatments, only a few constituents showed trends, which in one case differed from rainy season (winter) samples relative to irrigation (summer) samples. During the rainy season, calcium showed a strong trend (Figure 57). There was more calcium in the water collected from underneath the 30 cm (12-inch) GW surface-applied treatments, less under the 15 cm (6”) GW surface applied and 15 cm GW-tilled treatments, and the least amount under the untilled and tilled controls. Potassium (Figure 58) had a similar trend, though not as pronounced. Lastly, iron (Figure 59) was generally low, but much higher in four of the 12 15 cm (six-inch) GW samples (three untilled and one tilled). Arsenic (Figure 60) showed more scatter than trend and might have raised concern for having concentrations higher than the drinking water standard of 10 parts per billion (ppb; ng/mL, ug/L); however, these amounts are not far above what is typical for potable wells in the Davis area (http://www.cityofdavis.org/city-hall/public-works/water/water-quality-information/annual-water-quality-report). Wells with higher arsenic have been retired in the past.

After irrigations, iron concentrations were higher in nearly all samples and no longer showed a trend (Figure 61). Since the irrigation water had elevated iron, this is not surprising. In addition, calcium concentrations no longer showed a trend relative to treatment (Figure 62). They were also higher than in winter, and at higher concentrations than in the irrigation water used. Hence, the GW is delivering calcium to a depth of 30 cm (12 inches).

Conclusions

Direct land application of un-composted GW has been an increasingly common practice in California. To address many potential environmental impacts of GW, this study was conducted to assess emissions from this material, and to compare the emissions, especially VOC and GHG emissions, between surface application and incorporation of GW into soil. VOCs, GHGs, nutrient nitrogen, soil carbon, subsurface delivery of metals, and pesticides were all measured.

In addition, controlled laboratory studies of the same material were conducted to understand the mechanisms of green waste application on GHG production in different soils and under different soil moisture conditions. Furthermore, a variety of seven green materials, including the one used in the field and lab studies, from around the state were assessed for nutrient, bacteria, metal, and pesticide content to put the current study into the broadest possible context. (The source used was generally in the range of materials statewide.)

VOCs and the GHGs N_2O and CO_2 were greatly reduced by incorporating GW into the soil in comparison to surface application. The composition of VOCs was similar to that seen from compost piles but shifted more toward monoterpenes (which are more reactive toward formation of ozone) and away from methanol (which is less reactive toward formation of ozone). In addition, both GW surface and incorporated treatments led to increased nitrate concentrations in the soil. No other impacts were observed to be of concern, though differences were seen with soil incorporation in a few cases. Specifically, calcium and potassium in soil water were increased modestly due to winter rains from the addition of GW (whether incorporated or not), though less prominently due to summer irrigation. The application of GW significantly increased O_2 consumption, which promoted N_2O consumption, hence lowering net emissions. The surface-applied GW played a role in keeping more moisture in the soil underneath the GW than near the surface of the bare soil. Thus WFPS in the surface GW applications was greater than 60 percent during most of the entire year, and this contributed to the higher N_2O emissions in those treatments. These results indicate that to reduce some environmental impacts of GW application, it should be incorporated into the soil when direct land application of GW is practiced. The land application of uncomposted green waste still poses a risk of delivering pests, weed seeds, and pathogens to the areas where it is used.

Further experiments over a longer period to investigate the potential of GW application to cause GHG emissions and nitrate leaching, especially under different cover crop systems, would be useful to extend this research. In addition, water use savings (due to the mulching effect) could be studied. Replenishment of O_2 in the GW piles could have kept N_2O production within the GW piles relatively low. Meanwhile, the GHG emissions results in this report need to be compared with that from managed composting (including mitigations), as does the risk of introducing uncomposted weed seeds, pests, and pathogens when considering direct land application. GHG emissions from

composting are a current area of established measurement, as documented by the ARB:

(http://www.arb.ca.gov/cc/protocols/localgov/pubs/compost_method.pdf).

References (Bibliography)

Air Resources Board, 2014. Method for estimating greenhouse gas emission reductions from compost from commercial organic waste. http://www.arb.ca.gov/cc/protocols/localgov/pubs/compost_method.pdf

Balaine, N., Clough, T.J., Beare, M.H., Thomas, S.M., Meenken, E.D., Ross, J.G., 2013. Changes in Relative Gas Diffusivity Explain Soil Nitrous Oxide Flux Dynamics. Soil Sci. Soc. Am. J. 77, 1496-1505.

Avrahami, S., Bohannan, B.J.A., 2007. Response of Nitrosospira sp strain AF-Like ammonia oxidizers to changes in temperature, soil moisture content, and fertilizer concentration. Appl Environ Microb 73, 1166-1173.

Balaine, N., Clough, T.J., Beare, M.H., Thomas, S.M., Meenken, E.D., Ross, J.G., 2013. Changes in Relative Gas Diffusivity Explain Soil Nitrous Oxide Flux Dynamics. Soil Sci. Soc. Am. J. 77, 1496-1505.

Bremner, J.M., Blackmer, A.M., 1978. Nitrous oxide emission from soils during nitrification of fertilizer nitrogen. Science (Washington DC) 199, 295-296.

Burger, M., Horwath, W.R., 2012. Assessment of baseline nitrous oxide emissions in California cropping systems. In: California Air Resources Board, c.-. (Ed.).

Burger, M., Jackson, L.E., Lundquist, E.J., Louie, D.T., Miller, R.L., Rolston, D.E., Scow, K.M., 2005. Microbial responses and nitrous oxide emissions during wetting and drying of organically and conventionally managed soil under tomatoes. Biol. Fertility Soils 42, 109-118.

CalRecycle, (accessed April 15, 2015). Title 14, Chapter 3.1, Section 17868.3 Composting Operations Regulatory Requirements Pathogen Reduction. http://www.calrecycle.ca.gov/laws/regulations/title14/ch31a5.htm. Dalal, R.C., Gibson, I., Allen, D.E., Menzies, N.W., 2010. Green waste compost reduces nitrous oxide emissions from feedlot manure applied to soil. Agriculture, Ecosystems and Environment 136, 273-281.

Doane, T.A., Horwath, W.R., 2003. Spectrophotometric determination of nitrate with a single reagent. Anal Lett 36, 2713-2722.

Dumas, J.B., 1848. Sur les procédés de l'analyse organique. Ann. Chim., 195-213.

Ferguson, D., Signoretto, C., 2011. Environmental Persistence and Naturalization of Fecal Indicator Organisms. Microbial source tracking: Methods, applications, and case studies, 379-397. Firestone, M.K., Davidson, E.A., 1989. Microbiological Basis of NO and N2O Production and Consumption. In: Andreae, M.O., Schimel, D.S. (Eds.), Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere. Wiley, New York, pp. 7-21.

Forster, J.C., 1995. Soil nitrogen. In: K., A., P, N. (Eds.), Methods in Applied Soil Microbiology and Biochemistry. Academic Press, San Diego, pp. 79-87.

Hutchinson, G.L., Mosier, A.R., 1981. Improved soil cover method for field measurement of nitrous oxide fluxes. Soil Sci. Soc. Am. J. 45, 311-316.

IPCC, 2007. Intergovernmental Panel on Climate Change WGI, Fourth Assessment Report, Climate Change, c/o WMO,7bis, Avenue de la Paix, C.P.N. 2300, 1211 Geneva 2, Switzerland.

Kennedy, T.L., Suddick, E.C., Six, J., 2013. Reduced nitrous oxide emissions and increased yields in California tomato cropping systems under drip irrigation and fertigation. Agriculture Ecosystems & Environment 170, 16-27.

Kumar, A., Alaimo, C, Horowitz, R, Mitloehner, F, Kleeman, M, Green, P., 2011. Volatile organic compound emissions from green water composting: Characterization and ozone formation. Atmospheric Environment 45: 1841-1848.

Linn, D.M., Doran, J.W., 1984. Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and nontilled soils. Soil Sci. Soc. Am. J. 48, 1267-1272.

Parkin, T.B., Venterea, R.T., 2010. Chapter 3. Chamber-based trace gas flux measurements. In: Follett, R.F. (Ed.), Sampling Protocols.

United States Environmental Protection Agency (USEPA), 2014. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM) - Composting Version 13. http://epa.gov/epawaste/conserve/tools/warm/pdfs/Composting.pdf.

Venterea, R.T., Burger, M., Spokas, K.A., 2005. Nitrogen oxide and methane emissions under varying tillage and fertilizer management. J Environ Qual 34, 1467-1477.

Venterea, R.T., Spokas, K.A., Baker, J.M., 2009. Accuracy and Precision Analysis of Chamber-Based Nitrous Oxide Gas Flux Estimates. Soil Sci. Soc. Am. J. 73, 1087-1093.

Wagner, S.W., Reicosky, D.C., Alessi, R.S., 1997. Regression models for calculating gas fluxes measured with a closed chamber. Agron. J. 89, 279-284.

Wrage, N., Velthof, G.L., van Beusichem, M.L., Oenema, O., 2001. Role of nitrifier denitrification in the production of nitrous oxide. Soil Biol Biochem 33, 1723-1732.

Wright, A.L., Provin, T.L., Hon, F.M., Zuberer, D.A., White, R.H., 2007.Compost impacts on dissolved organic carbon and available nitrogen and phosphorus in turfgrass soil. Waste Manage. 28, 1057-1063.

Ye, R., Doane, T.A., Morris, J., Horwath, W.R., 2015. Effect of rice straw on the priming of soil organic matter and methane production in peat soils. Soil Biol. Biochem. 81, 98-107.

Zhu, X., Burger, M., Doane, T.A., Horwath, W.R., 2013. Ammonia oxidation pathways and nitrifier denitrification are significant sources of N_2O and NO under low oxygen availability. P Natl Acad Sci USA 110, 6328-6333.

Appendices

Appendix A. Daily GHG Fluxes.

Table A-1-1. Daily N_2O fluxes, N_2O-N (g/d-ha).

Sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
10/17/2013	1.97	0.28	0.90	0.33	1.88	0.19	1.87	0.51	2.09	0.23
10/24/2013	17.73	2.79	0.23	0.12	0.78	0.07	0.43	0.04	1.03	0.10
10/31/2013	7.70	2.41	0.00	0.00	0.32	0.05	0.00	0.00	0.51	0.16
11/7/2013	1.35	0.55	0.16	0.13	0.47	0.04	0.00	0.00	0.50	0.07
11/15/2013	3.47	0.94	2.03	0.24	2.37	0.18	2.26	0.06	2.59	0.07
11/18/2013	1.15	0.16	0.33	0.10	0.53	0.17	0.34	0.24	0.41	0.08
11/19/2013	1.09	0.06	0.76	0.31	0.59	0.02	0.11	0.11	0.73	0.24
11/20/2013	15.35	3.18	2.47	0.42	16.79	11.34	1.36	0.30	5.19	1.67
11/21/2013	23.53	11.18	2.05	0.90	26.88	24.31	0.90	0.22	8.79	5.91
11/22/2013	4.19	1.08	0.35	0.26	13.70	11.91	0.00	0.00	4.00	1.04
11/23/2013	1.14	0.14	0.19	0.15	6.84	6.18	0.00	0.00	0.88	0.41
12/4/2013	2.48	0.04	0.10	0.08	0.70	0.20	0.30	0.02	1.51	0.20
12/7/2013	4.42	0.57	0.13	0.11	-0.37	0.24	0.17	0.10	1.73	0.22
12/8/2013	3.85	0.58	0.55	0.30	0.51	0.16	0.21	0.21	1.58	0.31
12/11/2013	2.42	0.18	0.28	0.09	1.03	0.42	0.79	0.18	1.07	0.18
12/18/2013	2.13	0.13	0.16	0.09	0.53	0.16	0.02	0.08	1.65	0.35
12/27/2013	1.32	0.17	0.37	0.06	0.21	0.10	0.95	0.40	1.02	0.09
1/2/2014	0.94	0.11	0.11	0.09	0.00		0.00	0.00	0.38	0.00
1/10/2014	0.98	0.21	0.32		0.27	0.10	0.10	0.10	0.51	0.15
1/14/2014	27.48	10.37	0.94	0.14	1.69	0.23	0.81	0.00	12.10	1.51
1/15/2014	31.72	6.13	1.26	0.23	10.88	5.18	1.02	0.24	18.80	3.38
1/16/2014	9.49	1.27	3.21	1.19	26.61	16.61	4.97	2.77	61.00	23.42
1/17/2014	6.49	1.26	3.43	0.24	18.51	16.38	6.23	1.77	38.34	18.85
1/19/2014	3.39	0.86	5.30	2.37	9.88	6.11	5.28	1.53	18.09	8.05
1/23/2014	10.54	3.68	4.06	0.66	7.56	4.50	2.04	0.16	25.46	4.55
1/24/2014	7.65	2.24	7.29	0.29	13.46	7.77	4.90	1.05	55.66	21.77
1/26/2014	5.85	0.80	5.83	1.83	3.92	2.16	4.27	1.20	43.60	11.37
1/28/2014	5.42	0.74	4.07	2.04	3.55	2.17	2.27	0.60	31.37	6.52
1/31/2014	5.59	1.02	4.17	1.47	2.74	1.59	5.39	3.88	29.40	7.64
2/4/2014	3.93	0.19	1.66	0.68	1.25	0.57	2.25	0.64	10.18	2.49
2/7/2014	6.16	1.42	1.17	0.51	1.74	1.80	3.44	0.39	7.11	2.29
2/11/2014	9.51	0.60	5.86	0.58	6.76	3.26	8.04	3.07	9.82	3.33
2/14/2014	7.51	1.15	5.17	1.05	5.24	2.70	5.54	1.58	7.48	2.80
2/18/2014	7.53	1.80	2.33	0.26	2.73	1.58	3.40	1.15	5.84	0.83

Table A-1-1. Daily N_2O fluxes, N_2O-N (g/d-ha) (continued).

Sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
2/21/2014	7.99	1.67	1.29	0.08	1.91	1.13	3.67	1.45	6.15	2.41
2/25/2014	6.86	0.99	1.11	0.32	1.93	0.40	1.77	0.59	4.68	0.47
2/27/2014	12.18	4.38	2.11	1.47	1.16	0.73	1.97	0.50	6.58	1.35
3/2/2014	16.33	4.87	1.70	0.60	2.71	1.25	2.01	0.53	10.31	2.32
3/5/2014	14.58	4.60	1.88	0.57	3.56	1.51	3.32	1.53	4.18	0.59
3/9/2014	9.81	1.77	1.46	0.06	1.88	0.76	1.78	0.24	3.20	0.41
3/12/2014	12.85	5.68	0.15	0.12	1.43	1.07	1.57	1.54	4.22	1.34
3/17/2014	7.67	3.08	-0.06	0.18	1.08	0.79	0.30	0.10	6.68	1.51
3/24/2014	8.28	0.71	0.54		0.61	0.36	0.42	0.09		
3/27/2014	9.50	3.07	-0.04	0.23	0.91	0.68	0.25		4.20	0.05
3/30/2014	9.06	1.29	1.59	0.36	2.65	1.22	1.50	0.38	5.27	0.36
4/2/2014	11.43	3.37	2.24	0.47	4.12	1.31	2.17	0.14	13.69	3.28
4/6/2014	12.15	2.41	3.34	0.84	3.41	1.11	1.76	0.13	8.82	2.72
4/11/2014	30.22	5.64	4.55	0.55	5.29	1.30	3.37	0.25	10.67	2.34
4/15/2014	35.38	14.11	4.25	0.79	6.61	0.80	2.60	0.22	10.67	3.07
4/22/2014	26.47	9.85	0.67	0.33	2.67	1.36	0.10		10.03	3.19
4/26/2014	27.52	4.08	1.68	0.99	4.81	1.77	4.48	1.33	11.34	0.74
4/28/2014	35.78	16.05	1.68	1.07	2.28	0.99	2.69	0.73	25.42	8.75
5/2/2014	38.94	13.43	3.21	0.87	4.04	1.08	2.52	0.34	7.83	0.26
5/6/2014	26.64	8.75	0.31	0.82	0.13	0.28	1.18	0.84	18.30	6.91
5/12/2014	12.85	2.62	-0.16	0.13	1.02	0.89	0.72	0.53	16.24	4.27
5/19/2014	15.38	4.17	0.21	0.33	0.04	0.24	0.42	0.24	6.61	4.53
5/26/2014	6.27	5.27	1.12	0.68	5.66	4.04	0.48	0.16	6.13	2.52
6/2/2014	4.09	3.74	0.55	0.52	4.42	4.42	-0.09	0.14	3.92	2.46
6/9/2014	6.10	3.32	4.47	3.20	3.81	2.39	3.45	0.91	5.55	2.76
6/23/2014	2.72	1.68	1.26	0.22	1.12	0.70	1.44	0.79	1.97	0.75
6/25/2014	90.75	26.83	45.44	30.11	118.71	49.89	60.15	16.68	102.71	37.73
6/26/2014	147.45	25.59	90.94	54.94	95.90	45.51	29.75	22.69	100.38	37.36
6/27/2014	46.90	13.30	13.77	10.21	38.04	12.44	16.75	5.51	54.77	4.80
6/30/2014	62.31	22.70	27.37	2.92	45.60	25.26	16.55	5.93	70.40	5.81
7/3/2014	40.13	26.11	15.42	5.17	36.76	22.27	10.82	2.69	29.61	6.48
7/7/2014	27.98	19.78	1.84	1.86	15.62	8.24	6.08	3.57	17.58	6.37
7/11/2014	13.19	10.16	3.26	1.48	12.41	6.99	3.81	1.68	10.73	4.32

Table A-1-1. Daily N_2O fluxes, N_2O-N (g/d-ha) (continued).

Sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
7/16/2014	9.42	6.11	2.74	1.46	9.91	5.46	1.10	0.36	7.72	3.67
7/23/2014	21.56	17.47	1.55	0.83	8.17	5.46	0.72	0.35	6.33	3.12
7/31/2014	7.59	5.66	1.49	0.31	4.79	2.79	0.57	0.24	5.22	3.45
8/6/2014	13.85	1.03	1.74	0.48	1.67	0.45	1.60	0.22	6.15	2.92
8/14/2014	8.65	1.34	1.71	0.45	1.38	0.23	2.44	0.70	3.24	1.06
8/21/2014	12.97	3.52	0.82	0.41	1.05	0.16	2.17	1.07	2.40	0.43
8/29/2014	14.42	5.48	0.67	0.13	0.35	0.23	0.61	0.18	0.94	0.31
9/6/2014	47.90	38.59	1.62	0.62	0.65	0.37	0.93	0.37	1.12	0.04
9/9/2014	125.35	49.10	100.91	19.78	110.51	97.13	128.23	62.53	163.62	65.10
9/10/2014	119.03	26.23	169.24	46.85	123.22	39.48	142.47	23.18	172.46	31.70
9/12/2014	50.40	15.48	62.14	12.28	41.53	17.51	60.54	8.66	72.25	7.98
9/15/2014	41.21	3.80	16.60	6.42	10.39	2.26	22.72	11.48	30.81	14.36
9/18/2014	26.61	8.30	28.62	12.27	3.67	1.27	10.38	3.03	23.22	12.36
9/22/2014	21.74	1.24	8.33	3.13	4.07	1.53	7.79	0.55	18.54	5.68
9/25/2014	20.26	2.33	1.90	0.84	2.48	0.68	1.45	0.54	9.20	2.53
9/26/2014	18.57	4.11	7.02	1.24	3.03	1.94	7.73	1.65	17.79	9.05
9/29/2014	14.81	2.06	4.00	1.19	5.37	2.80	5.22	1.63	6.11	1.83
10/2/2014	12.89	1.39	2.90	1.00	1.80	1.18	3.30	0.95	3.52	1.62
10/9/2014	22.96	3.35	4.21	0.88	3.46	1.12	3.48	0.88	7.93	3.45
10/16/2014	13.84	3.64	0.75	0.26	0.80	0.44	1.64	0.26	4.60	2.82

Table A-1-2. Daily CO_2 fluxes, CO_2-C (in kg/d-ha).

Sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
10/17/2013	231.73	165.04	6.42	0.51	171.82	46.71	8.68	0.61	14.51	4.42
10/24/2013	1166.77	71.29	8.62	1.59	66.48	7.85	4.65	0.93	113.24	85.17
10/31/2013	197.26	58.07	9.22	4.45	34.17	4.98	5.57	0.54	47.31	11.95
11/7/2013	43.00	7.80	4.05	0.36	35.67	2.84	4.53		25.89	7.67
11/15/2013	37.30	7.67	4.98	0.54	26.44	8.10	6.83	2.31	13.68	0.45
11/18/2013	21.48	0.63	10.33	0.83	22.97	4.67	16.91	1.94	15.07	3.46
11/19/2013	23.63	3.48	5.37	1.02	20.20	1.38	3.36	0.41	8.95	0.48
11/20/2013	89.35	7.79	25.43	2.81	92.07	21.92	26.23	7.45	57.58	11.42
11/21/2013	147.98	68.48	26.21	12.53	76.28	34.77	7.88	3.31	90.29	36.56
11/22/2013	106.02	24.58	8.77	2.73	68.42	10.21	2.34	0.00	80.05	12.66
11/23/2013	54.77	2.93	8.18	1.89	66.05	11.45	11.14	2.28	85.88	0.77
12/4/2013	45.98	7.18	4.46	2.22	18.12	1.80	2.97	1.29	42.01	0.81
12/7/2013	64.29	7.93	4.57	1.83	13.67	10.31	2.31	0.68	46.20	2.84
12/8/2013	48.70	6.09	6.18	1.42	14.33	4.48	8.97	7.01	42.78	13.61
12/11/2013	56.20	6.85	5.50	0.51	29.31	12.04	3.54	0.97	39.61	2.60
12/18/2013	84.49	16.23	6.98	1.27	26.57	3.40	9.43	4.48	57.29	0.72
12/27/2013	47.04	10.26	6.78	0.23	9.81	2.02	2.80	1.06	26.04	1.45

Table A-1-2. Daily CO_2 fluxes, CO_2-C (in kg/d-ha) (continued).

Sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
1/2/2014	45.27	8.98	4.75	0.29	15.37	3.48	4.06	0.60	25.31	1.09
1/10/2014	42.58	8.12	2.43	0.17	10.26	1.63	1.41	0.64	22.59	2.08
1/14/2014	98.98	8.28	35.73	4.40	32.05	3.81	31.74	1.75	94.46	5.46
1/15/2014	137.78	20.78	34.15	2.06	39.73	8.17	27.21	3.60	117.64	8.46
1/16/2014	135.84	18.04	22.69	2.95	68.97	8.35	20.10	1.23	127.49	9.40
1/17/2014	133.43	16.92	18.23	3.22	56.00	13.71	19.40	2.93	101.87	2.20
1/19/2014	109.95	11.99	13.67	2.89	39.12	11.01	16.56	3.49	74.36	3.22
1/23/2014	145.82	8.01	16.17	1.77	28.08	10.50	17.03	3.26	59.23	3.96
1/24/2014	174.86	13.19	33.02	6.31	69.37	17.09	28.54	4.64	80.89	13.16
1/26/2014	135.14	9.46	23.61	4.27	38.26	11.79	19.62	4.06	57.52	5.58
1/28/2014	193.51	27.90	14.95	3.21	44.87	7.22	14.65	3.74	77.98	7.74
1/31/2014	103.48	21.86	19.55	5.26	42.88	17.77	25.46	14.17	49.30	20.29
2/4/2014	94.98	7.42	15.89	1.88	31.88	8.28	13.74	2.71	37.85	3.44
2/7/2014	81.79	10.37	2.54	1.08	10.56	4.85	6.21	1.51	17.33	9.24
2/11/2014	286.08	14.67	25.69	2.90	69.91	23.68	22.51	5.75	84.66	4.43
2/14/2014	248.21	16.02	21.78	1.67	61.55	22.18	20.58	6.56	71.72	7.31
2/18/2014	187.86	5.47	14.63	3.43	43.14	13.75	21.53	9.54	59.48	11.05
2/21/2014	115.23	15.50	16.70	2.69	28.17	12.78	14.97	0.64	34.69	3.66
2/25/2014	189.17	6.37	14.31	2.73	46.20	8.57	11.96	1.55	66.57	9.00
2/27/2014	145.17	21.33	16.57	6.99	18.86	6.62	7.15	1.80	48.13	4.62
3/2/2014	199.03	18.35	13.50	2.70	30.95	13.83	7.01	0.35	44.84	7.35
3/5/2014	229.09	16.20	23.73	0.37	61.31	17.05	32.50	14.98	65.82	2.90
3/9/2014	283.31	20.05	25.32	3.42	54.85	7.97	27.34	9.12	95.16	7.67
3/12/2014	107.12	32.61	8.85	1.28	36.91	9.50	22.81	9.10	35.10	0.80
3/17/2014	78.81	22.16	11.94	5.36	38.06	17.04	17.34	4.54	28.55	3.46
3/24/2014	181.47	13.71	42.54	19.70	60.65	10.23	22.51	2.44		
3/27/2014	126.16	7.03	16.57	0.14	50.39	5.02	65.88	26.23	102.93	29.06
3/30/2014	140.36	16.74	17.57	1.79	70.53	8.44	15.24	1.23	53.79	2.73
4/2/2014	152.43	22.98	13.17	1.98	40.95	15.51	10.65	0.77	35.39	4.02
4/6/2014	254.67	4.87	19.81	1.66	63.97	10.36	23.33	6.52	72.80	3.53
4/11/2014	229.37	23.90	15.85	3.82	57.19	9.43	17.17	1.67	54.60	4.82
4/15/2014	189.86	19.37	15.99	1.32	65.97	10.78	17.31	0.40	51.17	3.75
4/22/2014	85.26	16.39	6.87	0.26	27.26	4.75	7.78	1.94	32.05	3.41
4/26/2014	109.05	9.34	13.08	2.46	43.61	11.60	19.64	3.88	48.62	5.60
4/28/2014	66.36	11.67	8.27	4.55	22.43	3.47	15.17	3.76	41.08	7.67

Table A-1-2. Daily CO_2 fluxes, CO_2-C (in kg/d-ha) (continued).

Sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
5/2/2014	106.69	7.62	11.27	1.54	26.40	5.90	11.92	0.33	32.00	3.02
5/6/2014	42.09	13.51	6.56	3.99	9.77	2.59	0.06	13.07	31.61	7.20
5/12/2014	36.20	7.47	2.39	0.83	19.37	3.43	13.76	8.25	26.65	0.64
5/19/2014	45.62	7.79	8.25	0.72	3.29	1.04	3.20	2.61	18.18	11.64
5/26/2014	25.80	20.86	7.14	2.31	26.08	8.81	8.90	0.22	34.20	17.05
6/2/2014	17.80	14.63	4.04	3.30	21.65	6.13	8.11	2.22	30.22	20.27
6/9/2014	38.27	18.23	19.65	8.73	28.04	12.49	26.91	9.36	47.47	25.21
6/23/2014	22.22	11.13	10.20	2.54	14.48	4.61	9.00	13.42	24.29	10.27
6/25/2014	66.93	29.92	19.91	6.34	58.51	13.87	36.48	13.29	115.82	52.33
6/26/2014	86.95	19.92	33.49	13.61	56.54	9.88	43.67	25.44	110.28	37.83
6/27/2014	77.96	35.69	9.90	7.61	54.79	11.30	42.83	20.18	94.24	47.67
6/30/2014	116.95	28.97	58.53	5.35	62.59	10.39	83.73	21.93	112.11	43.06
7/3/2014	107.96	43.72	38.65	18.52	36.59	8.03	35.01	5.41	62.45	34.90
7/7/2014	83.09	47.52	48.60	32.57	40.27	11.51	51.67	3.61	57.57	30.57
7/11/2014	80.37	35.55	25.51	12.56	36.34	10.45	68.58	23.37	96.22	71.66
7/16/2014	13.69	1.43	11.54	5.45	21.50	8.59	8.78	2.46	35.09	19.80
7/23/2014	100.93	85.00	12.40	0.95	26.22	10.83	8.73	0.63	30.76	17.11
7/31/2014	37.10	22.92	12.15	2.22	22.58	6.22	6.34	0.94	29.10	17.10
8/6/2014	59.60	8.88	11.26	1.25	14.95	1.69	12.22	2.00	45.71	20.00
8/14/2014	40.25	7.36	10.87	4.74	10.45	2.86	9.46	0.72	19.88	6.41
8/21/2014	42.14	9.22	9.06	3.07	10.10	1.86	17.98	5.18	16.97	5.95
8/29/2014	37.10	13.09	2.71	0.64	0.69	1.38	6.31	2.65	6.51	1.66
9/6/2014	64.51	36.79	17.95	2.43	29.23	6.81	56.05	16.94	42.30	18.16
9/9/2014	131.20	22.50	28.29	4.02	37.16	12.84	66.53	26.04	74.51	25.47
9/10/2014	127.46	17.56	71.95	6.48	64.69	21.15	55.69	9.66	47.18	8.94
9/12/2014	93.25	22.76	40.50	8.79	39.79	9.57	30.31	2.65	39.13	6.75
9/15/2014	139.88	43.02	26.85	5.05	50.04	8.37	31.73	3.16	49.51	27.56
9/18/2014	97.64	8.32	33.89	21.14	12.03	7.52	27.94	0.46	56.94	14.16
9/22/2014	59.18	11.67	16.06	2.98	21.58	4.74	15.79	3.93	24.55	6.02
9/25/2014	98.36	30.23	3.53	0.50	9.27	3.18	2.19	0.24	15.73	5.59
9/26/2014	44.64	5.28	19.36	12.56	11.79	4.82	7.54	1.28	19.83	11.36
9/29/2014	37.43	3.51	4.63	0.85	26.59	9.52	6.15	1.45	11.00	4.80
10/2/2014	59.85	7.09	40.03	18.43	10.31	5.36	14.19	7.60	56.29	18.43
10/9/2014	82.73	12.85	10.99	5.20	29.81	8.89	14.45	2.09	44.01	3.82
10/16/2014	42.65	6.43	6.61	3.32	6.19	3.03	11.42	5.64	16.41	9.31

Table A-1-3. Daily CH fluxes, CH_4-C (in g/d-ha).

Sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
10/17/2013	-2.68	0.35	-4.18	0.66	-3.81	0.41	-4.09	0.62		
10/24/2013	1.41	1.24	-3.41	0.59	-2.49	2.03	1.44	5.14	-4.56	
10/31/2013	-2.67	0.44	-3.40	0.08	-2.33	1.90	-2.40	1.96	-4.67	0.58
11/7/2013	-0.38	1.78	-3.52	0.02	-4.52	0.34	-2.11	1.06	-3.91	0.38
11/15/2013	3.36		-3.08				-2.72	2.22	-0.19	5.56
11/18/2013	-2.92	0.47	-1.51	2.59	-3.72		0.91		-4.90	0.16
11/19/2013	-2.09	0.04	-4.16		-3.15		2.53	2.07	-4.29	0.99
11/20/2013	-5.41	1.33	-5.11	0.61	-5.29	0.47	-1.66	1.14	-6.68	0.33
11/21/2013	-6.81		-4.39	3.65	2.00	0.43	0.27	0.54	-10.41	1.42
11/22/2013	-10.93	1.27	0.22	0.76	-3.27	0.37	-1.39	0.59	-7.37	1.08
11/23/2013	20.74		-7.64		-6.22		59.53	21.33	-7.92	0.64
12/4/2013	-5.14	0.18	-4.14	0.80	-5.29	0.69	-3.74	1.18	-6.35	0.26
12/7/2013	-4.64	1.14	-5.09	1.00	-1.77	1.35	-4.42	0.94	-5.12	0.47
12/8/2013	-5.38	0.56	-5.19	1.64	-2.59	1.24	-3.85	0.13	-5.49	1.19
12/11/2013	-3.93	0.74	-5.60	0.42	-3.87	0.96	-5.17	0.53	-3.41	1.67
12/18/2013	-4.03		-7.76	0.33	-3.03	2.06	-7.06	0.14	-2.36	4.29
12/27/2013	-3.02	1.52	-7.35	2.52	-4.03	0.99	-8.72	0.86	-4.65	0.86
1/2/2014	-3.74	0.97	-6.95	1.01	0.06	3.47	-7.07	0.95	-5.63	0.69
1/10/2014	2.60		-6.55	1.04	-3.02	2.63	-5.79	0.83	-6.15	0.75
1/14/2014	-4.91	0.51	-5.25	0.70	-3.90	0.84	-5.97	0.70	-4.79	0.20
1/15/2014	-5.14	0.14	-3.51	0.85	-3.03	0.83	-3.28	0.92	-0.10	0.53
1/16/2014	-5.05	2.64	-4.77	0.52	-4.18	0.99	-5.42	0.57	-4.31	
1/17/2014	-3.11	1.29	-4.07	1.09	-0.63	1.47			-1.75	2.47
1/19/2014	-5.00	0.86	-6.26	1.11	-2.58	1.38	-7.40	1.25	-3.60	0.19
1/23/2014	-2.99	0.65	2.59	3.04	-0.79	1.67	0.24		1.33	0.16
1/24/2014	-3.55	0.20	0.00		-1.54	1.85	-4.64	0.67	-1.29	1.14
1/26/2014	-2.65	2.17	-6.36	0.74	-3.13	1.11	-5.90	0.61	-8.72	3.81
1/28/2014	-5.70	2.88	-2.60	0.18	-4.21	1.32	-5.04		-1.14	1.73
1/31/2014	1.14	5.42	-4.86	0.83	-2.08	2.29	-12.05		-0.26	0.89
2/4/2014	0.99	2.34	-2.30	2.18	-0.03	2.31	-3.10	2.53	-3.24	2.64
2/7/2014	-3.85	5.59	0.08	2.25	4.31	8.29	-5.52	6.84	3.81	
2/11/2014	8.72		-1.47	0.97	0.39	2.82	-2.97	0.36	1.40	
2/14/2014	-1.53	1.85	-6.04	1.31	-0.27	2.75	-6.21	1.70	0.32	
2/18/2014	-0.80	2.60	-6.64		-3.98	1.75	-4.86	3.97	0.00	
2/21/2014	-4.10				-3.54	0.99	-9.66	3.92	-3.95	2.56

Table A-1-3. Daily CH fluxes, CH_4-C (in g/d-ha) (continued).

Sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
2/25/2014	-0.72	2.02	-3.99	1.44	-2.41	1.45	-5.55	2.07	3.55	
2/27/2014	-5.87	0.18	-5.13	0.93	1.56	2.67	-1.49	1.58	-0.40	2.54
3/2/2014	11.75	8.71	0.95	2.30	-1.23	1.08	-0.77	1.27	7.71	3.53
3/5/2014			-3.99	0.72	-1.71	1.90	-5.89	0.57	2.39	3.75
3/9/2014			-1.45	2.11	0.44	2.76	-5.06	1.00	3.82	
3/12/2014	-2.23	2.03			-1.04	1.56	-10.63	1.33	1.84	1.37
3/17/2014	9.77		-1.16	0.62	0.18	2.52	-3.94	3.90	2.97	1.57
3/24/2014	-1.14	3.05	-3.46	2.97	-3.75	2.12	-9.99	2.25		
3/27/2014	-5.48		-2.36	1.09	-2.39	1.69	-5.74	1.69	1.03	3.14
3/30/2014	6.72	10.10	-6.77	2.54	1.48	4.65	-6.83	0.41	2.53	
4/2/2014			-4.05	2.28	0.37	3.37	4.39	8.90	0.52	
4/6/2014	8.50		1.23	0.15	2.38	2.85	-8.81	0.64	-1.47	
4/11/2014	-2.98		-4.40	0.99	-2.34	1.10	-5.27	0.10	-0.38	1.40
4/15/2014	-5.24	4.66	-4.53	1.04	1.31	1.83	-3.02	5.94	8.54	8.85
4/22/2014	-2.78	0.61	-3.71	0.17	-2.32	0.74	-3.99	0.12	-3.02	1.23
4/26/2014	-4.05	0.58	-3.20	0.40	-0.13	1.44	-7.09	1.80	-3.07	0.74
4/28/2014	0.01	3.29	-2.07	0.52	-1.48	0.94	-8.33	0.01	-5.25	1.74
5/2/2014	3.04	1.60	-4.88	0.65	-1.41	1.03	-6.97	1.36	-1.76	1.63
5/6/2014	0.90	3.67	-3.78	5.40	-0.03	1.19	-3.58	1.59	-2.14	2.82
5/12/2014	26.92	22.48	-0.18	0.65	0.83	5.63	-3.10	1.09	0.18	4.40
5/19/2014	-0.38	3.15	-0.79	0.20	0.34	0.87	-3.53	0.53	-0.84	1.63
5/26/2014	-1.57	0.83	-3.62	1.63	-3.75	0.78	-1.88	0.21	-3.75	1.25
6/2/2014	-4.76	0.48	-3.91	1.59	-6.05	1.30	-5.28	1.54	-4.18	1.16
6/9/2014	-4.17	2.22	15.59	15.79	-2.29	2.38	-1.67	0.89	-2.47	3.21
6/23/2014	-4.55		-4.84	2.10	-2.85	2.98	-3.01	1.56	-8.61	2.99
6/25/2014	-3.87	0.12	-2.69		-3.23	1.15	0.65		-4.20	1.48
6/26/2014	75.00	51.86	6.32	0.45	21.89	3.15	14.60	0.83	20.32	3.58
6/27/2014	1.88		2.92	3.39	-0.04	1.15	-0.92		-0.69	0.56
6/30/2014	-3.30	2.48	-5.13	2.57	-1.98	3.28	-0.99	3.18	-7.03	1.69
7/3/2014	-5.12	1.22	-1.81	3.76	-3.77	2.22	-3.28	1.16	-2.20	2.44
7/7/2014	-4.24	0.86	-3.56	1.75	-3.14	2.36	-0.11	1.44	-5.44	0.09
7/11/2014	-4.70	1.95	-5.53	2.91	-5.32	1.79	-4.13	1.75	-4.74	0.91
7/16/2014	-6.07	1.50	-8.81	1.76	-7.56	1.79	-9.54		-7.03	0.22
7/23/2014	0.17	2.75	5.62		-1.53	1.22	4.19		-4.24	
7/31/2014	-1.18	2.59	-6.21	2.91	-5.90	0.96	-3.19	1.04	-3.66	0.65

Table A-1-3. Daily CH fluxes, CH_4-C (in g/d-ha) (continued).

Sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
8/6/2014	-1.32	2.91	-5.10	2.23	-4.36	0.93	-7.28	0.48	-2.73	1.23
8/14/2014	-1.84	0.35	-4.71	0.82	-2.23	0.85	-6.89	1.34	-5.72	0.65
8/21/2014	-3.32		-3.71	0.47	-3.37	0.44	-5.79	1.36	-2.79	4.09
8/29/2014	-5.05	5.03	-3.68	0.50	0.38	2.29	-6.34	0.25	-5.17	2.31
9/6/2014	-4.46	0.63	-5.29	0.85	-2.85	0.89	-4.75	0.45	-3.97	1.10
9/9/2014	-2.48	0.64	-1.67	0.46	-0.86	0.88	-1.98	0.21	-2.30	0.27
9/10/2014	-1.93	0.60	-3.58	0.83	-2.76	0.85	-3.30	0.21	-4.23	0.60
9/12/2014	-1.73	1.68	-4.87	0.61	-3.14	1.58	-7.07	1.26	-4.01	0.21
9/15/2014	-3.21	0.27	-3.94	0.33	-3.48	1.20	-5.90	1.26	-2.13	0.24
9/18/2014	-3.14	1.48	-3.08	0.74	-1.96	0.92	-6.71	0.83	-2.26	0.37
9/22/2014	-3.83	0.22	-5.02	0.12	-4.33	0.84	-7.10	0.76	-4.08	0.36
9/25/2014	-2.47	0.58	-1.22	1.32	-2.28	0.78	-2.04	0.64	-2.49	0.56
9/26/2014	-3.31	2.62	-4.49	0.49	-3.20	1.26	-6.09	1.06	-5.99	1.02
9/29/2014	-4.70		-2.46	1.27	-3.47	0.94	-6.66	1.04	-1.52	1.75
10/2/2014	-4.24	0.56	-3.66	2.25	-3.38	0.93	-7.54	1.31	-3.13	0.56
10/9/2014	-4.74	0.44	-5.02	1.64	-3.65	1.20	-8.71	0.69	-2.18	2.39
10/16/2014	-5.16	0.84	-5.04	0.36	-3.33	0.98	-7.16	1.01	-7.46	1.82

Appendix A-2. Incubation Data.

Table A-2-1. CH_4, CO_2, and N_2O concentration in the headspace of the loam soil incubation vials over time. The treatments were control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

Treat-ment Type	Day																	
	0.0		0.2		0.4		1.2		2.7		5.6		12.0		20.0		28.0	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
CH4-C, ng/g																		
soil-50%	19.33	3.54	15.13	2.11	1.76	0.82	1.50	0.22	2.43	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
soil-100%	22.27	4.01	13.41	1.06	2.56	1.00	1.65	0.37	4.65	0.17	1.12	0.26	1.48	0.33	3.74	0.63	3.03	1.01
soilGW50%	16.60	2.72	6.91	0.71	3.12	0.42	3.82	0.20	12.02	0.06	15.95	0.76	30.20	0.33	141.65	20.68	867.85	205.1
soilGW100%	11.86	2.81	8.01	1.21	1.46	0.52	2.04	0.20	6.30	0.31	14.13	0.93	32.06	3.13	52.62	8.14	87.65	15.32
GW-50%	101.69	17.13	78.25	5.40			28.58	2.11	64.48	1.28	76.10	1.65	122.16	3.27	186.64	3.31	207.15	3.77
GW-100%	62.18	9.64	59.20	6.05			25.88	1.60	60.59	1.87	95.51	3.06	197.06	10.13	301.31	13.33	320.81	8.13
CO2-C, ug/g																		
soil---50%	3.04	0.08	5.54	0.52	6.03	0.53	22.29	3.31	46.95	4.25	63.07	3.22	96.35	5.55	114.40	5.61	116.63	10.63
soil---100%	2.00	0.17	2.76	0.11	3.42	0.17	11.20	1.21	26.06	0.80	37.52	1.22	62.75	3.25	91.72	3.54	103.85	6.98
soilGW50%	17.24	0.07	116.83	1.53	195.48	6.67	356.87	4.94	507.70	2.38	609.84	1.09	732.74	2.77	730.43	38.70	809.44	8.70
soilGW100%	5.93	0.71	35.77	1.51	39.05	3.08	107.44	4.65	353.87	1.93	523.50	2.92	700.31	5.23	727.21	11.50	729.70	19.67
GW---50%	55.82	4.54	573.00	31.54	546.53	24.76	2040.2	87.96	2566.9	115.23	3070.0	143.5	3535.9	155.3	3361.3	162.5	3442.4	186.1
GW-100%	47.69	2.94	383.65	20.34	392.64	25.74	2067.1	18.24	2789.1	18.73	3313.7	30.91	3829.5	33.43	3753.6	47.77	3801.7	76.63
CO2-C, g/kg																		
soil---50%	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.05	0.00	0.06	0.00	0.10	0.01	0.11	0.01	0.12	0.01
soil---100%	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.04	0.00	0.06	0.00	0.09	0.00	0.10	0.01
soilGW50%	0.02	0.00	0.12	0.00	0.20	0.01	0.36	0.00	0.51	0.00	0.61	0.00	0.73	0.00	0.73	0.04	0.81	0.01
soilGW100%	0.01	0.00	0.04	0.00	0.04	0.00	0.11	0.00	0.35	0.00	0.52	0.00	0.70	0.01	0.73	0.01	0.73	0.02
GW---50%	0.06	0.00	0.57	0.03	0.55	0.02	2.04	0.09	2.57	0.12	3.07	0.14	3.54	0.16	3.36	0.16	3.44	0.19
GW-100%	0.05	0.00	0.38	0.02	0.39	0.03	2.07	0.02	2.79	0.02	3.31	0.03	3.83	0.03	3.75	0.05	3.80	0.08
N2O-N, ng/g																		
soil---50%	0.00	0.03	1.52	0.02	1.15	0.35	2.36	0.24	5.59	1.29	11.26	2.50	20.45	8.50	18.87	7.62	18.01	7.07
soil---100%	---0.06	0.01	1.09	0.02	2.47	1.42	216.45	28.77	164.45	21.58	108.10	12.64	43.80	5.61	14.41	1.15	6.09	0.52
soilGW50%	0.25	0.05	1.83	0.03	4.38	0.53	0.15	0.01	0.24	0.03	6.82	0.07	1.33	0.20	0.33	0.09	0.43	0.02
soilGW100%	0.59	0.04	17.06	1.40	21.12	3.52	3.61	1.00	0.13	0.02	3.13	0.18	5.30	0.21	4.53	0.40	2.85	0.57
GW---50%	6.63	0.35	7.24	1.35	333.36	51.97	0.67	0.14	1.75	0.09	5.76	0.44	3.82	0.22	0.30	0.12	1.04	2.34
GW-100%	5.74	0.15	8.82	0.91	1972.51	1216.2	0.45	0.06	0.92	0.06	1.56	0.30	3.26	0.08	0.12	0.13	0.00	0.00

Sandy CH4-C, ng/g	Day																	
	0.00		0.20		0.40		1.20		2.70		5.60		12.00		20.00		28.00	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
soil-50%	24.93	3.02	8.31	0.61	5.46	0.58			4.77	0.15	1.61	0.55	2.63	0.17	4.89	0.83	2.07	0.27
soil-100%	16.28	10.78	8.72	0.51	3.71	0.38	2.40	0.45	3.67	0.09	2.01	0.51	2.94	0.16	3.82	0.81	4.57	0.38
soil+GW-50%	14.66	3.11	8.11	1.09	3.03	0.11	4.54	0.07	12.13	0.29	15.22	0.11	21.68	0.28	18.13	9.96	29.04	0.59
soil+GW-100%	16.07	1.59	9.60	1.54	2.36	0.20	1.94	0.19	9.44	0.20	13.78	0.22	26.73	0.93	35.88	1.71	27.67	13.25
GW-50%	101.69	17.13	78.25	5.40			28.58	2.11	64.48	1.28	76.10	1.65	122.16	3.27	186.64	3.31	207.15	3.77
GW-100%	62.18	9.64	59.20	6.05			25.88	1.60	60.59	1.87	95.51	3.06	197.06	10.13	301.31	13.33	320.81	8.13
CO2-C, ug/g	0.00		0.20		0.40		1.20		2.70		5.60		12.00		20.00		28.00	
soil-50%	5.61	1.60	11.06	0.50	11.11	0.37	15.43	0.78	55.24	3.22	76.18	1.57	105.41	0.63	111.51	0.67	116.34	2.21
soil-100%	2.41	0.21	5.36	0.24	5.56	0.44	13.68	0.34	39.97	0.68	53.36	0.90	78.95	2.04	71.23	10.86	117.34	0.94
soil+GW-50%	19.83	3.52	123.89	2.70	207.88	2.20	364.11	0.86	490.38	2.11	562.97	2.65	652.58	2.94	666.16	7.62	693.28	4.91
soil+GW-100%	6.41	0.29	48.67	3.49	58.56	6.50	170.24	23.51	449.54	1.97	558.00	3.27	677.29	2.01	694.72	4.75	727.22	3.58
CO2-C, g/kg	0.00		0.20		0.40		1.20		2.70		5.60		12.00		20.00		28.00	
soil-50%	0.01	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.06	0.00	0.08	0.00	0.11	0.00	0.11	0.00	0.12	0.00
soil-100%	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.04	0.00	0.05	0.00	0.08	0.00	0.07	0.01	0.12	0.00
soil+GW-50%	0.02	0.00	0.12	0.00	0.21	0.00	0.36	0.00	0.49	0.00	0.56	0.00	0.65	0.00	0.67	0.01	0.69	0.00
soil+GW-100%	0.01	0.00	0.05	0.00	0.06	0.01	0.17	0.02	0.45	0.00	0.56	0.00	0.68	0.00	0.69	0.00	0.73	0.00
GW-50%	0.06	0.00	0.57	0.03	0.55	0.02	2.04	0.09	2.57	0.12	3.07	0.14	3.54	0.16	3.36	0.16	3.44	0.19
GW-100%	0.05	0.00	0.38	0.02	0.39	0.03	2.07	0.02	2.79	0.02	3.31	0.03	3.83	0.03	3.75	0.05	3.80	0.08
N2O-N, ng/g	0.00		0.20		0.40		1.20		2.70		5.60		12.00		20.00		28.00	
soil-50%	0.14	0.05	1.71	0.04	2.81	0.20	19.08	4.45	26.91	1.08	39.46	7.06	47.74	6.11	32.63	6.79	30.24	6.59
soil-100%	0.44	0.45	12.23	0.92	43.79	2.06	712.81	25.72	2175.92	78.14	1532.50	39.66	773.84	25.79	271.08	51.00	209.09	14.95
soil+GW-50%	0.55	0.16	39.06	6.50	94.71	11.86	0.05	0.15	1.52	0.51	5.83	0.63	11.19	0.95	15.13	0.94	17.13	0.85
soil+GW-100%	0.10	0.03	40.38	2.31	120.68	18.58	37.02	11.05	0.25	0.00	0.88	0.24	4.00	0.97	8.85	1.84	11.80	1.83
GW-50%	6.63	0.35	7.24	1.35	333.36	51.97	0.67	0.14	1.75	0.09	5.76	0.44	3.82	0.22	0.30	0.12	1.04	2.34
GW-100%	5.74	0.15	8.82	0.91	1972.51	1216.28	0.45	0.06	0.92	0.06	1.56	0.30	3.26	0.08	0.12	0.13	0.00	0.00

Clay CH4-C, ng/g	Day																	
																	-	
		SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
Soil 50%	23.58	3.74	15.22	0.84	1.53	0.48	1.96	0.42	3.89	0.14	1.65	0.51	2.30	0.37	4.82	0.31	3.07	0.42
soil-100%	23.75	4.06	7.52	0.45	1.84	0.11	1.65	0.27	4.32	0.23	1.94	0.24	4.89	1.04	10.54	1.94	22.02	6.09
soil+GW-50%	10.56	1.38	9.73	1.05	4.71	0.18	12.07	0.19	15.94	0.35	26.16	0.34	35.66	1.66	58.18	7.54		
soil+GW-100%	17.86	1.57	7.08	0.75	1.34	0.20	7.21	0.28	13.50	0.62	30.97	2.20	42.90	2.98	52.44	2.51		
GW-50%	101.69	17.13	78.25	5.40	28.58	2.11	64.48	1.28	76.10	1.65	122.16	3.27	186.64	3.31	207.15	3.77		
GW-100%	62.18	9.64	59.20	6.05	25.88	1.60	60.59	1.87	95.51	3.06	197.06	10.13	301.31	13.33	320.81	8.13		
CO2-C, ug/g																		
soil-50%	4.87	0.20	13.86	0.38	16.55	0.60	46.66	0.89	97.74	1.54	163.07	2.36	214.54	1.19	233.16	2.79	247.72	6.03
soil-100%	2.26	0.07	4.34	0.07	7.06	1.56	17.10	0.25	43.45	0.87	85.22	1.67	149.96	2.40	176.17	1.67	188.01	6.24
soil+GW-50%	20.44	2.09	116.63	2.44	102.91	2.66	337.70	3.79	446.24	1.43	546.60	1.38	656.52	5.54	689.17	4.22	725.89	14.15
soil+GW-100%	3.84	0.47	22.47	3.39	24.76	2.78	104.37	12.70	350.87	2.99	486.45	3.54	627.03	7.69	661.40	7.79	711.80	6.74

Clay -cont.		SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
CO2-C, g/kg																		
soil-50%	0.00	0.00	0.01	0.00	0.02	0.00	0.05	0.00	0.10	0.00	0.16	0.00	0.21	0.00	0.23	0.00	0.25	0.01
soil-100%	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.04	0.00	0.09	0.00	0.15	0.00	0.18	0.00	0.19	0.01
soil+GW-50%	0.02	0.00	0.12	0.00	0.10	0.00	0.34	0.00	0.45	0.00	0.55	0.00	0.66	0.01	0.69	0.00	0.73	0.01
soil+GW-100%	0.00	0.00	0.02	0.00	0.02	0.00	0.10	0.01	0.35	0.00	0.49	0.00	0.63	0.01	0.66	0.01	0.71	0.01
GW-50%	0.06	0.00	0.57	0.03	0.55	0.02	2.04	0.09	2.57	0.12	3.07	0.14	3.54	0.16	3.36	0.16	3.44	0.19
GW-100%	0.05	0.00	0.38	0.02	0.39	0.03	2.07	0.02	2.79	0.02	3.31	0.03	3.83	0.03	3.75	0.05	3.80	0.08
N2O-N, ng/g																		
soil-50%	0.75	0.02	1.89	0.35	3.12	0.08	9.24	0.27	12.09	0.60	14.35	0.46	17.54	2.11	18.30	1.64	22.32	5.97
soil-100%	0.49	0.02	7.61	0.50	56.01	26.13	22.67	1.20	15.55	0.96	8.42	0.53	6.36	0.25	4.53	0.35	6.65	3.43
soil+GW-50%	1.16	0.07	6.95	1.74	9.14	2.20	0.09	0.01	0.21	0.01	6.02	0.34	10.06	1.02	11.17	1.11	6.16	2.06
soil+GW-100%	0.89	0.10	5.41	1.21	23.54	7.67	5.73	1.06	0.14	0.01	1.48	0.10	2.80	0.40	3.99	0.60	5.37	0.42
GW-50%	6.63	0.35	7.24	1.35	333.36	51.97	0.67	0.14	1.75	0.09	5.76	0.44	3.82	0.22	0.30	0.12	1.04	2.34
GW-100%	5.74	0.15	8.82	0.91	1972.51	1216.28	0.45	0.06	0.92	0.06	1.56	0.30	3.26	0.08	0.12	0.13	0.00	0.00

Table A-2-2. Mean O_2 concentration over time in closed vials in the silt loam soil. Control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), the GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and in GW at 50 percent (GW-50%) and 100 percent (GW-100%) of WHC.

Loam soil	soil-50%		soil-100%		soil+GW-50%		soil+GW-100%		GW-50%		GW-100%	
Days	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
0	19.74	0.18	17.86	0.14	18.59	0.17	11.18	2.93	15.83	0.21	17.45	0.10
0.08	19.29	0.20	14.63	0.48	13.86	0.06	7.50	3.96	11.32	0.42	14.73	0.18
0.19	19.12	0.23	12.98	0.98	9.69	0.11	5.38	3.62	8.68	0.27	12.62	0.19
0.27	19.09	0.21	11.76	1.41	6.93	0.14	1.11	0.74	5.54	0.29	10.33	0.31
0.4	19.12	0.20	10.73	1.96	3.38	0.15	0.07	0.03	0.06	0.04	0.65	0.54
1.2	18.18	0.20	8.43	2.98	0.04	0.03	0.03	0.01	0.02	0.01	0.03	0.01
1.7	17.34	0.30	1.45	0.00	0.04	0.02	0.03	0.01	0.04	0.01	0.03	0.00
2.7	16.75	0.35	0.41	0.00	0.04	0.02	0.04	0.01	0.05	0.01	0.04	0.00
5.6	15.18	0.50	0.04	0.00	0.07	0.00	0.07	0.02	0.04	0.01	0.03	0.01
7.5	14.61	0.54	0.03	0.01	0.06	0.02	0.08	0.03	0.05	0.03	0.04	0.01
13	13.09	0.70	0.03	0.00	0.07	0.02	0.07	0.00	0.03	0.01	0.06	0.01
28	11.92	0.92	0.03	0.01	0.09	0.02	0.06	0.00	0.03	0.01	0.03	0.00

Table A-2-3. Mean O_2 concentration over time in closed vials in the sandy soil. Control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), the GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and in GW at 50 percent (GW50%) and 100 percent (GW-100%) of WHC.

Sandy soil	soil-50%		soil-100%		soil+GW-50%		soil+GW-100%		GW-50%		GW-100%	
Days	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
0	19.42	0.07	16.35	0.95	5.19	3.15	2.08	1.76	15.83	0.21	17.45	0.10
0.08	18.88	0.07	3.35	2.40	13.25	1.04	4.20	3.87	11.32	0.42	14.73	0.18
0.19	18.60	0.04	0.94	0.89	9.76	0.35	2.94	2.89	8.68	0.27	12.62	0.19
0.27	18.46	0.09	0.18	0.13	6.77	0.35	1.06	1.02	5.54	0.29	10.33	0.31
0.4	18.35	0.12	0.05	0.01	3.14	0.36	0.13	0.09	0.06	0.04	0.65	0.54
1.2	18.03	0.05	0.05	0.01	0.03	0.01	0.06	0.02	0.02	0.01	0.03	0.01
1.7	16.91	0.16	0.04	0.01	0.05	0.03	0.08	0.04	0.04	0.01	0.03	0.00
2.7	16.18	0.09	0.04	0.01	0.04	0.00	0.06	0.02	0.05	0.01	0.04	0.00
5.6	11.56	2.72	0.04	0.01	0.05	0.00	0.09	0.02	0.04	0.01	0.03	0.01
7.5	11.58	2.44	0.04	0.01	0.05	0.00	0.10	0.02	0.05	0.03	0.04	0.01
13	10.98	2.08	0.04	0.01	0.07	0.02	0.08	0.02	0.03	0.01	0.06	0.01
28	9.88	2.54	0.04	0.00	0.06	0.00	0.11	0.02	0.03	0.01	0.03	0.00

Table A-2-3. Mean O_2 concentration over time in closed vials in the sandy soil. Control soil at 50 percent (soil-50%) and 100 percent of WHC (soil-100%), the GW-amended soil at 50 percent (soil+GW-50%) and 100 percent of WHC (soil+GW-100%), and in GW at 50 percent (GW50%) and 100 percent (GW-100%) of WHC.

Clay soil	soil-50%		soil-100%		soil+GW-50%		soil+GW-100%		GW-50%		GW-100%	
Days	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
0	19.63	0.14	13.68	1.58	13.48	4.38	1.56	1.42	15.83	0.21	17.45	0.10
0.08	18.91	0.11	3.06	2.88	12.56	1.47	3.95	3.89	11.32	0.42	14.73	0.18
0.19	18.65	0.12	1.55	1.49	7.97	1.79	4.03	3.97	8.68	0.27	12.62	0.19
0.27	18.26	0.16	0.64	0.59	5.16	1.49	3.74	3.69	5.54	0.29	10.33	0.31
0.4	18.05	0.19	0.10	0.04	2.63	0.76	3.13	3.07	0.06	0.04	0.65	0.54
1.2	16.89	0.11	0.04	0.01	0.02	0.01	0.04	0.01	0.02	0.01	0.03	0.01
1.7	14.64	0.16	0.07	0.03	0.03	0.00	0.10	0.07	0.04	0.01	0.03	0.00
2.7	13.28	0.23	0.05	0.01	0.04	0.00	0.05	0.00	0.05	0.01	0.04	0.00
5.6	10.79	0.11	0.05	0.01	0.07	0.01	0.08	0.01	0.04	0.01	0.03	0.01
7.5	9.52	0.12	0.03	0.01	0.06	0.01	0.08	0.01	0.05	0.03	0.04	0.01
13	7.11	0.20	0.04	0.01	0.07	0.01	0.08	0.01	0.03	0.01	0.06	0.01
28	5.61	0.37	2.69	2.65	0.07	0.01	0.09	0.01	0.03	0.01	0.03	0.00

Table A-2-4. Dynamics of NH_4^+ concentration in the incubation soils.

NH_4^+ ug/g	Treatment Type	Day 0		Day 7		Day 14		Day 21		Day 27	
		Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
Sandy soil	soil~50%	2.93	0.07	0.04	0.02	0.35	0.03	0.20	0.02	0.32	0.01
	soil~100%	2.93	0.07	3.08	0.54	0.40	0.07	0.33	0.03	1.76	0.13
	soil+GW~50%	1.62	0.11	1.80	0.96	3.95	0.96	11.84	0.49	10.47	2.67
	soil+GW~100%	1.62	0.11	0.00	0.00	0.46	0.39	1.54	1.01	7.94	5.86
Loam soil	soil~50%	0.30	0.29	0.00	0.00	0.23	0.02	0.01	0.08	0.02	0.01
	soil~100%	0.30	0.29	0.22	0.22	0.52	0.08	0.19	0.03	4.91	0.64
	soil+GW~50%	0.66	0.05	2.64	1.22	1.61	0.70	5.47	0.64	2.55	0.70
	soil+GW~100%	0.66	0.05	0.00	0.00	0.37	0.10	0.60	0.16	0.63	0.29
Clay soil	soil~50%	3.60	0.09	0.00	0.00	0.18	0.04	0.46	0.08	0.15	0.06
	soil~100%	3.60	0.09	1.61	0.82	1.28	0.13	1.70	0.29	4.68	0.40
	soil+GW~50%	1.13	0.16	1.58	0.27	2.04	0.77	7.44	0.87	3.66	0.33
	soil+GW~100%	1.13	0.16	0.77	0.39	0.00	0.00	0.45	0.21	0.71	0.26
	GW~50%	11.04	0.74	21.89	9.19	37.51	20.04	98.15	8.11	72.28	2.56
	GW~100%	11.04	0.74	0.00	0.00	5.58	0.53	23.76	2.19	41.77	5.16

Table A-2-5. Dynamics of NO_3^- concentration in the incubation soils.

NO_3^- ug/g	Treatment Type	Day 0		Day 7		Day 14		Day 21		Day 27	
		Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
Sandy soil	soil~50%	21.00	0.30	31.94	1.60	32.30	0.44	35.24	0.55	38.14	0.31
	soil~100%	21.00	0.30	21.98	6.27	16.10	1.84	22.25	0.77	0.00	0.00
	soil+GW~50%	19.63	0.47	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00
	soil+GW~100%	19.63	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Loam soil	soil~50%	20.90	0.25	34.59	1.05	35.06	0.18	35.37	0.65	39.26	1.30
	soil~100%	20.90	0.25	15.08	7.21	31.70	3.33	37.99	2.97	0.10	0.00
	soil+GW~50%	20.12	0.53	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
	soil+GW~100%	20.12	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clay soil	soil~50%	0.52	0.02	10.14	0.18	10.10	0.77	10.88	1.44	16.41	0.25
	soil~100%	0.52	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	soil+GW~50%	7.21	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	soil+GW~100%	7.21	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	GW~50%	27.54	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	GW~100%	27.54	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A-2-6. Dynamics of DOC concentration in the incubation soils.

DOC g/kg	Treatment Type	Day 0		Day 7		Day 14		Day 21		Day 27	
		Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
Sandy soil	soil~50%	0.12	0.00	0.43	0.08	0.30	0.01	0.26	0.01	0.24	0.01
	soil~100%	0.12	0.00	0.35	0.01	0.40	0.09	0.28	0.01	0.27	0.01
	soil+GW~50%	2.31	0.01	13.66	3.93	20.02	1.89	24.55	3.83	32.00	0.61
	soil+GW~100%	2.31	0.01	17.75	0.11	22.54	0.31	22.66	1.97	34.29	0.00
Loam soil	soil~50%	0.04	0.00	0.22	0.03	0.33	0.04	0.25	0.01	0.15	0.01
	soil~100%	0.04	0.00	0.25	0.02	0.37	0.11	0.40	0.03	0.17	0.00
	soil+GW~50%	1.93	0.08	11.33	4.54	18.95	1.51	20.77	2.51	32.46	0.00
	soil+GW~100%	1.93	0.08	16.49	0.54	20.02	1.36	26.44	0.63	35.20	1.22
Clay soil	soil~50%	0.05	0.02	0.27	0.06	0.30	0.07	0.13	0.00	0.12	0.00
	soil~100%	0.05	0.02	0.50	0.06	0.28	0.05	0.77	0.17	0.21	0.01
	soil+GW~50%	1.91	0.04	11.71	3.03	9.80	5.73	20.77	2.03	30.17	0.61
	soil+GW~100%	1.91	0.04	13.60	5.48	21.72	0.22	22.66	0.63	34.29	1.06
	GW~50%	2.41	0.04	13.79	4.37	15.99	5.47	22.66	1.09	28.80	3.39
	GW~100%	2.41	0.04	18.32	0.79	21.15	0.58	26.44	2.27	31.09	0.61

Appendix B. Green Waste Characterization Raw Data.

Table B-1. Raw data for determination of green waste (GW) density. (density = mass / volume)

GW Sample	Density(g/mL)	Mass (g)	Volume (mL)
1	0.23	72.5	320
2	0.32	122	380
3	0.29	135	460
4	0.25	78	310
5	0.19	67	350
6	0.41	244	600
7	0.35	698	2000

Table B-2. Results from commercial green waste (GW) testing lab analysis.

GW Sample	Density (g/mL)	E coli (MPN/ g DW)	Salmonella (MPN/ 4g DW)	N (% Wet Basis)	C (% Wet Basis)	C:N (C/N)	Moisture Content (%)
Autumn 2013							
1	0.23	<2	<3	0.61	30	49.2	25.3
2	0.32	>1600	<3	0.7	15	21.4	47.7
3	0.29	>1200	<3	0.67	15	22.4	29.7
4	0.25	6.9	<3	0.67	24	35.8	40.6
5	0.19	42	<3	0.54	31	57.4	29
6	0.41	>1100	<3	0.3	8.9	29.7	28.9
7	0.35	180	<3	0.84	21	25.0	32.2
Spring 2014							
1	0.27	>1100	<3	0.50	15	29.2	31.3
2	0.3	>1500	<3	0.49	19	39.1	47.2
3	0.28	230	<3	0.74	23	30	36.7
4	0.29	>1200	<3	0.52	26	48.7	31
5	0.24	>1200	<3	0.41	24	57.6	37.6
6	0.37	>1300	<3	0.67	16	23.6	38.3
7	0.31	6	<3	0.83	24	29.2	35.2

Table B-3. Fraction of criteria metals in green waste (GW) samples (in mg/kg-dry weight).

GW Sample	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn	Co
Autumn 2013											
1	1.2	<1	13	46	4.7	<1	1.1	4.9	<1	52	1.3
2	2.9	1.4	16	57	22	<1	3.3	12	<1	130	3.3
3	2.1	<1	33	37	16	<1	1.4	10	<1	130	4.3
4	1.1	<1	11	23	7.9	<1	1.6	5.3	<1	76	1.4
5	<1	<1	6.3	16	3.6	<1	<1	4.1	<1	43	<1
6	4.2	<1	44	60	67	<1	1.5	19	<1	130	4.4
7	3.6	<1	28	42	25	<1	1.3	19	<1	120	4.4
Spring 2014											
1	3.6	<1	30	46	17	<1	1.6	11	<1	77	4.5
2	4	<1	29	54	14	<1	2.1	12	<1	82	2.9
3	3.2	<1	39	45	25	<1	1.5	14	<1	87	2.6
4	6.1	<1	25	98	9.5	<1	1.3	9.8	<1	77	2.3
5	6.4	<1	17	34	3.4	<1	<1	6.1	<1	39	2.5
6	4	<1	44	44	27	<1	12	12	<1	93	3.6
7	6.8	<1	30	88	16	<1	<1	19	<1	99	3.4

Table B-4. Fraction of other metals in green waste (GW) samples (in mg/kg dry weight) – Part 1.

GW Sample	Li	Be	Na	Mg	Al	K	Ca	V
Autumn 2013								
1	0.82	0.00	1098.28	631.69	7.97	8062.81	537.15	0.04
2	2.66	0.00	1901.63	968.59	42.84	10724.62	1776.00	0.42
3	0.44	0.00	1392.96	1444.73	56.42	7746.20	2902.53	0.54
4	1.77	0.00	2637.32	1114.56	37.35	12164.82	1390.41	0.21
5	0.65	0.00	1198.04	920.93	4.28	8588.11	1131.91	0.03
6	0.11	0.00	430.66	457.92	31.07	2510.93	1102.28	0.22
7	1.18	0.00	1569.65	2697.80	62.37	16388.07	3802.03	0.29
Spring 2014								
1	0.42	0.00	1741.93	699.67	9.72	12412.77	1009.99	0.10
2	0.66	0.01	841.80	1023.37	9.33	5116.84	1347.83	0.07
3	0.20	0.00	1155.16	1077.54	1.82	9131.67	2171.05	0.02
4	0.28	0.00	498.14	518.94	0.60	2431.81	2145.26	0.01
5	0.08	0.00	164.61	369.35	0.84	1999.73	898.90	0.01
6	0.04	0.00	216.47	327.12	1.34	2491.61	560.78	0.03
7	0.15	0.01	798.26	1254.21	11.16	7014.59	2304.53	0.05

Table B-5. Fraction of other metals in green waste (GW) samples (in mg/kg dry weight) – Part 1.

GW Sample	Mn	Fe	Rb	Sr	Ag	Cs	Ba	Tl	U
Autumn 2013									
1	3.61	18.96	1.91	2.65	0.00	0.00	0.78	0.00	0.01
2	3.27	123.67	2.31	4.78	0.01	0.01	1.35	0.00	0.02
3	13.02	167.50	2.91	13.64	0.01	0.01	2.83	0.00	0.04
4	6.55	95.84	3.10	7.77	0.01	0.01	1.20	0.00	0.02
5	6.11	15.99	1.74	4.44	0.00	0.00	0.61	0.00	0.00
6	3.64	85.12	0.60	5.15	0.00	0.00	1.33	0.00	0.01
7	39.76	132.71	2.47	14.74	0.00	0.01	2.81	0.00	0.01
Spring									
1	7.11	181.60	0.94	5.49	0.00	0.00	1.06	0.00	0.01
2	19.02	36.63	1.15	6.19	0.00	0.00	1.30	0.00	0.01
3	8.51	27.87	1.49	7.12	0.00	0.00	0.77	0.00	0.00
4	4.59	18.47	0.59	7.88	0.00	0.00	0.72	0.00	0.00
5	3.36	11.47	0.57	3.26	0.00	0.00	0.46	0.00	0.00
6	4.48	18.80	0.58	2.23	0.00	0.00	0.62	0.00	0.00
7	32.33	39.04	1.12	7.37	0.00	0.00	1.93	0.00	0.01

Appendix C. Data for Soil Solution Samples.

Table C-1-1. Concentration of metals in soil solution water collected by lysimeters in 2013 – February through March.

Month	Plot	Treatment	Li ppb	Be ppb	Na ppb	Mg ppb	Al ppb	K ppb	Ca ppb	V ppb	Cr ppb
Feb	1	12" GW	68.35	0.01	23020	178800	33.18	36130	210300	194	12.75
Feb	8		41.44	0.01	27840	102000	17.23	7004	104700	93.81	6.33
Feb	14		67.41	0.02	22490	167000	17.69	20920	144600	166.1	8.99
Mar	1		70.27	0.01	46550	190100	23.86	29500	225600	166	9.65
Mar	8		42.23	0.01	41330	116300	24.98	5567	113800	75.42	7.52
Mar	14		65.52	0.02	29710	174500	20.6	18140	150700	109.1	7.06
Feb	5	6" GW	38.88	0.01	18010	90980	19.86	21250	85880	88.35	3.67
Feb	7		55.36	0.01	13860	84370	226	8468	85340	246.1	7.92
Feb	15		44.99	0.01	19070	102200	24.13	7563	90000	157.4	11.36
Mar	5		31.6	0.02	25470	86740	15.47	17350	81740	57.13	3.51
Mar	7		54.76	0.01	17580	99050	31.49	9679	100800	195.1	6.87
Mar	15		34.51	0.01	20310	70300	9.53	4451	63240	126.1	4.13
Feb	3	6" GW,	46.75	0.02	35180	161400	14.4	23920	151000	145.7	10.41
Feb	10	disked	61.62	0.02	16310	104800	22.9	11350	94420	217.8	10.48
Feb	12		59.04	0.01	20070	108900	26.12	8090	99610	249.1	8.94
Mar	3		34.32	0.01	38820	121400	17.33	16500	109900	111.1	7.39
Mar	10		44.83	0.01	15410	86100	13.75	7112	83480	158	4.31
Mar	12		31.72	0.01	22190	85250	12.05	4927	76860	95.93	3.04
Feb	2	Control	36.45	0.02	12180	39650	27.7	15590	46480	137.7	14.1
Feb	6		44.54	0.02	9315	46190	19.39	13100	46400	167.8	13.09
Feb	13		33.05	0.01	7065	47910	17.88	3732	43210	138.3	12.61
Mar	2		29.84	0.01	12090	30380	8.93	13250	38510	103.8	7.66
Mar	6		33.96	0.01	8470	37420	4.78	10460	37790	104.8	8.71
Feb	4	Control,	52.71	0.01	13400	48560	35.83	14590	52370	228.4	19.34
Feb	11	disked	43.13	0.01	14070	78220	31.77	9684	70810	166.2	5.15
Mar	4		33.39	0.01	10610	38010	16.61	11230	41440	145.2	7.82
Mar	9		32.23	0.01	10750	37120	12.91	4109	35870	150.4	4.99

Table C-1-1. Concentration of metals in soil solution water collected by lysimeters in 2013 – February through March (continued).

Month	Plot	Treatment	Fe ppb	Mn ppb	Co ppb	Ni ppb	Cu ppb	Zn ppb	As ppb	Se ppb
Feb	1	12" GW	21.99	72.74	5.93	69.5	19.86	45.17	28.94	3.6
Feb	8		9.21	57.24	3.56	44.73	8.65	45.11	12.79	1.87
Feb	14		12.36	83.83	5.9	51.37	12.41	39.83	21.89	2.3
Mar	1		20.03	75.98	5.52	73.1	17.46	86.75	23.89	3.21
Mar	8		11.19	37.37	2.85	37.77	8.32	41.3	10.97	0.52
Mar	14		11.12	162.4	4.88	52.4	10.82	36.63	15.57	1.5
Feb	5	6" GW	68.43	1294	15.55	86.18	11.02	29.02	11.05	2.32
Feb	7		292.5	94.37	4.85	34.62	8.63	44.67	17.21	1.89
Feb	15		16.76	52.25	5.5	39.75	9.12	42.82	18.71	2.15
Mar	5		625.6	1052	10.39	75.99	8.14	32.94	11.72	0.49
Mar	7		22.75	77.15	5.41	40.69	5.75	57.71	22.64	0.91
Mar	15		14.58	223.5	4.61	38.93	6.34	31.06	18	0
Feb	3	6" GW,	15.32	184.7	16.55	91.87	22.5	35.33	14.08	3.29
Feb	10	disked	23.8	127.6	7.09	45.79	10.71	45.66	17.28	3.05
Feb	12		21.12	431.4	11.46	61.09	10.38	39.52	19.28	2.85
Mar	3		17.63	170.8	9.1	72.41	15.05	26.44	11.93	2.16
Mar	10		4.61	257.8	5.25	39.88	6.8	42.44	19.1	0.56
Mar	12		71.98	1119	11.28	63.24	5.67	29.73	13.43	0.4
Feb	2	Control	31.45	31.76	2.04	30.12	9.53	50.56	9.86	1.16
Feb	6		16.67	46.54	2.22	31.63	8.46	50.73	11.09	1.35
Feb	13		14.39	23.58	3.23	24.69	6.72	49.81	8.3	2.13
Mar	2		5.55	37.14	1.44	24.37	6.26	29.3	10.26	0.69
Mar	6		4.14	40.82	1.4	23.48	6.1	26.51	11.51	0
Feb	4	Control,	42.79	52.7	2.54	29.08	8.05	50.38	14.25	1.6
Feb	11	disked	31.85	193.3	6.02	47.71	14.46	36.64	16.05	2.48
Mar	4		9.48	52.71	1.46	20.58	4.76	23.38	15.07	0
Mar	9		3.12	62.61	1.62	21.83	3.87	37.58	14.24	0

Table C-1-1. Concentration of metals in soil solution water collected by lysimeters in 2013 – February through March (continued).

Month	Plot	Treatment	Rb ppb	Sr ppb	Cd ppb	Cs ppb	Ba ppb	Tl ppb	Pb ppb	U ppb
Feb	1	12" GW	9.1	2527	0.13	0.48	868.6	0.07	1.07	9.6
Feb	8		3.82	1373	0.11	0.33	515.1	0.03	0.26	3.78
Feb	14		7.47	2058	0.13	0.61	601.1	0.05	0.4	4.63
Mar	1		7.92	2773	0.17	0.37	828.6	0.05	0.46	9.3
Mar	8		3.25	1611	0.13	0.26	570.3	0.02	0.92	3.91
Mar	14		6.56	2228	0.16	0.35	557.2	0.04	0.58	5.15
Feb	5	6" GW	5	1120	0.1	0.4	512.6	0.05	0.25	5.45
Feb	7		6.73	997.4	0.09	0.29	290.5	0.03	0.77	4.33
Feb	15		4.56	1247	0.11	0.32	359.1	0.02	0.82	3.77
Mar	5		4.53	1076	0.11	0.25	413	0.03	1.29	4.47
Mar	7		6.91	1226	0.25	0.35	375.8	0.02	0.41	3.84
Mar	15		3	875.1	0.09	0.2	193.7	0.01	0.3	3.22
Feb	3	6" GW,	6.07	1927	0.13	0.51	574.1	0.07	0.37	12.21
Feb	10	disked	7.57	1296	0.11	0.52	425.7	0.04	0.53	3.7
Feb	12		7.11	1316	0.1	0.43	334.3	0.03	0.38	5.34
Mar	3		4.71	1401	0.13	0.31	358.2	0.03	0.17	12.28
Mar	10		5.08	1046	0.12	0.28	249.2	0.02	0.31	3.29
Mar	12		3.78	1067	0.1	0.24	225.6	0.02	0.61	5.07
Feb	2	Control	4.6	537.8	0.14	0.44	270.4	0.05	2.31	2.22
Feb	6		5.74	591.6	0.1	0.47	254.3	0.04	0.46	1.87
Feb	13		4.44	575.9	0.12	0.22	198.2	0.01	0.33	1.63
Mar	2		3.53	434.8	0.1	0.28	195.5	0.02	0.21	1.38
Mar	6		4.01	487.9	0.1	0.28	173.4	0.02	0.3	1.08
Feb	4	Control,	7.03	619.7	0.11	0.53	303.5	0.04	1.32	2.56
Feb	11	disked	6.47	917.7	0.1	0.45	349.4	0.03	0.67	2.57
Mar	4		4.67	484.2	0.09	0.3	172	0.02	1.03	1.67
Mar	9		3.77	460.9	0.1	0.2	166.5	0.01	0.71	1.46

Table C-1-2. Concentration of metals in soil solution water collected by lysimeters in 2013 – June through September.

Month	Plot	Treatment	Li ppb	Be ppb	Na ppb	Mg ppb	Al ppb	K ppb	Ca ppb	V ppb	Mn ppb
June	2	12" GW	47.34	0.09	38730	74900	8.3	31960	109400	222.8	121
Sept	2		41.38	0.06	50050	90890	8.96	33820	110600	48.92	44.57
Sept	8		37.18	0.07	121000	357900	21.84	11480	312000	31.16	10.16
Sept	15		34.32	0.09	46000	231400	20.96	10070	195100	42.05	7.06
Sept	11	6" GW	36.16	0.06	45070	179400	6.7	8572	151000	72.82	119.7
Sept	9		27.08	0.06	42060	88400	9.49	7449	84080	75.88	18.56
June	4	6" GW,	43.11	0.09	39030	136300	11.61	39060	153000	280.4	20.36
June	6	disked	50.22	0.08	30020	120400	11.31	30950	132200	186.4	56.36
Sept	4		35.26	0.05	32710	90840	5.67	28060	105000	93.89	30.09
Sept	6		41.67	0.07	35730	132900	6.74	28940	121400	46.45	33.42
Sept	13		28.43	0.05	20890	124900	11.59	4405	115500	94.4	32.14
June	10	Control	50.37	0.13	64240	210100	16.6	15360	175700	177.2	50.19
Sept	3		44.48	0.07	97000	303700	24.58	52390	269700	95.99	19.31
Sept	10		41.12	0.06	61410	213900	6.16	10570	177700	68.59	14.22
June	11	Control,	42.5	0.07	36160	139900	15.25	12340	146000	233.6	171
June	12	disked	39.63	0.1	51000	211800	13.33	10640	188500	123.8	47.23
Sept	5		39.35	0.04	83000	215000	14.46	33140	209000	60.8	18.89
Sept	7		35.44	0.06	66750	182900	13.48	16510	167400	41.24	4.66
Sept	12		30.83	0.06	85730	231200	6.32	6730	196300	31.57	18.31

Table C-1-2. Concentration of metals in soil solution water collected by lysimeters in 2013 – June through September (continued).

Month	Plot	Treatment	Fe ppb	Co ppb	Rb ppb	Sr ppb	Ag ppb	Cs ppb	Ba ppb	Tl ppb	U ppb
June	2	12" GW	442.7	2.28	6.44	416.8	0	0.44	265.8	0.04	0.81
Sept	2		415.9	1.49	4.17	513.7	0.01	0.24	366.6	0.03	1.44
Sept	8		1400	1.48	2.34	1851	0	0.15	623.1	0.02	4.42
Sept	15		891.6	2.05	2.43	1156	0	0.16	460.5	0.02	2.27
Sept	11	6" GW	635.9	2.05	3.4	843.6	0	0.17	264	0.02	1.73
Sept	9		364.8	0.72	2.98	435.6	0	0.16	237.9	0.01	1.11
June	4	6" GW,	655.9	1.26	7.35	643.4	0	0.41	342.2	0.04	3.24
June	6	disked	546.4	1.86	6.29	646.5	0	0.43	359.5	0.04	0.79
Sept	4		402.2	1.19	5.26	491.2	0	0.21	314.8	0.02	1.35
Sept	6		517.8	1.48	4	737.2	0	0.24	368.7	0.03	1.14
Sept	13		479.8	0.98	3.13	608.4	0	0.13	271.9	0.01	1.2
June	10	Control	784.6	2.92	6.23	923.8	0	0.38	265	0.02	2.87
Sept	3		1145	2.43	7.16	1459	0.01	0.32	569.7	0.04	8.28
Sept	10		714.1	1.77	3.17	1091	0	0.17	307.8	0.02	1.63
June	11	Control,	605.1	2.81	5.8	612.5	0	0.3	312.6	0.02	2.32
June	12	disked	817.8	3.7	4.39	1015	0	0.28	305.9	0.02	6.34
Sept	5		837.9	2.95	4.29	1124	0	0.21	427	0.03	4.49
Sept	7		703.1	1.56	2.31	988.3	0	0.13	438.9	0.01	1.65
Sept	12		848.7	1.99	2.07	1185	0	0.13	352.4	0.01	2.88

Appendix C-2. Reports from Commercial Testing Lab.

ANALYTICAL CHEMISTS
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SOIL CONTROL LAB

42 HANGAR WAY
WATSONVILLE
CALIFORNIA
95076
USA

TEL: 831-724-5422
FAX: 831-724-3188
www.compostlab.com

Account #: 3120507-1/7-6680
Group: Dec.13 C #40
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: RL1 - 1RL
Sample ID #: 3120507 - 1/7

Metals & Bacteria

Metals		Results	Units	MDL	% Recovery	Date Tested
Arsenic (As):		1.2	mg/kg dw	1.0	91.9	26 Dec. 13
Cadmium (Cd):	Less than	1.0	mg/kg dw	1.0	94.3	26 Dec. 13
Chromium (Cr):		13	mg/kg dw	1.0	89.5	26 Dec. 13
Copper (Cu):		46	mg/kg dw	1.0	90.2	26 Dec. 13
Lead (Pb):		4.7	mg/kg dw	1.0	89.8	26 Dec. 13
Mercury (Hg):	Less than	1.0	mg/kg dw	1.0	86.6	26 Dec. 13
Molybdenum (Mo):		1.1	mg/kg dw	1.0	95.3	26 Dec. 13
Nickel (Ni):		4.9	mg/kg dw	1.0	94.5	26 Dec. 13
Selenium (Se):	Less than	1.0	mg/kg dw	1.0	94.9	26 Dec. 13
Zinc (Zn):		52	mg/kg dw	1.0	93.5	26 Dec. 13
Cobalt (Co)		1.3	mg/kg dw	1.0	90.2	26 Dec. 13
Total Solids (TMECC 03.09)		75	%	0.05	NA	20 Dec. 13

Bacteria		Results	Units	MDL		Date Tested
E. Coli	Less than	2.0	MPN/g dw	2		17 Dec. 13
Salmonella	Less than	3	MPN/4g dw	3		17 Dec. 13

Pollutant Loading Rate:
Multiply mg/kg dry weight values times 0.0678 to give you kilograms pollutant per 100 metric ton compost as-received based on a moisture content of 25.3 percent.

Method (metals): EPA 3050B / EPA 6010
Method (metals): TMECC 04.12-B / 04.14-A
Method (Mercury Hg) TMECC 04.06 / EPA 7471
Method (E. Coli): TMECC 07.01-C
Method (Salmonella): TMECC 04.02-A

Analyst: Assaf Sadeh

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Account #: 3120507-1/7-6680
Group: Dec.13 C #40
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: RL1 - 1RL
Sample ID #: 3120507 - 1/7

	Units	Wet wt. Basis	Dry wt. Basis	TMECC Method
Total Nitrogen:	%	0.61	0.81	4.02-D
Organic Carbon:	%	30	40	4.01
C/N Ratio	ratio	50	50	calc.
Moisture:	%	25.3	0	3.09

To Calculate lbs/ton: (%Nutrient) x (20)
To Calculate lbs/ton: (mg/kg Nutrient/10,000) x (20)

Analyst: Assaf Sadeh

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Account #: 3120507-2/7-6680
Group: Dec.13 C #41
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: CL2 - 2CL
Sample ID #: 3120507 - 2/7

Metals & Bacteria

Metals		Results	Units	MDL	% Recovery	Date Tested
Arsenic (As):		2.9	mg/kg dw	1.0	91.9	26 Dec. 13
Cadmium (Cd):		1.4	mg/kg dw	1.0	94.3	26 Dec. 13
Chromium (Cr):		16	mg/kg dw	1.0	89.5	26 Dec. 13
Copper (Cu):		57	mg/kg dw	1.0	90.2	26 Dec. 13
Lead (Pb):		22	mg/kg dw	1.0	89.8	26 Dec. 13
Mercury (Hg):	Less than	1.0	mg/kg dw	1.0	86.6	26 Dec. 13
Molybdenum (Mo):		3.3	mg/kg dw	1.0	95.3	26 Dec. 13
Nickel (Ni):		12	mg/kg dw	1.0	94.5	26 Dec. 13
Selenium (Se):	Less than	1.0	mg/kg dw	1.0	94.9	26 Dec. 13
Zinc (Zn):		130	mg/kg dw	1.0	93.5	26 Dec. 13
Cobalt (Co)		3.3	mg/kg dw	1.0	90.2	26 Dec. 13
Total Solids (TMECC 03.09)		52	%	0.05	NA	20 Dec. 13

Bacteria		Results	Units	MDL		Date Tested
E. Coli	Greater than	1600	MPN/g dw	2		17 Dec. 13
Salmonella	Less than	3	MPN/4g dw	3		17 Dec. 13

Pollutant Loading Rate:
Multiply mg/kg dry weight values times 0.0474 to give you kilograms pollutant per 100 metric ton compost as-received based on a moisture content of 47.7 percent.

Method (metals): EPA 3050B / EPA 6010
Method (metals): TMECC 04.12-B / 04.14-A
Method (Mercury Hg) TMECC 04.06 / EPA 7471
Method (E. Coli): TMECC 07.01-C
Method (Salmonella): TMECC 04.02-A

Analyst: Assaf Sadeh

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Group: Dec.13 C #41
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: CL2 - 2CL
Sample ID #: 3120507 - 2/7

	Units	Wet wt. Basis	Dry wt. Basis	TMECC Method
Total Nitrogen:	%	0.70	1.3	4.02-D
Organic Carbon:	%	15	29	4.01
C/N Ratio	ratio	21	21	calc.
Moisture:	%	47.7	0	3.09

To Calculate lbs/ton: (%Nutrient) x (20)
To Calculate lbs/ton: (mg/kg Nutrient/10,000) x (20)

Analyst: Assaf Sadeh

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Account #: 3120507-3/7-6680
Group: Dec.13 C #42
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: BR3 - 3BR
Sample ID #: 3120507 - 3/7

Metals & Bacteria

Metals		Results	Units	MDL	% Recovery	Date Tested
Arsenic (As):		2.1	mg/kg dw	1.0	91.9	26 Dec. 13
Cadmium (Cd):	Less than	1.0	mg/kg dw	1.0	94.3	26 Dec. 13
Chromium (Cr):		33	mg/kg dw	1.0	89.5	26 Dec. 13
Copper (Cu):		37	mg/kg dw	1.0	90.2	26 Dec. 13
Lead (Pb):		16	mg/kg dw	1.0	89.8	26 Dec. 13
Mercury (Hg):	Less than	1.0	mg/kg dw	1.0	86.6	26 Dec. 13
Molybdenum (Mo):		1.4	mg/kg dw	1.0	95.3	26 Dec. 13
Nickel (Ni):		10	mg/kg dw	1.0	94.5	26 Dec. 13
Selenium (Se):	Less than	1.0	mg/kg dw	1.0	94.9	26 Dec. 13
Zinc (Zn):		130	mg/kg dw	1.0	93.5	26 Dec. 13
Cobalt (Co)		4.3	mg/kg dw	1.0	90.2	26 Dec. 13
Total Solids (TMECC 03.09)		70	%	0.05	NA	20 Dec. 13

Bacteria		Results	Units	MDL		Date Tested
E. Coli	Greater than	1200	MPN/g dw	2		17 Dec. 13
Salmonella	Less than	3	MPN/4g dw	3		17 Dec. 13

Pollutant Loading Rate:
Multiply mg/kg dry weight values times 0.0638 to give you kilograms pollutant per 100 metric ton compost as-received based on a moisture content of 29.7 percent.

Method (metals): EPA 3050B / EPA 6010
Method (metals): TMECC 04.12-B / 04.14-A
Method (Mercury Hg) TMECC 04.06 / EPA 7471
Method (E. Coli): TMECC 07.01-C
Method (Salmonella): TMECC 04.02-A

Analyst: Assaf Sadeh

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Group: Dec.13 C #42
Reporting Date: January 2, 2014

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Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: BR3 - 3BR
Sample ID #: 3120507 - 3/7

	Units	Wet wt. Basis	Dry wt. Basis	TMECC Method
Total Nitrogen:	%	0.67	0.95	4.02-D
Organic Carbon:	%	15	21	4.01
C/N Ratio	ratio	22	22	calc.
Moisture:	%	29.7	0	3.09

To Calculate lbs/ton: (%Nutrient) x (20)
To Calculate lbs/ton: (mg/kg Nutrient/10,000) x (20)

Analyst: Assaf Sadeh

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Account #: 3120507-4/7-6680
Group: Dec.13 C #43
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: TI4 - 4TI
Sample ID #: 3120507 - 4/7

Metals & Bacteria

Metals		Results	Units	MDL	% Recovery	Date Tested
Arsenic (As):		1.1	mg/kg dw	1.0	91.9	26 Dec. 13
Cadmium (Cd):	Less than	1.0	mg/kg dw	1.0	94.3	26 Dec. 13
Chromium (Cr):		11	mg/kg dw	1.0	89.5	26 Dec. 13
Copper (Cu):		23	mg/kg dw	1.0	90.2	26 Dec. 13
Lead (Pb):		7.9	mg/kg dw	1.0	89.8	26 Dec. 13
Mercury (Hg):	Less than	1.0	mg/kg dw	1.0	86.6	26 Dec. 13
Molybdenum (Mo):		1.6	mg/kg dw	1.0	95.3	26 Dec. 13
Nickel (Ni):		5.3	mg/kg dw	1.0	94.5	26 Dec. 13
Selenium (Se):	Less than	1.0	mg/kg dw	1.0	94.9	26 Dec. 13
Zinc (Zn):		76	mg/kg dw	1.0	93.5	26 Dec. 13
Cobalt (Co)		1.4	mg/kg dw	1.0	90.2	26 Dec. 13
Total Solids (TMECC 03.09)		59	%	0.05	NA	20 Dec. 13

Bacteria		Results	Units	MDL		Date Tested
E. Coli		6.9	MPN/g dw	2		17 Dec. 13
Salmonella	Less than	3	MPN/4g dw	3		17 Dec. 13

Pollutant Loading Rate:
Multiply mg/kg dry weight values times 0.0539 to give you kilograms pollutant per 100 metric ton compost as-received based on a moisture content of 40.6 percent.

Method (metals): EPA 3050B / EPA 6010
Method (metals): TMECC 04.12-B / 04.14-A
Method (Mercury Hg) TMECC 04.06 / EPA 7471
Method (E. Coli): TMECC 07.01-C
Method (Salmonella): TMECC 04.02-A

Analyst: Assaf Sadeh

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Account #: 3120507-4/7-6680
Group: Dec.13 C #43
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: TI4 - 4TI
Sample ID #: 3120507 - 4/7

	Units	Wet wt. Basis	Dry wt. Basis	TMECC Method
Total Nitrogen:	%	0.67	1.1	4.02-D
Organic Carbon:	%	24	40	4.01
C/N Ratio	ratio	36	36	calc.
Moisture:	%	40.6	0	3.09

To Calculate lbs/ton: (%Nutrient) x (20)
To Calculate lbs/ton: (mg/kg Nutrient/10,000) x (20)

Analyst: Assaf Sadeh

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Account #: 3120507-5/7-6680
Group: Dec.13 C #44
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: VC5 - 5VC
Sample ID #: 3120507 - 5/7

Metals & Bacteria

Metals		Results	Units	MDL	% Recovery	Date Tested
Arsenic (As):	Less than	1.0	mg/kg dw	1.0	91.9	26 Dec. 13
Cadmium (Cd):	Less than	1.0	mg/kg dw	1.0	94.3	26 Dec. 13
Chromium (Cr):		6.3	mg/kg dw	1.0	89.5	26 Dec. 13
Copper (Cu):		16	mg/kg dw	1.0	90.2	26 Dec. 13
Lead (Pb):		3.6	mg/kg dw	1.0	89.8	26 Dec. 13
Mercury (Hg):	Less than	1.0	mg/kg dw	1.0	86.6	26 Dec. 13
Molybdenum (Mo):	Less than	1.0	mg/kg dw	1.0	95.3	26 Dec. 13
Nickel (Ni):		4.1	mg/kg dw	1.0	94.5	26 Dec. 13
Selenium (Se):	Less than	1.0	mg/kg dw	1.0	94.9	26 Dec. 13
Zinc (Zn):		43	mg/kg dw	1.0	93.5	26 Dec. 13
Cobalt (Co)	Less than	1.0	mg/kg dw	1.0	90.2	26 Dec. 13
Total Solids (TMECC 03.09)		71	%	0.05	NA	20 Dec. 13

Bacteria		Results	Units	MDL		Date Tested
E. Coli		42	MPN/g dw	2		17 Dec. 13
Salmonella	Less than	3	MPN/4g dw	3		17 Dec. 13

Pollutant Loading Rate:
Multiply mg/kg dry weight values times 0.0644 to give you kilograms pollutant per 100 metric ton compost as-received based on a moisture content of 29.0 percent.

Method (metals): EPA 3050B / EPA 6010
Method (metals): TMECC 04.12-B / 04.14-A
Method (Mercury Hg) TMECC 04.06 / EPA 7471
Method (E. Coli): TMECC 07.01-C
Method (Salmonella): TMECC 04.02-A

Analyst: Assaf Sadeh

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Account #: 3120507-5/7-6680
Group: Dec.13 C #44
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: VC5 - 5VC
Sample ID #: 3120507 - 5/7

	Units	Wet wt. Basis	Dry wt. Basis	TMECC Method
Total Nitrogen:	%	0.54	0.76	4.02-D
Organic Carbon:	%	31	44	4.01
C/N Ratio	ratio	58	58	calc.
Moisture:	%	29.0	0	3.09

To Calculate lbs/ton: (%Nutrient) x (20)
To Calculate lbs/ton: (mg/kg Nutrient/10,000) x (20)

Analyst: Assaf Sadeh

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Account #: 3120507-6/7-6680
Group: Dec.13 C #45
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: WW6 - 6WW
Sample ID #: 3120507 - 6/7

Metals & Bacteria

Metals		Results	Units	MDL	% Recovery	Date Tested
Arsenic (As):		4.2	mg/kg dw	1.0	91.9	26 Dec. 13
Cadmium (Cd):	Less than	1.0	mg/kg dw	1.0	94.3	26 Dec. 13
Chromium (Cr):		44	mg/kg dw	1.0	89.5	26 Dec. 13
Copper (Cu):		60	mg/kg dw	1.0	90.2	26 Dec. 13
Lead (Pb):		67	mg/kg dw	1.0	89.8	26 Dec. 13
Mercury (Hg):	Less than	1.0	mg/kg dw	1.0	86.6	26 Dec. 13
Molybdenum (Mo):		1.5	mg/kg dw	1.0	95.3	26 Dec. 13
Nickel (Ni):		19	mg/kg dw	1.0	94.5	26 Dec. 13
Selenium (Se):	Less than	1.0	mg/kg dw	1.0	94.9	26 Dec. 13
Zinc (Zn):		130	mg/kg dw	1.0	93.5	26 Dec. 13
Cobalt (Co)		4.4	mg/kg dw	1.0	90.2	26 Dec. 13
Total Solids (TMECC 03.09)		71	%	0.05	NA	20 Dec. 13

Bacteria		Results	Units	MDL		Date Tested
E. Coli	Greater than	1100	MPN/g dw	2		17 Dec. 13
Salmonella	Less than	3	MPN/4g dw	3		17 Dec. 13

Pollutant Loading Rate:
Multiply mg/kg dry weight values times 0.0645 to give you kilograms pollutant per 100 metric ton compost as-received based on a moisture content of 28.9 percent.

Method (metals): EPA 3050B / EPA 6010
Method (metals): TMECC 04.12-B / 04.14-A
Method (Mercury Hg) TMECC 04.06 / EPA 7471
Method (E. Coli): TMECC 07.01-C
Method (Salmonella): TMECC 04.02-A

Analyst: Assaf Sadeh

ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY
WATSONVILLE
CALIFORNIA
95076
USA

TEL: 831-724-5422
FAX: 831-724-3188
www.compostlab.com

Account #: 3120507-6/7-6680
Group: Dec.13 C #45
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: WW6 - 6WW
Sample ID #: 3120507 - 6/7

	Units	Wet wt. Basis	Dry wt. Basis	TMECC Method
Total Nitrogen:	%	0.30	0.43	4.02-D
Organic Carbon:	%	8.9	13	4.01
C/N Ratio	ratio	29	29	calc.
Moisture:	%	28.9	0	3.09

To Calculate lbs/ton: (%Nutrient) x (20)
To Calculate lbs/ton: (mg/kg Nutrient/10,000) x (20)

Analyst: Assaf Sadeh

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Account #: 3120507-7/7-6680
Group: Dec.13 C #46
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: 7YZ - 7YZ
Sample ID #: 3120507 - 7/7

Metals & Bacteria

Metals		Results	Units	MDL	% Recovery	Date Tested
Arsenic (As):		3.6	mg/kg dw	1.0	91.9	26 Dec. 13
Cadmium (Cd):	Less than	1.0	mg/kg dw	1.0	94.3	26 Dec. 13
Chromium (Cr):		28	mg/kg dw	1.0	89.5	26 Dec. 13
Copper (Cu):		42	mg/kg dw	1.0	90.2	26 Dec. 13
Lead (Pb):		25	mg/kg dw	1.0	89.8	26 Dec. 13
Mercury (Hg):	Less than	1.0	mg/kg dw	1.0	86.6	26 Dec. 13
Molybdenum (Mo):		1.3	mg/kg dw	1.0	95.3	26 Dec. 13
Nickel (Ni):		19	mg/kg dw	1.0	94.5	26 Dec. 13
Selenium (Se):	Less than	1.0	mg/kg dw	1.0	94.9	26 Dec. 13
Zinc (Zn):		120	mg/kg dw	1.0	93.5	26 Dec. 13
Cobalt (Co)		4.4	mg/kg dw	1.0	90.2	26 Dec. 13
Total Solids (TMECC 03.09)		68	%	0.05	NA	20 Dec. 13

Bacteria		Results	Units	MDL		Date Tested
E. Coli		180	MPN/g dw	2		17 Dec. 13
Salmonella	Less than	3	MPN/4g dw	3		17 Dec. 13

Pollutant Loading Rate:
Multiply mg/kg dry weight values times 0.0615 to give you kilograms pollutant per 100 metric ton compost as-received based on a moisture content of 32.2 percent.

Method (metals): EPA 3050B / EPA 6010
Method (metals): TMECC 04.12-B / 04.14-A
Method (Mercury Hg) TMECC 04.06 / EPA 7471
Method (E. Coli): TMECC 07.01-C
Method (Salmonella): TMECC 04.02-A

Analyst: Assaf Sadeh

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Account #: 3120507-7/7-6680
Group: Dec.13 C #46
Reporting Date: January 2, 2014

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Date Received: 17 Dec. 13
Sample Identification: 7YZ - 7YZ
Sample ID #: 3120507 - 7/7

	Units	Wet wt. Basis	Dry wt. Basis	TMECC Method
Total Nitrogen:	%	0.84	1.2	4.02-D
Organic Carbon:	%	21	31	4.01
C/N Ratio	ratio	25	25	calc.
Moisture:	%	32.2	0	3.09

To Calculate lbs/ton: (%Nutrient) x (20)
To Calculate lbs/ton: (mg/kg Nutrient/10,000) x (20)

Analyst: Assaf Sadeh

Appendix C-3. Reports from Commercial Testing Lab for Lysimeter (Soil Solution) Water.

ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY
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TEL: 831-724-5422
FAX: 831-724-3188

UC Davis- Civil & Environmental Engir.
One Shields Ave., Ghausi Hall, Room 2001
Davis, CA 95616
Attn: Peter Green

Reporting Date: October 29, 2014

Bacteriological Examination of Water for Coliform Organisms

Date Received:	Water sample(s) received October 28, 2014
Project # / Name:	3.14 / Green Waste Soil Water
Water System #/Name:	NA
Sampling Type:	Special Sampling Period: October 2014
Sampler's Name:	Peter Green / UC Davis- Civil & Environmental Engineer
Matrix:	Water

Sample ID	Sampling Date	Sampling Time	E. coli (MPN/100ml)
AA88	10/27/14	12:00	< 2.0
BB1515	10/27/14	12:00	< 2.0
CC1010	10/27/14	12:00	< 2.0
DD55	10/27/14	12:00	< 2.1
EE66	10/27/14	12:00	< 1.9
FF99	10/27/14	12:00	< 2.4
GG1111	10/27/14	12:00	< 4.0
HH1212	10/27/14	12:00	< 1.9
II1313	10/27/14	12:00	< 3.2
JJ1414	10/27/14	12:00	< 2.0
KK00	10/27/14	12:00	< 2.2
TBTB	10/27/14	12:00	< 1.0

Please note - the variations in reporting limits between samples had to do with the client not providing 100mls of volume for several of the samples.

Date/Time Analyzed: 10/28/14 17:30Method of Analysis: SM 9223 B *MPN stands for "Most Probable Number"

CA ELAP Certificate #1494 (This identifies our Laboratory to the Health Department)

Mike Galloway

Appendix C-4. Data for Water-Filled Pore Space, Soil Water, and Temperature.

Table C-4-1. Soil water-filled pore space, %

Soil moisture, WFPS,% sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
10/17/2013	21.93	0.90	21.93	0.90	21.93	0.90	21.93	0.90	21.93	0.90
11/19/2013	35.09	3.50	32.32	0.75	27.72	2.02	35.30	3.91	29.35	1.32
11/21/2013	77.47	4.18	62.56	5.84	51.49	7.11	64.75	3.45	66.72	0.19
12/7/2013	47.20	5.18	52.56	4.92	46.02	4.19	53.12	4.57	26.72	2.60
12/8/2013	47.20	5.18	38.35	2.09	35.25	2.62	40.46	2.42	26.72	2.60
12/11/2013	47.20	5.18	50.42	4.08	44.92	2.54	51.78	2.63	26.72	2.60
12/18/2013			38.32	3.28	30.10	2.47	36.44	4.66		
1/2/2014	35.30	1.78	24.73	1.44	22.33	1.51	23.92	2.45	19.53	3.08
1/10/2014			23.17	1.49	17.78	0.39	18.75	1.75		
1/15/2014			95.92	9.96	88.36	8.36	93.15	12.08		
1/16/2014	66.71	26.34	65.83	6.93	55.07	6.13	68.16	5.76	62.58	9.16
1/17/2014	49.34		72.93	8.16	65.38	7.09	64.81	16.94	83.77	
1/19/2014	60.67		69.35	6.98	57.91	3.06	75.51	12.39	103.6	
1/23/2014	72.74		82.36	8.26	83.26	6.19	89.95	8.68	93.83	
1/24/2014	65.14	1.99	70.75	9.23	63.24	0.44	73.87	4.09	67.93	8.51
1/26/2014	64.53		70.81	8.32	59.89	3.31	76.32	6.74		
1/28/2014			68.68	7.93	55.25	2.55	72.16	5.18		
1/31/2014	70.27		68.13	7.23	55.51	4.87	72.20	5.64	62.73	
2/4/2014			67.54	8.37	57.84	4.44	73.64	4.84		
2/7/2014			81.33	9.10	73.01	5.45	85.23	7.72		
2/11/2014	95.12		73.85	7.43	59.21	4.43	76.79	5.19	67.22	
2/14/2014	52.73		56.08	5.97	44.83	1.63	57.84	4.78	57.87	
2/18/2014	64.82	3.57	57.46	4.92	51.92	2.36	64.10	6.30	65.48	4.00
2/21/2014			54.00	6.00	50.11	3.23	63.77	6.42		
2/25/2014			69.98	4.49	57.56	3.00	76.66	5.97	84.33	

Table C-4-1. Soil water-filled pore space, % (continued).

Soil moisture, WFPS,% sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
2/27/2014			54.05	6.05	50.11	3.23	69.55	3.94		
3/2/2014	85.53		93.71	9.37	99.26	8.45	93.27	6.55		
3/5/2014	75.57		80.70	8.10	67.87	1.06	79.85	5.27	70.35	
3/9/2014	75.29		70.65		57.83	1.94	75.21	6.82	71.91	
3/12/2014	69.94	1.44	62.75	5.84	62.83	2.61	67.78	3.78	70.82	3.43
3/17/2014	72.81	0.67	48.49	2.97	50.41	4.75	51.83	3.60	71.19	3.83
3/27/2014	74.63	6.10	60.87	10.77	55.81	6.27	55.72	5.15	89.42	9.28
3/30/2014			64.61	8.88	64.04	9.31	61.57	4.11	83.78	9.40
4/2/2014	76.82	4.21	65.70	7.05	53.62	3.11	69.43	4.71	71.37	4.46
4/6/2014	82.97	4.04	87.13	13.80	56.04	3.82	70.07	3.96	88.01	9.36
4/11/2014	83.23	4.43	82.05	13.23	59.48	5.65	66.61	7.92	87.64	9.40
4/15/2014	82.15	6.64	75.05	10.05	56.56	4.32	63.76	5.32	86.79	9.75
4/22/2014	81.06	4.83	66.93	7.54	41.43	2.45	52.43	3.51	85.77	9.94
4/26/2014	80.88	4.83	64.97	7.46	64.45	9.48	69.94	5.12	92.91	7.85
4/28/2014	79.58	4.63	59.12	7.77	50.61	2.48	64.81	2.69	86.06	9.29
5/2/2014	71.73	2.57	52.95	10.46	44.87	2.70	51.07	4.58	75.51	4.47
5/6/2014	78.98	4.63	35.35	3.37	36.44	4.08	43.55	3.58	85.36	9.37
5/12/2014	77.44	5.14	61.82	6.06	39.76	12.18	49.93	13.41	83.40	9.24
5/19/2014	76.46	5.55	59.37	5.46	31.21	2.76	38.43	2.64	81.25	11.10
5/26/2014	58.01	3.16	31.28	3.72	27.01	2.99	37.55	3.24	53.54	7.09
6/2/2014	63.40	2.83	55.53	5.18	25.93	4.48	23.51	6.08	70.08	11.82
6/9/2014	61.62	3.69	55.15	5.54	22.04	1.76	24.63	8.95	66.40	9.57
6/23/2014	40.84	1.31	14.68	2.22	17.80	1.26	17.47	0.16	32.57	3.85
6/25/2014	53.15	12.2	65.92	3.61	56.94	3.01	76.36	4.39	56.89	3.55
6/26/2014	89.04	2.35	77.11	9.52	68.45	3.71	80.84	4.83	80.62	13.20
6/27/2014	85.86	0.59	73.08	10.77	62.34	3.57	79.95	4.40	74.98	1.91
6/30/2014	66.10	2.23	64.00	8.29	53.92	2.70	62.84	5.65	66.29	4.13
7/3/2014	66.35	1.59	56.35	5.67	47.81	3.25	58.68	3.85	71.92	3.55
7/7/2014	70.98	3.03	46.49	4.11	42.14	3.56	53.13	4.19	74.48	2.32
7/11/2014	73.07	1.52	44.09	3.50	34.44	3.81	48.30	4.79	67.37	3.19
7/16/2014	69.39	1.65	47.56	5.02	37.11	1.56	46.30	0.57	69.01	2.57
7/23/2014	68.21	1.69	37.94	3.56	36.15	4.22	44.38	2.22	68.02	2.23
7/31/2014	69.81	2.22	36.13	3.60	29.45	4.81	42.34	3.10	62.97	2.82
8/6/2014	64.58	3.33	34.75	7.79	30.79	2.93	34.36	4.05	61.66	3.01
8/14/2014	70.75	1.88	56.32	4.59	31.20	2.85	33.02	0.49	74.81	12.39

Table C-4-1. Soil water-filled pore space, % (continued).

Soil moisture, WFPS,% sampling date	12 in		Control		6 in +till		Control + till		6 in	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
8/21/2014	67.76	1.67	54.39	4.14	24.25	2.76	37.85	3.68	72.95	12.08
8/29/2014	50.43	4.65	27.70	2.25	23.36	2.09	30.49	3.44	47.52	4.42
9/6/2014	65.30	1.00	52.02	3.62	23.58	5.74	31.41	3.20	69.23	11.60
9/9/2014	70.98	5.76	79.10	9.05	66.58	4.43	84.19	6.85	77.45	3.87
9/10/2014	74.37	3.47	75.31	8.80	63.74	3.51	80.73	7.06	76.83	4.25
9/12/2014	73.90	2.49	69.30	7.63	61.50	6.59	74.13	5.32	83.11	2.03
9/15/2014	70.01	2.24	55.68	5.46	48.06	1.83	60.05	5.15	71.00	2.81
9/18/2014	70.02	3.25	51.12	6.00	41.32	3.01	54.02	5.49	71.43	2.84
9/22/2014	64.75	1.31	43.09	5.10	39.52	3.05	51.67	3.72	70.75	7.65
9/25/2014	74.63	1.74	56.32	7.83	46.84	6.49	56.47	4.64	69.25	5.65
9/26/2014	70.47	2.81	53.17	4.52	47.04	3.63	62.50	6.72	67.01	4.85
9/29/2014	84.15	2.54	48.44	4.93	41.72	1.34	54.28	3.77	69.63	4.47
10/2/2014	69.38	3.04	47.31	5.20	38.41	2.12	53.40	3.35	65.26	3.35
10/9/2014	67.17	4.77	39.31	2.82	36.25	2.18	45.47	3.66	63.76	3.91
10/16/2014	66.91	6.59	33.99	3.57	31.48	2.86	39.08	3.09	54.46	2.52

Table C-4-2. Soil volumetric water content 0-15 cm soil depth.

Date	Treatment (in cm)				
	12 inches GW	Control	6 in GW + till	Control + till	6 inches GW
11/19/13	2.49	2.31	2.24	2.43	2.10
11/21/13	3.61	4.43	4.16	4.47	4.77
12/7/13	3.37	3.72	3.72	3.66	1.91
12/8/13	3.37	2.73	2.85	2.79	1.91
12/11/13	3.37	3.58	3.63	3.57	1.91
12/18/13		2.72	2.43	2.50	
1/2/14	2.51	1.76	1.80	1.65	1.40
1/10/14		1.65	1.44	1.29	
1/15/14		6.79	7.13	6.40	
1/16/14	4.69	4.66	4.44	4.70	4.46
1/17/14	3.39	5.16	5.21	4.43	6.07
1/19/14	4.17	4.91	4.68	5.13	7.52
1/23/14	5.00	5.83	6.73	6.19	6.80
1/24/14	4.63	4.99	5.12	5.09	4.84
1/26/14	4.61	5.00	4.84	5.25	
1/28/14		4.85	4.47	4.97	
1/31/14	4.83	4.82	4.48	4.97	4.55
2/4/14		0.68	0.58	0.74	
2/7/14		5.75	5.90	5.87	
2/11/14	6.53	5.23	4.78	5.29	4.87
2/14/14	3.62	3.97	3.63	3.98	4.20
2/18/14	4.61	4.07	4.21	4.41	4.67
2/21/14		3.82	4.05	4.39	

Table C-4-2. Soil volumetric water content 0-15 cm soil depth (continued).

Date	Treatment (in cm)				
	12 inches GW	Control	6 in GW + till	Control + till	6 inches GW
2/25/14		4.98	4.66	5.28	6.12
2/27/14		3.82	4.05		
3/2/14	5.87	6.64		6.43	
3/5/14	5.19	5.71	5.49	5.50	5.10
3/9/14	5.17	5.27	4.68	6.03	5.21
3/12/14	4.97	4.45	5.09	4.67	5.07
3/17/14	5.18	3.46	4.08	3.57	5.09
3/24/14					
3/27/14	5.24	4.14	4.52	3.84	6.30
3/30/14		4.56	5.19	4.24	5.97
4/3/14	5.45	4.65	4.33	4.78	5.10
4/6/14	5.91	6.14	4.53	4.83	6.27
4/11/14	5.93	5.78	4.82	4.58	6.25
4/15/14	5.76	5.31	4.59	4.39	6.18
4/22/14	5.77	4.76	3.35	3.61	6.11
4/26/14	5.76	4.62	5.23	4.82	6.55
4/28/14	5.67	4.17	4.09	4.47	6.13
5/2/14	5.11	3.81	3.63	3.52	5.39
5/6/14	5.62	2.50	2.94	3.00	6.08
5/12/14	5.51	4.40	3.25	3.49	5.94
5/19/14	5.45	4.23	2.52	1.81	5.78
5/26/14	4.13	4.75	2.18	2.58	3.82

Table C-4-2. Soil volumetric water content 0-15 cm soil depth (continued).

Date	Treatment (in cm)				
	12 inches GW	Control	6 in GW + till	Control + till	6 inches GW
6/2/14	4.51	3.95	2.10	1.64	4.98
6/9/14	4.39	3.91	1.78	1.68	4.73
6/23/14	2.90	1.06	1.44	1.21	2.33
6/25/14	3.75	4.70	4.60	5.26	4.06
6/26/14	4.16	5.45	5.53	5.57	6.32
6/27/14	6.10	5.15	5.04	5.51	5.37
6/30/14	4.69	4.53	4.36	4.32	4.73
7/3/14	4.72	3.99	3.87	4.04	5.14
7/7/14	5.04	3.30	3.40	3.66	5.33
7/11/14	5.19	3.13	2.79	3.32	4.81
7/16/14	4.93	3.37	3.00	3.20	4.93
7/23/14	4.85	2.69	2.92	3.06	4.86
7/31/14	4.97	2.56	2.38	2.92	4.50
8/6/14	4.59	2.44	2.49	2.38	4.41
8/14/14	5.03	4.00	2.52	2.28	5.32
8/21/14	4.82	3.87	1.96	2.61	5.19
8/29/14	3.58	1.98	1.89	2.10	3.39
9/6/14	4.65	3.71	1.90	2.16	4.92
9/9/14	5.04	5.59	5.38	5.80	5.53
9/10/14	5.28	5.32	5.15	5.55	5.49
9/12/14	5.25	4.90	4.96	5.11	5.95

Table C-4-2. Soil volumetric water content 0-15 cm soil depth (continued).

Date	Treatment (in cm)				
	12 inches GW	Control	6 in GW + till	Control + till	6 inches GW
9/15/14	4.97	3.94	3.89	4.13	5.07
9/18/14	4.98	3.61	3.34	3.71	5.11
9/22/14	4.60	3.05	3.19	3.56	5.04
9/25/14	5.31	3.97	3.78	3.92	4.95
9/26/14	5.00	3.77	3.80	4.30	4.79
9/29/14	5.98	3.43	3.37	3.74	4.97
10/2/14	4.93	3.35	3.10	3.68	4.66
10/9/14	4.77	2.79	2.93	3.13	4.55
10/16/14	4.74	2.41	2.54	2.69	3.89

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer.

Date						
10/23/2013	22.23	22.12	22.20	22.18	22.30	22.30
10/24/2013	43.00	50.11	22.25	22.05	26.29	27.92
10/25/2013	49.23	57.49	17.62	18.33	23.99	23.31
10/26/2013	49.11	57.33	18.01	18.63	22.93	22.33
10/27/2013	47.39	54.83	16.17	16.96	21.94	20.47
10/28/2013	44.97	52.66	16.04	16.79	21.23	20.34
10/29/2013	42.99	50.47	16.68	17.27	21.13	20.54
10/30/2013	40.80	46.48	15.71	16.33	20.42	19.28
10/31/2013	38.62	42.23	15.68	16.16	19.87	18.71
11/1/2013	36.82	38.81	16.35	16.30	19.58	18.49
11/2/2013	35.06	36.38	16.27	16.32	19.32	18.20
11/3/2013	33.45	34.03	15.87	16.00	19.07	18.20
11/4/2013	31.70	30.64	15.91	15.88	18.44	17.69
11/5/2013	30.32	28.73	16.99	16.93	18.57	17.83
11/6/2013	29.38	27.91	16.27	16.22	18.47	17.25
11/7/2013	28.52	27.12	16.81	16.75	18.47	17.50
11/8/2013	27.75	26.28	16.68	16.46	18.35	17.48
11/9/2013	27.05	25.50	16.32	16.18	18.21	17.10
11/10/2013	26.33	24.51	15.87	15.66	17.85	16.78
11/11/2013	25.67	23.66	14.73	14.66	17.49	16.04
11/12/2013	25.09	23.38	16.72	16.57	17.81	17.24
11/13/2013	24.65	22.85	15.80	15.63	17.52	16.39
11/14/2013	24.13	22.20	14.58	14.69	17.25	15.84
11/15/2013	23.59	21.38	13.81	13.59	16.71	14.96
11/16/2013	23.02	20.64	14.25	13.82	16.46	15.26
11/17/2013	22.61	20.38	13.82	13.45	16.39	15.05
11/18/2013	22.22	19.88	12.76	12.46	16.02	14.34
11/19/2013	21.89	19.66	13.97	14.11	16.50	15.80
11/20/2013	21.59	19.37	14.10	14.34	17.18	16.03
11/21/2013	21.99	20.65	10.98	11.40	17.21	15.94
11/22/2013	21.60	19.83	10.14	10.55	15.99	14.49
11/23/2013	21.24	18.99	10.67	10.88	15.96	14.45
11/24/2013	20.96	18.65	10.21	10.24	15.92	14.54
11/25/2013	20.64	18.20	9.82	9.79	15.65	14.14
11/26/2013	20.30	17.88	9.53	9.60	15.41	13.69
11/27/2013	20.02	17.80	10.24	10.43	15.42	14.09

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
11/28/2013	19.83	18.01	11.22	11.34	15.62	14.61
11/29/2013	19.68	18.21	11.39	11.38	15.74	14.70
11/30/2013	19.51	18.10	11.02	10.93	15.58	14.21
12/1/2013	19.33	18.00	11.07	10.95	15.46	14.40
12/2/2013	19.20	17.99	10.76	10.79	15.39	13.87
12/3/2013	19.14	18.23	10.84	11.25	15.47	13.88
12/4/2013	18.90	17.25	6.84	7.38	14.08	11.18
12/5/2013	18.38	15.56	5.02	5.27	12.54	9.16
12/6/2013	17.85	14.30	4.01	4.19	11.57	8.52
12/7/2013	17.26	14.08	5.37	5.53	11.85	9.60
12/8/2013	17.13	14.36	2.58	2.87	10.94	7.32
12/9/2013	16.76	13.76	2.77	3.39	10.18	7.13
12/10/2013	16.46	13.49	3.21	3.90	9.86	6.85
12/11/2013	16.21	13.44	4.09	4.69	9.88	7.52
12/12/2013	16.01	13.47	4.50	5.32	9.84	7.56
12/13/2013	15.85	13.63	5.29	6.05	9.96	7.94
12/14/2013	15.73	13.84	5.94	6.72	10.15	8.55
12/15/2013	15.66	13.95	5.90	6.73	10.16	8.37
12/16/2013	15.56	14.07	6.70	7.48	10.32	9.03
12/17/2013	15.57	14.42	7.28	7.95	10.63	9.42
12/18/2013	15.58	14.67	7.91	8.33	10.87	9.99

12/19/2013	15.66	15.11	7.70	8.33	11.05	9.72
12/20/2013	15.57	14.94	8.14	8.85	10.90	9.92
12/21/2013	15.49	14.53	7.73	8.44	10.73	9.42
12/22/2013	15.33	14.16	7.42	8.17	10.56	9.29
12/23/2013	15.22	14.22	7.71	8.50	10.67	9.56
12/24/2013	15.16	14.29	8.17	8.90	10.77	9.72

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
12/25/2013	15.08	14.03	7.38	8.20	10.52	9.10
12/26/2013	14.91	13.68	7.06	7.92	10.26	8.72
12/27/2013	14.72	13.31	6.39	7.00	9.96	8.15
12/28/2013	14.53	12.90	6.57	7.18	9.61	8.00
12/29/2013	14.51	13.78	9.22	9.89	10.47	10.01
12/30/2013	14.56	13.67	7.52	8.31	10.13	8.81
12/31/2013	14.48	13.64	8.22	8.79	10.31	9.27
1/1/2014	14.39	13.36	7.49	8.22	10.03	8.78
1/2/2014	14.31	13.34	7.85	8.43	10.08	8.96
1/3/2014	14.23	13.37	8.30	8.96	10.18	9.20
1/4/2014	14.22	13.45	8.27	8.93	10.15	8.90
1/5/2014	14.16	13.38	8.42	9.15	10.09	8.75
1/6/2014	14.04	12.90	7.49	7.85	9.73	8.27

1/7/2014	13.96	13.02	8.49	8.81	10.00	9.13
1/8/2014	14.00	13.31	8.09	8.39	10.12	8.99
1/9/2014	14.02	13.52	9.19	9.65	10.45	10.07
1/10/2014	14.06	13.61	8.76	9.15	10.44	9.54
1/11/2014	14.07	13.73	9.08	9.17	10.62	9.97
1/12/2014	14.13	13.78	8.97	9.43	10.65	9.81
1/13/2014	14.16	14.09	10.05	10.58	10.99	10.59
1/14/2014	14.23	13.93	8.11	8.52	11.53	10.15
1/15/2014	14.25	13.86	8.31	8.66	12.29	11.27
1/16/2014	14.40	14.12	8.23	8.68	12.13	10.75
1/17/2014	14.36	13.90	7.87	8.26	11.67	10.38
1/18/2014	14.28	13.62	7.53	8.22	11.34	10.14
1/19/2014	14.20	13.62	7.26	7.81	11.16	9.89
1/20/2014	14.14	13.51	7.14	7.39	10.95	9.69
1/21/2014	14.04	13.37	6.89	6.83	10.73	9.10

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
1/22/2014	13.64	13.08	8.22	7.47	11.01	10.22
1/23/2014	13.64	13.09	8.67	8.18	11.17	10.20
1/24/2014	13.84	13.60	9.07	9.00	11.29	10.94
1/25/2014	14.20	14.63	9.20	9.24	11.50	11.05
1/26/2014	14.41	14.80	8.43	8.38	11.40	10.56
1/27/2014	14.43	14.46	8.34	8.47	11.21	10.71
1/28/2014	14.73	16.14	11.25	11.36	12.32	13.06
1/29/2014	15.39	17.75	11.91	11.89	13.03	13.32
1/30/2014	15.80	18.10	12.67	12.92	13.57	14.27
1/31/2014	16.02	17.40	9.78	10.14	13.10	12.00
2/1/2014	15.51	14.94	7.47	8.21	11.74	10.36
2/2/2014	15.15	14.46	6.85	7.14	11.35	9.85
2/3/2014	14.88	14.15	8.67	9.06	11.33	11.01
2/4/2014	14.85	14.29	7.56	7.61	11.08	9.89
2/5/2014	14.61	13.71	7.12	7.37	10.70	9.59
2/6/2014	14.53	14.00	8.62	8.65	11.08	10.60
2/7/2014	14.66	14.37	9.13	9.09	11.20	10.78
2/8/2014	14.85	14.63	10.79	10.76	11.70	11.83
2/9/2014	15.45	15.93	12.83	12.91	12.80	13.48
2/10/2014	16.14	17.29	13.76	13.68	13.66	14.38
2/11/2014	16.54	17.77	12.90	12.69	13.68	13.79
2/12/2014	16.76	17.83	12.26	12.17	13.73	13.62
2/13/2014	16.95	18.32	13.95	13.89	14.30	15.09
2/14/2014	17.55	19.77	14.39	14.29	15.07	15.59
2/15/2014	17.90	19.58	13.12	13.05	14.94	14.80
2/16/2014	17.86	19.06	12.81	13.42	14.85	14.89
2/17/2014	17.67	18.21	11.23	11.93	14.16	13.57
2/18/2014	17.49	18.01	11.43	11.88	14.04	13.70
2/19/2014	17.59	18.68	12.19	13.12	14.50	14.37
2/20/2014	17.50	18.04	11.20	12.04	13.97	13.41
2/21/2014	17.32	17.75	11.85	12.56	13.82	13.45
2/22/2014	17.31	18.03	12.60	13.19	13.99	13.76
2/23/2014	17.36	18.42	13.16	13.59	14.24	14.27
2/24/2014	17.61	19.28	13.81	14.26	14.74	14.86
2/25/2014	17.86	19.73	13.97	14.42	15.01	15.14
2/26/2014	18.13	20.04	13.40	13.55	15.22	14.99
2/27/2014	17.97	18.75	13.36	13.26	14.91	14.76
2/28/2014	17.77	17.58	12.86	12.59	14.53	14.07

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
3/1/2014	17.66	17.92	13.34	13.16	14.61	14.63
3/2/2014	17.89	18.65	12.96	12.78	14.73	14.35
3/3/2014	17.90	18.37	12.28	12.19	14.39	13.84
3/4/2014	17.88	18.50	13.63	13.44	14.71	14.82
3/5/2014	18.12	19.38	14.77	14.46	15.35	15.87
3/6/2014	18.60	20.49	15.51	15.11	16.09	16.39
3/7/2014	18.75	20.08	13.62	13.66	15.54	15.02
3/8/2014	18.63	19.70	13.86	14.20	15.45	15.53
3/9/2014	19.08	21.41	15.65	15.64	16.57	17.07
3/10/2014	19.66	22.29	16.09	16.46	17.27	17.67
3/11/2014	19.73	21.11	12.85	13.97	16.24	15.26
3/12/2014	19.28	19.87	13.21	14.24	15.68	15.28
3/13/2014	19.15	20.02	13.99	15.18	15.83	15.77
3/14/2014	19.35	20.84	14.65	15.70	16.33	16.30
3/15/2014	19.60	21.45	15.66	16.87	16.84	17.20
3/16/2014	20.02	22.55	16.38	17.58	17.57	18.03
3/17/2014	20.43	22.81	15.20	15.60	17.36	16.87
3/18/2014	20.47	20.64	14.84	15.32	16.60	16.56
3/19/2014	20.21	20.43	15.07	15.75	16.59	16.64
3/20/2014	20.36	21.55	16.25	16.88	17.26	17.51
3/21/2014	20.75	22.24	16.49	17.23	17.60	17.77
3/22/2014	21.01	21.99	16.38	17.06	17.64	17.71
3/23/2014	21.11	21.87	16.69	17.30	17.76	17.81
3/24/2014	21.30	22.33	17.32	18.28	18.07	18.23
3/25/2014	21.53	21.87	15.32	15.63	17.52	17.10
3/26/2014	21.15	20.48	14.28	14.32	16.79	16.44
3/27/2014	20.59	19.24	13.52	13.41	16.00	15.54
3/28/2014	20.17	19.61	15.09	15.23	16.46	16.51
3/29/2014	20.23	20.10	14.29	14.35	16.45	16.10
3/30/2014	19.80	18.63	13.94	13.53	15.74	15.47
3/31/2014	19.51	17.94	11.52	10.90	14.77	13.76
4/1/2014	18.48	15.69	11.09	10.56	13.39	12.63
4/2/2014	17.65	15.94	13.55	13.26	13.98	14.17
4/3/2014	18.16	17.89	14.23	13.55	15.05	14.96
4/4/2014	18.55	18.61	14.07	13.55	15.29	14.93
4/5/2014	18.51	17.83	14.54	14.17	14.89	14.62
4/6/2014	18.73	19.32	16.21	16.57	16.07	16.14
4/7/2014	19.30	21.25	18.39	19.42	17.58	18.15

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
4/8/2014	20.32	23.48	20.14	20.34	19.05	19.96
4/9/2014	21.28	25.07	21.36	21.20	20.25	21.21
4/10/2014	22.02	24.86	20.82	20.31	20.24	20.84
4/11/2014	22.36	24.84	20.79	20.35	20.40	20.88
4/12/2014	22.56	24.60	20.48	19.55	20.41	20.86
4/13/2014	22.73	24.44	20.74	19.44	20.39	20.73
4/14/2014	22.68	24.02	21.39	20.15	20.35	20.86
4/15/2014	23.02	25.13	22.64	21.30	21.11	21.76
4/16/2014	23.39	25.00	22.63	21.32	20.96	21.24
4/17/2014	23.39	24.75	23.07	21.71	20.95	21.40
4/18/2014	23.66	25.29	23.50	22.03	21.23	21.79
4/19/2014	23.79	25.09	22.93	21.29	21.23	21.53
4/20/2014	23.83	24.73	23.16	21.48	21.07	21.43
4/21/2014	23.84	24.44	21.81	20.49	20.86	20.82
4/22/2014	23.64	23.99	21.65	20.37	20.54	20.68
4/23/2014	23.50	23.57	21.79	20.10	20.41	20.61
4/24/2014	23.49	24.07	22.12	20.56	20.83	21.03
4/25/2014	23.57	23.48	18.42	17.43	20.01	19.45
4/26/2014	22.71	20.91	16.22	15.76	18.44	18.04
4/27/2014	22.30	21.69	17.69	17.70	18.99	18.96
4/28/2014	22.30	22.09	19.66	19.85	19.32	19.45
4/29/2014	22.38	22.68	22.15	22.12	19.93	20.39
4/30/2014	22.77	24.02	24.57	24.21	21.05	21.80
5/1/2014	23.38	25.47	25.95	25.35	22.12	22.89
5/2/2014	23.89	25.82	25.42	24.69	22.40	22.94
5/3/2014	24.14	25.65	24.13	23.51	22.34	22.61
5/4/2014	24.14	25.06	23.25	22.68	22.08	22.41
5/5/2014	24.11	24.96	22.86	22.49	21.98	22.15
5/6/2014	23.87	23.95	22.44	22.00	21.34	21.45
5/7/2014	23.70	23.86	23.06	22.51	21.41	21.68
5/8/2014	23.78	24.33	22.24	21.62	21.60	21.75
5/9/2014	23.79	24.80	23.65	23.18	22.13	22.71
5/10/2014	23.94	24.69	22.85	22.37	21.76	21.81
5/11/2014	23.70	23.68	22.43	22.02	20.99	21.14
5/12/2014	23.60	23.97	24.06	23.10	21.43	21.88
5/13/2014	23.84	25.16	25.89	23.69	22.35	23.02
5/14/2014	24.31	26.46	27.49	24.92	23.38	24.17
5/15/2014	24.79	27.12	27.73	25.29	23.93	24.61

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
5/16/2014	25.05	26.97	27.30	24.73	23.99	24.54
5/17/2014	25.26	26.80	26.27	23.76	23.95	24.36
5/18/2014	25.33	26.50	25.85	23.63	23.79	24.17
5/19/2014	25.30	25.91	24.80	22.75	23.41	23.60
5/20/2014	25.18	25.54	24.51	23.16	23.18	23.44
5/21/2014	25.13	25.99	25.66	24.53	23.55	24.06
5/22/2014	25.30	26.66	26.64	25.38	24.11	24.63
5/23/2014	25.56	27.03	27.01	25.78	24.54	25.08
5/24/2014	25.82	27.30	28.08	26.75	24.86	25.38
5/25/2014	26.06	27.45	28.14	27.04	25.21	25.75
5/26/2014	26.24	27.34	28.16	27.13	25.13	25.54
5/27/2014	26.33	27.01	27.51	26.80	25.09	25.49
5/28/2014	26.28	25.98	26.49	25.39	23.67	23.64
5/29/2014	26.03	25.34	26.55	25.91	23.07	23.54
5/30/2014	26.00	25.14	25.50	24.92	23.63	23.89
5/31/2014	25.90	24.84	25.15	24.94	23.41	23.72
6/1/2014	25.98	25.37	25.96	26.15	23.92	24.35
6/2/2014	26.07	25.20	25.48	25.40	23.73	24.17
6/3/2014	25.98	24.59	24.92	25.02	23.31	23.99
6/4/2014	25.98	25.05	25.99	26.51	23.71	24.60
6/5/2014	26.20	25.68	26.86	27.64	24.21	25.24
6/6/2014	26.40	25.58	26.70	27.47	24.25	25.16
6/7/2014	26.50	25.51	26.86	27.90	24.42	25.47
6/8/2014	26.69	25.88	27.80	29.01	24.78	25.59
6/9/2014	26.94	26.03	28.24	29.65	24.84	25.92
6/10/2014	27.19	26.11	28.37	29.69	24.95	25.90
6/11/2014	27.31	25.48	27.26	28.12	24.57	25.51
6/12/2014	27.11	24.57	25.88	26.56	23.98	24.79
6/13/2014	26.88	24.26	25.90	27.00	23.52	24.30
6/14/2014	26.81	24.40	25.84	26.64	23.29	23.91
6/15/2014	26.66	24.06	25.24	26.22	23.05	23.86
6/16/2014	26.55	23.91	24.81	25.42	23.13	23.95
6/17/2014	26.40	23.76	24.78	25.92	22.80	23.49
6/18/2014	26.39	24.23	25.39	26.88	22.94	23.82
6/19/2014	26.61	24.64	25.65	27.24	23.11	24.13
6/20/2014	26.83	24.93	26.19	27.98	23.62	24.67
6/21/2014	27.01	25.00	26.60	28.26	23.87	24.93
6/22/2014	27.09	24.78	26.26	27.82	23.85	24.74

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
6/23/2014	27.15	24.89	26.65	28.21	24.04	25.07
6/24/2014	27.22	25.80	26.70	27.05	25.09	25.86
6/25/2014	27.19	25.41	23.90	23.06	25.18	25.38
6/26/2014	27.00	25.32	23.26	22.68	25.15	25.41
6/27/2014	27.37	26.06	23.32	23.00	25.31	25.66
6/28/2014	27.80	27.75	24.51	24.38	25.95	26.50
6/29/2014	28.63	29.33	25.94	26.15	26.67	27.39
6/30/2014	29.77	30.91	27.33	27.93	27.48	28.37
7/1/2014	30.73	31.20	25.85	27.30	27.86	28.67
7/2/2014	30.97	30.63	24.84	26.93	27.59	28.19
7/3/2014	31.11	31.03	25.65	27.99	27.74	28.50
7/4/2014	31.34	31.20	26.10	28.09	27.76	28.42
7/5/2014	31.38	31.14	26.50	28.31	27.60	28.17
7/6/2014	31.54	31.50	27.66	29.35	27.72	28.37
7/7/2014	31.81	31.58	27.89	29.17	27.82	28.36
7/8/2014	31.92	31.39	28.03	29.31	27.92	28.46
7/9/2014	31.97	31.23	28.25	29.06	27.91	28.59
7/10/2014	32.01	31.17	28.37	28.83	27.97	28.61
7/11/2014	32.01	31.07	28.62	29.20	28.01	28.69
7/12/2014	31.99	31.07	28.76	29.48	27.92	28.56
7/13/2014	32.07	31.42	29.48	30.61	28.23	28.99
7/14/2014	32.45	32.25	31.25	32.17	28.88	29.79
7/15/2014	32.73	32.09	31.28	31.67	28.96	29.81
7/16/2014	32.80	31.82	30.82	30.93	28.93	29.64
7/17/2014	32.69	31.38	30.09	30.17	28.72	29.36
7/18/2014	32.49	31.04	29.61	29.71	28.44	29.02
7/19/2014	32.40	31.08	29.82	30.06	28.37	28.94
7/20/2014	32.30	30.42	28.32	28.02	27.78	27.95
7/21/2014	31.84	30.48	29.50	29.31	27.92	28.63
7/22/2014	31.91	30.51	28.91	28.60	27.77	28.12
7/23/2014	31.79	30.60	29.26	29.33	27.71	28.29
7/24/2014	31.87	31.17	30.55	31.19	27.89	28.47
7/25/2014	32.04	31.47	31.51	32.24	28.03	28.69
7/26/2014	32.21	31.52	31.85	32.39	28.18	28.83
7/27/2014	32.32	31.36	31.40	31.92	28.32	28.89
7/28/2014	32.23	30.90	30.60	30.77	28.03	28.51
7/29/2014	31.96	30.79	30.91	31.25	28.01	28.72
7/30/2014	32.00	31.08	31.31	31.83	28.21	28.90

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
7/31/2014	32.05	31.11	31.33	31.88	28.34	28.98
8/1/2014	32.06	31.12	31.78	32.22	28.36	28.99
8/2/2014	32.03	30.73	30.90	30.88	28.10	28.62
8/3/2014	31.69	29.74	28.89	28.75	27.34	27.63
8/4/2014	31.14	28.71	26.96	26.88	26.42	26.42
8/5/2014	30.54	28.42	26.39	26.47	25.97	25.85
8/6/2014	30.18	29.58	29.09	29.68	26.70	27.41
8/7/2014	30.61	29.93	29.54	29.97	27.07	27.64
8/8/2014	30.63	29.74	29.46	30.07	27.00	27.62
8/9/2014	30.55	29.34	28.92	29.33	26.79	27.31
8/10/2014	30.26	28.63	27.83	28.33	26.22	26.67
8/11/2014	29.93	28.55	28.25	28.91	26.05	26.60
8/12/2014	29.89	28.26	28.09	28.24	25.97	26.46
8/13/2014	29.59	27.88	27.75	27.98	25.75	26.37
8/14/2014	29.48	28.14	28.20	28.64	25.79	26.48
8/15/2014	29.44	28.25	28.55	29.03	25.87	26.54
8/16/2014	29.40	28.28	28.74	29.24	25.78	26.39
8/17/2014	29.25	28.03	28.34	28.92	25.54	26.09
8/18/2014	29.12	27.91	28.17	28.67	25.51	26.02
8/19/2014	28.98	27.54	27.60	27.92	25.32	25.77
8/20/2014	28.81	27.34	27.37	27.53	25.17	25.56
8/21/2014	28.64	27.29	27.38	27.80	25.05	25.50
8/22/2014	28.68	27.38	27.79	27.98	25.31	25.74
8/23/2014	28.52	27.10	27.29	27.74	24.87	25.07
8/24/2014	28.46	27.25	27.77	28.14	24.95	25.17
8/25/2014	28.43	27.04	27.51	27.61	24.79	24.90
8/26/2014	28.31	27.03	27.44	27.79	24.61	24.68
8/27/2014	28.32	27.40	28.24	28.64	24.81	24.91
8/28/2014	28.38	27.55	28.63	29.00	24.92	24.97
8/29/2014	28.34	27.05	27.66	27.69	24.64	24.70
8/30/2014	28.09	27.19	28.04	28.26	24.70	24.65
8/31/2014	28.06	27.31	28.22	28.71	24.67	24.52
9/1/2014	27.98	27.30	28.49	28.96	24.55	24.43
9/2/2014	27.93	27.05	28.33	28.50	24.55	24.36
9/3/2014	27.73	26.64	27.21	27.74	24.06	23.75
9/4/2014	27.60	26.78	27.58	28.10	23.97	23.65
9/5/2014	27.50	26.50	27.13	27.50	23.83	23.41
9/6/2014	27.45	26.22	27.18	27.42	23.83	23.36

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
9/7/2014	26.32	24.54	24.51	24.88	23.74	23.08
9/8/2014	26.52	23.22	23.19	22.62	23.62	22.71
9/9/2014	26.19	23.25	22.36	22.17	23.01	22.80
9/10/2014	26.20	24.31	23.57	23.52	23.24	23.21
9/11/2014	26.45	25.25	24.32	24.18	23.72	23.69
9/12/2014	26.74	25.84	24.51	24.32	23.96	23.90
9/13/2014	27.10	26.59	25.18	24.98	24.45	24.51
9/14/2014	27.39	26.83	24.95	24.72	24.61	24.51
9/15/2014	27.48	26.70	24.51	24.46	24.58	24.49
9/16/2014	27.27	26.31	23.96	24.07	24.16	24.07
9/17/2014	27.14	26.14	24.26	24.13	23.95	23.76
9/18/2014	27.16	26.35	25.09	24.08	24.28	24.26
9/19/2014	27.19	26.11	24.76	23.76	23.98	23.72
9/20/2014	27.22	26.40	25.55	24.14	24.16	23.97
9/21/2014	27.33	26.09	24.87	23.72	24.03	23.68
9/22/2014	27.11	25.79	24.76	24.88	23.64	23.30
9/23/2014	27.02	25.64	24.97	24.65	23.53	23.18
9/24/2014	26.91	25.68	25.37	25.02	23.65	23.49
9/25/2014	26.85	24.99	23.15	22.84	23.22	22.65
9/26/2014	26.17	24.26	21.11	20.66	22.11	21.29
9/27/2014	25.56	24.25	21.64	20.74	21.78	21.25
9/28/2014	25.35	23.73	20.04	19.63	21.43	20.56
9/29/2014	24.79	22.90	20.60	20.36	20.76	20.21
9/30/2014	24.74	23.59	21.91	21.58	21.13	20.71
10/1/2014	24.61	23.51	22.03	21.56	20.79	20.24
10/2/2014	24.19	22.79	21.62	20.93	20.12	19.59
10/3/2014	24.03	22.95	22.49	21.63	20.20	19.86
10/4/2014	24.04	23.08	23.06	22.12	20.36	20.14
10/5/2014	24.15	23.29	23.56	22.60	20.57	20.45
10/6/2014	24.23	23.32	23.65	22.68	20.61	20.46
10/7/2014	24.23	23.29	23.70	22.95	20.64	20.50
10/8/2014	24.19	23.13	23.56	22.92	20.51	20.32
10/9/2014	24.04	22.93	23.22	22.60	20.36	20.17
10/10/2014	23.89	22.72	22.72	22.18	20.21	19.95
10/11/2014	23.69	22.54	22.45	21.98	19.97	19.69
10/12/2014	23.58	22.62	22.60	22.22	19.93	19.70
10/13/2014	23.24	21.78	21.69	21.18	19.33	19.03
10/14/2014	23.12	21.83	20.89	20.55	19.55	19.31

Table C-4-3. Soil temperature ^{o}C 0-15 cm layer (continued).

Date	12 in	12 in-GW	Control	6 in + till	6 in	6 in-GW
10/15/2014	23.00	21.59	19.71	19.54	19.54	19.26
10/16/2014	23.11	21.04	16.62	16.52	18.81	17.65

Appendix C-5. Data for Soil Nutrients, DOC, and Nitrate After Irrigation.

Table C-5-1. Soil NH_4^+-N content (µg N/g).

Sample date	12in-S		Control		6in+till		Control +till		6 in -S		12 in-GW		6 in -GW	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
10/14/2013	3.15	0.7	3.15	0.74	3.15	0.74	3.15	0.74	3.15	0.74	39.33		39.33	
11/19/2013	5.75	2.0	3.47	1.48	17.57	4.50	2.86	0.92	8.96	0.27				
11/21/2013	7.59	3.3	0.67	0.17	1.39	0.32	0.45	0.03	0.98	0.12				
12/7/2013	1.35	0.2	0.68	0.10	0.91	0.13	0.60	0.21	3.60	1.79				
1/17/2014											3.86		33.41	
1/24/2014	5.36	3.4	0.60	0.04	2.26	0.78	0.91	0.21	1.78	0.90	69.29	47.88	102.75	15.32
2/18/2014	0.31	0.1	0.35	0.11	0.27	0.09	0.15	0.03	0.15	0.05	0.17	0.03	1.46	1.35
3/12/2014	0.59	0.1	0.97	0.08	1.58	0.56	1.31	0.25	0.96	0.23	22.14	3.60	18.38	1.20
4/3/2014	0.55	0.0	0.33	0.07	0.60	0.10	0.26	0.04	0.64	0.20	9.03	1.90	13.15	2.11
5/2/2014	1.63	0.1	0.99	0.12	1.15	0.12	0.86	0.01	1.63	0.17	77.63	27.74	169.23	72.46
5/26/2014	1.16	0.6	0.62	0.34	1.37	0.19	0.25	0.15	0.39	0.24	44.05	9.81	17.38	2.32
6/23/2014	3.69	1.4	1.38	0.13	2.65	0.34	2.22	0.96	2.03	0.58	39.41	4.11	28.13	2.00
6/30/2014	1.06	0.2	4.22	2.12	5.54	1.44	1.78	0.61	3.04	0.38	153.3	12.32	147.52	15.44
7/31/2014	8.86	0.9	3.34	3.23	2.50	1.39	0.36	0.18	5.99	1.71	100.2	7.00	62.83	25.68
8/29/2014	1.25	0.2	4.17	2.90	2.02	0.03	0.69	0.03	0.76	0.21	49.58	6.65	46.11	2.87
9/9/2014	1.08	0.1	1.68	0.30	2.40	0.58	1.78	0.51	3.76	1.52	61.29	5.25	48.79	10.47
9/15/2014	0.00	0.0	0.51	0.14	0.96	0.64	0.00	0.00	0.00	0.00	46.68	7.94	31.38	13.19
9/26/2014	1.55	0.4	0.40	0.03	5.04	4.12	0.49	0.05	0.81	0.06	30.74	12.51	31.75	3.62
10/16/2014	2.60	0.3	1.55	0.67	1.16	0.27	0.53	0.12	1.65	0.35	74.78	31.28	32.30	8.69

Table C-5-2. Soil NO_3^--N content (µg N/g).

Sample Date	12in-S		Control		6 in+till		Control+till		6 in -S		12 in-GW		6 in -GW	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
10/14/2013	33.97	3.58	33.97	3.58	33.97	3.58	33.97	3.58	33.97	3.58	2.60		2.60	
11/19/2013	39.10	4.32	47.94	2.51	29.84	6.58	30.27	3.29	38.66	7.67				
11/21/2013	44.57	11.21	52.16	5.30	13.71	2.97	33.30	1.34	43.80	9.98				
12/7/2013	30.51	7.15	54.87	9.89	2.59	1.15	39.31	6.44	32.34	2.06				
1/17/2014											43.81		2.75	
1/24/2014	19.37	10.33	3.33	0.90	4.12	2.11	4.27	1.20	11.56	4.06	4.58	2.49	10.07	1.87
2/18/2014	4.75	1.13	2.69	0.32	1.28	0.05	1.94	0.22	5.56	1.20	0.00	0.00	0.00	0.00
3/12/2014	14.25	2.70	2.13	0.80	2.44	0.30	2.33	0.85	9.03	2.51	0.00	0.00	0.08	0.08
4/3/2014	20.64	1.18	2.54	0.42	4.39	0.54	1.92	0.09	11.01	1.97	0.00	0.00	0.00	0.00
5/2/2014	25.49	0.12	12.65	1.02	19.05	1.61	11.43	1.79	25.45	0.97	67.44	30.51	67.22	22.95
5/26/2014	39.77	5.15	11.05	5.77	23.59	3.60	6.76	4.05	27.07	9.05	27.95	14.49	25.71	14.16
6/23/2014	20.38	8.54	25.72	6.95	17.44	3.75	12.22	3.74	16.30	6.51	16.93	4.27	28.17	16.53
6/30/2014	32.15	13.42	7.98	0.14	12.71	1.43	7.16	0.92	10.99	3.88	41.95	7.25	10.31	1.08
7/31/2014	60.42	7.82	18.20	1.69	31.86	9.84	19.23	5.16	40.64	8.87	44.63	13.73	91.07	13.66
8/29/2014	59.82	0.69	25.91	3.51	45.09	2.70	18.48	4.63	47.37	3.29	209.46	7.27	145.37	16.56
9/9/2014	50.34	12.54	9.74	5.84	13.98	7.00	3.38	0.83	21.27	7.29	98.64	50.13	10.80	0.88
9/15/2014	41.15	14.15	18.21	4.68	27.72	4.31	10.20	1.02	29.72	9.35	145.29	26.57	36.79	11.69
9/26/2014	21.76	1.47	19.16	4.86	27.93	4.37	11.37	1.63	20.02	6.90	70.49	21.29	25.12	4.96
10/16/2014	50.29	11.46	35.12	7.32	29.78	6.44	17.61	4.68	42.00	10.93	181.11	20.72	90.35	26.51

Table C-5-3. Soil DOC content.

Sample Date	12in-S		Control		6 in + till		Control + till		6 in -S		12 in-GW		6 in -GW	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
10/14/2013	70.83	5.31	70.83	5.31	70.83	5.31	70.83	5.31	70.83		7623.47		7623.47	
11/19/2013	113.00	24.21	65.29	5.69	325.01	87.69	67.44	7.53	143.88	2.75				
11/21/2013	156.27	21.70	64.45	8.50	170.82	34.92	61.70	3.15	112.20	2.36				
12/7/2013	197.51	62.54	65.56	3.96	132.25	57.82	62.71	4.78	179.65	19.06				
1/17/2014											631.88		2102.32	
1/24/2014	188.34	75.33	419.01	370.30	177.01	57.18	44.25	5.66	90.58	36.23	2454.48	825.60	3457.43	2
2/18/2014	39.88	6.07	20.94	2.94	31.41	6.95	16.71	0.35	26.71	9.80	64.16	23.12	102.13	
3/12/2014	61.22	2.65	34.51	2.88	82.24	18.37	31.20	4.65	55.45	9.94	2062.75	80.08	2559.10	2
4/3/2014	51.53	2.55	31.66	3.36	52.98	4.42	26.67	0.40	44.05	3.22	1569.68	253.41	1191.09	2
5/2/2014	72.04	16.07	42.43	1.54	79.08	7.95	29.37	2.03	80.46	12.73	4555.59	1160.24	3936.34	4
5/26/2014	128.37	31.82	35.20	1.66	71.46	3.35	31.48	5.86	76.51	5.18	2143.42	153.07	1338.26	
6/23/2014	131.26	35.40	96.63	42.56	113.02	14.48	56.53	18.34	124.56	10.67	3788.26	101.57	2828.50	2
6/30/2014	72.25	10.38	57.98	21.84	74.56	16.69	33.23	5.18	69.86	19.10	1961.24	116.00	1995.62	3
7/31/2014	295.50	34.20	31.93	3.90	62.51	21.08	35.40	14.63	117.59	34.54	2240.84	111.58	1656.43	4
8/29/2014	160.88	27.22	50.67	5.02	144.52	11.20	42.95	3.63	113.82	2.84	3403.43	466.37	3106.02	1
9/9/2014	140.63	91.53	48.41	3.38	67.74	4.33	40.14	2.27	118.56	11.72	1362.18	395.19	1146.49	1
9/15/2014	159.57	43.92	53.97	3.07	110.72	23.51	47.27	1.80	87.92	12.86	1685.83	178.30	1093.64	
9/26/2014	36.65	17.52	33.38	1.73	102.76	33.05	38.95	1.89	34.42	10.97	998.26	276.27	726.85	2
10/16/2014	47.55	8.70	62.51	22.35	54.63	7.93	92.80	33.65	104.39	34.81	2569.79	1536.82	1127.76	3

Table C-5-4. Nitrate concentration in the soil solution at 30 cm depth after three irrigation events.

Treatment	1/20/2014	see	1/20/2014	see	6/25/2014	see	9/8/2014	see
12 in	55.57	11.59	23.20	10.71	42.33		120.41	
Control	28.63	5.28	10.94	2.98	24.47	14.52	28.06	10.78
6 in+till	18.29	9.02	5.64	2.39	18.34	3.15	92.04	10.09
Control+till	60.13	17.48	18.02		21.27		32.24	15.68
6 in	24.34	8.51	6.24	0.55			83.98	23.40