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Supplemental material

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Table S1

Years when the initial observation (IO) and additional soil samples (S) were collected from Soil Health Partnership sites. The site-year count is also included.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Site** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** |
| 1 |  | IO |  | S |  | S |
| 2 |  | IO | S | S |  | S |
| 3 |  | IO | S | S |  | S |
| 4 |  | IO |  | S |  |  |
| 5 |  | IO | S |  | S |  |
| 6 |  | IO |  | S |  | S |
| 7 |  |  | IO |  | S |  |
| 8 |  | IO |  | S |  | S |
| 9 |  | IO | S |  |  | S |
| 10 |  | IO | S |  |  |  |
| 11 |  |  | IO |  | S |  |
| 12 |  |  | IO |  | S |  |
| 13 |  |  | IO |  | S |  |
| 14 |  |  | IO |  | S |  |
| 15 |  |  | IO |  | S |  |
| 16 |  |  | IO |  | S |  |
| 17 |  |  | IO |  | S |  |
| 18 |  |  | IO |  | S |  |
| 19 |  |  | IO |  | S |  |
| 20 |  |  |  | IO |  | S |
| 21 |  |  |  | IO |  | S |
| 22 |  |  |  | IO |  | S |
| 23 |  |  |  | IO |  | S |
| 24 |  |  |  | IO |  | S |
| 25 |  |  |  | IO |  | S |
| 26 |  |  |  | IO |  | S |
| 27 |  |  |  | IO |  | S |
| 28 |  |  |  | IO |  | S |
| 29 |  |  |  | IO |  | S |
| 30 |  |  |  | IO |  | S |
| 31 |  |  |  | IO |  | S |
| 32 |  |  |  | IO |  | S |
| 33 |  |  |  | IO |  | S |
| 34 |  |  |  | IO |  | S |
| 35 |  |  |  | IO | S | S |
| Site-years |  |  | 5 | 6 | 12 | 22 |

Table S2

Soil health indicator abbreviations and laboratory analysis methods used in this study.

|  |  |  |  |
| --- | --- | --- | --- |
| Soil health indicator | SHA | Analysis method | Citation |
| Organic matter (OM); soil organic carbon (SOC) | CASH, SMAF | Calculated as weight lost from a soil sample on ignition. SOC was calculated by multiplying percent OM by 0.58. | Schindelbeck et al. 2016, Cambardella et al. 2001 |
| Permanganate oxidizable carbon (POX-C) | CASH | Photospectrometry analysis of oxidized potassium permanganate extractant. | Schindelbeck et al., 2016 |
| Autoclaved citrate extractable soil protein index (ACE) | CASH | High pressure and temperature extraction of citrate solution. | Schindelbeck et al., 2016 |
| Soil microbial respiration 96-hour incubation (Resp (96 hr)) | CASH | Quantification of CO2 gas trapped in solution evolved from re-wetted soil incubated 96 hours. | Schindelbeck et al., 2016 |
| Soil microbial respiration 24-hour incubation (Resp (24 hr)) | HSHT | Paper chromatography quantification of CO2 gas evolved from re-wetted soil incubated 24 hours. | Haney 2020, Ward Laboratories 2020 |
| Water-extractable organic carbon (WEOC) | HSHT | Quantification of organic C extracted with water from a soil sample. | Haney 2020, Ward Laboratories 2020 |
| Water-extractable organic nitrogen (WEON) | HSHT | Quantification of organic N extracted with water from a soil sample. | Haney 2020, Ward Laboratories 2020 |
| pH | CASH | Voltage meter calibrated to determine Hydrogen ion activity in soil solution. | Watson and Brown 1998 |
| Soil chemical nutrients: P, K | SMAF | Mehlich-III extractant method and quantified using inductively coupled atomic plasma spectroscopy. | (Soil and Plant Analysis Council, 1999); Warncke and Brown 1998 |
| Available water capacity (AWC) | CASH, SMAF | Amount of water extracted from a pulverized and sieved soil sample using a pressure chamber. | Schindelbeck et al., 2016 |
| Soil wet aggregate stability (WAS) | CASH | Calculated from soil remaining on a 0.25 mm sieve following simulated rainfall. | Schindelbeck et al., 2016 |
| Sand, silt, and clay |  | Rapid 4-hour quantification of sand, silt, and clay from soil/water solution. | Schindelbeck et al., 2016 |

Notes: SHA, soil health assessment; CASH, Comprehensive assessment of soil health; SMAF, soil management assessment framework; HSHT, Haney soil health tool.

**Table S3**

The USDA-NRCS soil taxonomic classifications for 35 Soil Health Partnership sites.

|  |  |
| --- | --- |
| **Site** | **Taxonomic Classification** |
| 1 | Fine-silty, mixed, superactive, mesic Udic Haplustolls |
| 2 | Fine-loamy over sandy or sandy-skeletal, mixed, superactive, mesic Typic Argiaquolls |
| 3 | Fine-loamy, mixed, superactive, mesic Aquic Hapludolls |
| 4 | Fine-silty, mixed, superactive, mesic Typic Argiudolls |
| 5 | Fine, smectitic, mesic Vertic Endoaquolls |
| 6 | Fine-silty, mixed, superactive, mesic Typic Argiudolls |
| 7 | Fine-silty, mixed, superactive, mesic Oxyaquic Argiudolls |
| 8 | Fine, illitic, mesic Aeric Epiaqualfs |
| 9 | Fine, mixed, active, mesic Typic Hapludalfs |
| 10 | Fine-loamy, mixed, mesic, Typic Hapludolls |
| 11 | Fine-silty, mixed, superactive, mesic Cumulic Hapludolls |
| 12 | Fine-loamy, mixed, superactive, mesic Typic Endoaquolls |
| 13 | Fine-silty, mixed, superactive, mesic Aquic Argiudolls |
| 14 | Fine-silty, mixed, superactive, mesic Aeric Epiaqualfs |
| 15 | Fine-silty, mixed, superactive, mesic Typic Argiaquolls |
| 16 | Fine-loamy, mixed, superactive, mesic Typic Argiaquolls |
| 17 | Fine-loamy, mixed, superactive, mesic Typic Endoaquolls |
| 18 | Fine-silty, mixed, superactive, mesic Aquic Hapludalfs |
| 19 | Coarse-silty, mixed, active, acid, mesic Fluventic Endoaquepts |
| 20 | Fine-loamy, mixed, superactive, mesic Typic Endoaquolls |
| 21 | Fine-silty, mixed, mesic Cumilic Hapludolls |
| 22 | Fine-loamy, mixed, superactive, mesic Typic Endoaquolls |
| 23 | Fine-loamy, mixed, superactive, mesic Aquic Hapludolls |
| 24 | Fine, smectitic, mesic Aquic Argiudolls |
| 25 | Fine-silty, mixed, superactive, mesic Typic Endoaquolls |
| 26 | Fine, smectitic, mesic Aeric Fragic Epiaqualfs |
| 27 | Fine, montmorillonitic, mesic Udollic Ochraqualfs |
| 28 | Fine, smectitic, mesic Udollic Endoaqualfs |
| 29 | Fine, smectitic, mesic Aquic Argiudolls |
| 30 | Fine, smectitic, mesic Aquic Argiudolls |
| 31 | Fine, illitic, mesic Aquic Hapludalfs |
| 32 | Fine-loamy, mixed, superactive, mesic Typic Argiaquolls |
| 33 | Fine, smectitic, mesic Vertic Albaqualfs |
| 34 | Fine-silty, mixed, superactive, mesic Typic Argiustolls |
| 35 | Fine, mixed, active, mesic Typic Argiaquolls |

**Table S4**

List of response variables and transformations used for data preparation.

|  |  |
| --- | --- |
| Response Variable | Transformation |
| Soil health indicator observed values |  |
| OM | Square root |
| POX-C | None |
| ACE | Log |
| Resp 96 hr | Log |
| Resp 24 hr | Log |
| WEOC | Square root |
| WEON | Square root |
| pH | None |
| P | Log |
| K | Square root |
| WAS | Square root |
| AWC | Square |
| Crops |  |
| Corn | None |
| Soybean | None |
| Soil health assessment composite scores |  |
| SMAF | Square |
| CASH | None |
| HSHT | None |

Notes: ACE, autoclaved citrate extractable protein index; AWC, available water capacity; K, potassium; OM, organic matter loss on ignition; P, phosphorus; POX**-**C, permanganate oxidizable carbon; Resp (24 hr), microbial respiration 24-hour incubation; Resp (96 hr), microbial respiration 96-hour incubation; WAS, wet aggregate stability; WEOC, water-extractable organic carbon; WEON, water-extractable organic nitrogen.

**Table S5**

Statistical significance from the analysis of covariance for cover crop treatment (T), site (S), the initial observation of the response variable (IO), and their factorial interactions. Rows represent independent models for the response variable and fixed effects. Non-significant fixed effects were iteratively removed from the individual models until only significant factors remained.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Response Variable | Fixed Effects | | | | | | |
|  | T | S | IO | T x S | T x IO | S x IO | T x S x IO |
|  | Statistical Significance† | | | | | | |
| *Soil health indicators* |  |  |  |  |  |  |  |
| OM‡ | \* | \*\*\* | \*\*\* |  |  | \*\*\* |  |
| POX-C | \* | \*\*\* | \*\*\* |  |  |  |  |
| ACE |  | \*\*\* | \*\*\* |  |  |  |  |
| Resp 96 | \*\* | \*\*\* |  |  |  |  |  |
| Resp 24 |  | \*\*\* | + |  |  |  |  |
| WEOC |  | \*\*\* |  |  |  |  |  |
| WEON |  | \*\*\* |  |  |  |  |  |
| pH |  | \*\* | \*\*\* |  |  | \*\* |  |
| P |  | \*\*\* | \*\*\* |  |  | \*\*\* |  |
| K |  | \*\*\* | \*\*\* |  |  |  |  |
| WAS |  | \*\*\* | + |  |  |  |  |
| AWC |  | \*\*\* | \*\*\* |  |  |  |  |
| *Crops* |  |  |  |  |  |  |  |
| Corn |  | \*\*\* |  |  |  |  |  |
| Soybean |  |  |  |  |  |  |  |
| *Soil health assessment scores* | |  |  |  |  |  |  |
| SMAF |  | \* | \*\*\* |  |  | \* |  |
| CASH | \*\*\* | \* | \*\*\* |  |  | + |  |
| HSHT |  | \* | + |  |  |  |  |

Notes: ACE, autoclaved citrate extractable protein index; AWC, available water capacity; K, potassium; OM, organic matter loss on ignition; P, phosphorus; Resp 24 hr, microbial respiration 24-hour incubation; POX-C, permanganate oxidizable carbon; Resp 96 hr, microbial respiration 96-hour incubation; WAS, wet aggregate stability; WEOC, water-extractable organic carbon; WEON, water-extractable organic nitrogen. SMAF, Soil Management Assessment Framework; CASH, Comprehensive Assessment of Soil Health; HSHT, Haney Soil Health Tool.

† +Significant at the 0.1 probability level; \*Significant at the 0.05 probability level; \*\*Significant at the 0.01 probability level; \*\*\*Significant at the 0.001 probability level; ns, not significant.

‡ Only 34 sites were used in the OM analysis due to missing values.

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