GENERAL INFORMATION

DATA TITLE: Data for: Diversifying and Perennializing Plants in Agroecosystems Alters Retention of New C and N from Crop Residues

DATA ABSTRACT: These data are soil, CO_2 efflux, dissolved organic carbon leaching, and various other measures from a mesocosm experiment performed in long-term (12-years) crop diversity experiment near Hickory Corners, MI, United States. Briefly, we tracked dual-labelled (^{13}C and ^{15}N), isotopically enriched wheat (*Triticum aestivum*) residue *in situ* for two years as it decomposed in three agroecosystems: maize-soybean rotation (CS), maize-soybean-wheat plus red clover and cereal rye cover crops (CSW2), and spring fallow management with regeneration of natural grassland species (7-10 species; SF). We measured losses of wheat residue (C_{wheat} and N_{wheat}) in leached soil solution and greenhouse gas fluxes, as well as how much was recovered in microbial biomass and bulk soil at 5-cm increments down to 20 cm.

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ASSOCIATED PUBLICATIONS:

McDaniel, M.D., J.A. Bird, J. Pett-Ridge, E. Marin-Spiotta, T.M. Schmidt, A.S. Grandy. (2022). Diversifying and Perennializing Plants in Agroecosystems Alters Retention of New C and N from Crop Residues. In press at *Ecological Applications*.

McDaniel, M. D., Grandy, A. S., Tiemann, L. K., & Weintraub, M. N. (2014). Crop rotation complexity regulates the decomposition of high and low quality residues. *Soil Biology and Biochemistry*, 78, 243-254. https://doi.org/10.1016/j.soilbio.2014.07.027

McDaniel, M. D., & Grandy, A. S. (2016). Soil microbial biomass and function are altered by 12 years of crop rotation. *Soil*, 2(4), 583-599. https://doi.org/10.5194/soil-2-583-2016

COLLECTION INFORMATION:

Time period(s): 2011 to 2013
Location(s): Hickory Corners, MI, United States
Long-term Experiment: Cropping Biodiversity Gradient Experiment
Further Site Information: https://lter.kbs.msu.edu/research/long-term-experiments/biodiversity-gradient/

FILE DIRECTORY

FILE LIST

- **McDaniel2022_readme.pdf**
  - This file.
- **McDaniel2022_META-DATA.xlsx**
  - A list of general treatment abbreviations, definitions, and variable units. There is one tab in this sheet for each of the following datasheets.
- **McDaniel2022_Wheat_13CO2.csv**
  - Multiple daily measurements of air temp, soil CO2 efflux (from control and +wheat), and calculations of F_{litter} and primed carbon.
- **McDaniel2022_Wheat_13DOC.csv**
  - Multiple daily measurements of dissolved organic carbon concentration in lysimeters, delta ^{13}C of that leachate, and F_{litter}.
- **McDaniel2022_Wheat_AncillarySoilData.csv**
  - Soil data collected on November 1, 2012 (0-15 cm depth). See Meta-Data key for response variable abbreviations.
- **McDaniel2022_Wheat_BulkSoil.csv**
  - Soil carbon and nitrogen data from last, and 2nd, mesocosm. This includes percentage of wheat C and N at each depth. Also it includes metrics of C and N stabilization like Soil Stratification Index (SSI), Carbon Retention Efficiency (CRE), and percent change from Year-1 to Year-2.

CODEBOOK

- Period (.) or nd (no data) were used missing or null data.
- If value was below detection limit, then 0.5× (limit of detection) was used.
- See **McDaniel2022_META-DATA.xlsx** for abbreviations, definitions, explanations of data.

METHODS AND MATERIALS

STATISTICS AND DATA ANALYSES (FROM MCDANIEL ET AL. 2022)

To determine the source of CO_2 carbon we used the Keeling plot method (Keeling 1958). The $\delta^{13}C$ signature of CO_2 was calculated using a linear regression of the $\delta^{13}C$ and inverse of CO_2 concentration with a minimum of three time points for each chamber. This was calculated for both the wheat-added and control chambers. The $\delta^{13}C_{treatment}$ is the source value of CO_2 from the $^{13}C_{wheat}$-added soil using a Keeling plot.$\delta^{13}C_{control}$ is the source value of CO_2-^{13}C from endogenous soil organic C (derived from Keeling plot of the control).

To calculate ^{13}C or ^{15}N in all measured soil pools – SOC, total N, microbial biomass and extractable C from soil with salt (K_2SO_4) – we used $\delta^{13}C$ or $\delta^{15}N$ values from labelled and controlled soils. For example, the $\delta^{13}C_{MBC}$ values for both treatment and control soils were calculated based on mass balance as

$$\delta^{13}C_{MBC} = \frac{\delta^{13}C_F * [C]_F - \delta^{13}C_{NF} * [C]_{NF}}{[MBC]}$$

where $\delta^{13}C_F$ and $\delta^{13}C_{NF}$, and $[C]_F$ and $[C]_{NF}$ are the delta values and concentrations for fumigated and non-fumigated samples respectively and [MBC] is the calculated concentration of microbial biomass.

All wheat C and N pools and fluxes [from Equation 1] were then used in a two-source mixing model where treatment (wheat added) and control (no wheat added) were used to calculate f_{wheat}. Where f_{wheat} is the fraction of ^{13}C or ^{15}N derived from wheat residue. Here we show just ^{13}C for an example, but this equation also applies for ^{15}N.

$$f_{wheat} = \frac{\delta^{13}C_{treatment} - \delta^{13}C_{control}}{\delta^{13}C_{wheat} - \delta^{13}C_{control}}$$

$\delta^{13}C_{treatment}$ is the delta value from the wheat-added sample of interest, $\delta^{13}C_{control}$ is the respective sample from the mesocosm control, and $\delta^{13}C_{wheat}$ is the delta value of the wheat residue ($\delta^{13}C$ = 5,126 or$\delta^{15}N$ = 29,709). Accordingly, f_{wheat} can be applied to a pool or flux to derive proportion of C or N coming from the added wheat residue (e.g.,C_{wheat} leached as DOC). Primed SOC was calculated as control subtracted from treatment CO_2 flux multiplied by 1-f_{wheat}.

We also calculated three measures of efficiency of the soil decomposer community to convert the wheat residue into SOM. First, a 'Soil Stratification Index' [SSI, *sensu* Franzluebbers (2002) and Jarecki et al. (2005)] was calculated as the % wheat C and N in the top 0-5 cm depth divided by that in the 5-20 cm depth. The SSI in this case is a measure of the efficiency of the top 5 cm of soil to retain wheat C and N and not lose it through leaching to the 5-20 cm depth. Second, we used the change in total mesocosm wheat residue-derived C and N (0-20 cm) between Year 1 and Year 2 as a measure of whether the soil was accumulating or losing residue-derived C and N within the 1-2 y timeframe. Third, as a measure of carbon-retention-efficiency (CRE) at the soil profile level, we simply divided the remainder of residue-derived C stored in each soil mesocosm at 2 y by the amount emitted as CO_2-C plus DOC and that of C remaining in soil. The CRE is similar to C-use-efficiency metric that is typically used in more controlled incubation studies and reflects efficiency specific to microbial biomass (Manzoni et al. 2012, Spohn et al. 2016, Geyer et al. 2019). Here, however, the CRE reflects a soil-profile-level processes, and gives proportion of C that persisted for two years (at 0-20cm depth).

Because of infrequent measurements of CO_2 (due to logistics and the high cost of $\delta^{13}C$-CO_2 analyses), we also used a two-prong modelling approach to derive cumulative losses of CO_2-C_{wheat}.First, to interpolate daily CO_2 fluxes, we used known CO_2 flux measurements with soil temperature and moisture data from nearby sensors (< 0.5 km) in a step-wise multiple linear regression (MLR) model. The MLR variables included 239 log normal CO_2 flux ($lnCO_2$) with empirically linked measurements of year of experiment (Y, values of 0 or 1), soil temperature (T, 5.3 to 31.2 °C), gravimetric soil moisture (θ, 0.024 to 0.42 g g^{-1}).Terms not significant at $\alpha<0.05$ were dropped from the model.CO_2 fluxes can be modelled quite accurately from soil temperature and moisture alone (Tang et al. 2005, Sullivan et al. 2008, McDaniel et al. 2014b).Second, these predicted CO_2 fluxes from the MLR were used with an interpolated f_{wheat} to gap-fill and calculate cumulative losses of CO_2-C_{wheat}.We can also fit f_{wheat} to 3-parameter exponential decay models ($f_{wheat} = y_0 + ae^{-kx}$) to measure wheat decomposition kinetics including decay rate (k) and mean residence time (Adair et al., 2008).These modelled cumulative CO_2-C_{wheat} were also used to calculate CRE.

Data were checked for normality and heterogeneity of variances in R (v3.4.3, the R Foundation for Statistical Computing, Vienna, Austria) using Q-Q plots (*qqnorm*), a Shapiro test (*shapiro.test*), and a Bartlett test (*bartlett.test*); and outliers removed if greater than 1.5× interquartile range and transformed if tests showed $p < 0.05$.Based on these tests, there were no outliers (some missing values) and all the data were normally distributed and did not need transformation. ANOVAs among plant diversity treatments were carried out with the R package *aov* and comparison of means with *TukeyHSD*. Due to the high variability of field studies with stable isotopes in general and our specific highly variable soils, we used an $\alpha = 0.05$ for significance and $\alpha = 0.1$ for marginal significance (Enjalbert et al., 2013; Freedman and Zak, 2015). Where means are reported, so are standard errors (after ±) for reference. Repeated measures ANOVAs were used for CO_2 flux data in SAS (v9.4) using *proc mixed*, and *lsmeans* for separation of means and treatment effects by dates. To determine main drivers of wheat residue dynamics, Pearson correlation coefficients were calculated between decomposition/retention dynamics and 36 soil properties measured and published previously in McDaniel & Grandy (2016). We used SigmaPlot (v.13, Systat Software, Inc., San Jose, CA) for linear and non-linear correlations among variables and visualization of data.

SOFTWARE

Name: R
Version: v3.4.3
System Requirements:
URL: https://www.r-project.org/
Developer: Foundation for Statistical Computing

Name: SAS
Version: v9.4
System Requirements:
URL: https://www.sas.com/en_us/software/stat.html
Developer: SAS Institute

Name: SigmaPlot
Version: v14
System Requirements:
URL: https://systatsoftware.com/sigmaplot/
Developer: Systat

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