doi:10.2489/jswc.74.1.12A

FEATURE

State-wide soil health programs for education and on-farm assessment: Lessons learned

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Soil health has received increased attention in recent years. The USDA Natural Resources Conservation Service (NRCS), state agencies, extension services, farm groups, nongovernmental organizations, and many others are working with farmers to provide education on and promote adoption of soil health systems. Farmers adapting the management of their operations to include these systems typically wish to measure improvements in profitability along with measurable improvements of soil health over time.

Both the soil health assessment process and the educational programs require breadth and depth of knowledge from a team of people. The Indiana Conservation Cropping Systems Initiative (CCSI) is completing a comprehensive six year soil health project begun in 2012, involving 17 primary sites across the state in cooperation with numerous partners. Our experiences with this project, lessons learned, and recommendations for other projects of this type may be useful to groups just getting started with soil health education and on-farm assessment programs. Although some of our lessons learned are similar to those of the first three years of the Soil Health Partnership (Karlen et al. 2017), the CCSI project began two years earlier and was structured differently, with conservation partners as key drivers. Therefore, the lessons learned from both projects may be helpful to consider.

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PROJECT BACKGROUND

The soil health project itself was built upon the strength of the Indiana Conservation Partnership (ICP), a collaboration of eight different government and university organizations. For over three decades, the ICP has actively collaborated on conservation education and programming within the state of Indiana. A key program of the ICP is the CCSI. Launched in 2009, CCSI's mission is to improve soil health on Indiana cropland through education and technical assistance. Although these types of partnerships require effort and commitment on the part of leadership at state and local levels to establish and sustain them, we feel they are a critical first step before a project of this magnitude can be successful.

The soil health project was conceived as a way to enhance soil health education and successful adoption across the state of Indiana. We felt a need for more demonstration/research sites across the state to serve as locations for training and outreach, to document changes in soil health, and to verify the economics of the systems. We also wanted to harness the power and experience of innovative conservation farmers to help educate other farmers, conservation staff, and agriculture professionals on soil health. Finally, we wanted to foster partnerships and team-building at the local level with ICP staff, farmers, certified crop advisers, and the agriculture industry.

This project was originally funded through a USDA NRCS Conservation Innovation Grant (CIG) with an overall goal to "integrate long-term continuous no-till/strip-till, cover crops, precision technology, and nutrient and pest management practices into productive, profitable, and sustainable systems. The three main objectives included (1) demonstrating and quantifying the impacts of conservation systems on improving soil health; (2) providing training and technical information to ICP staff, farmers, and other agriculture professionals in the latest conservation cropping system technology; [and] (3) sparking greater adoption of conservation cropping systems that lead to long-term soil health" (CCSI 2016).

PROJECT IMPLEMENTATION

The core project team consisted of the CCSI Oversight Committee, comprised of ICP representatives, including a research/extension scientist, NRCS and state soil conservation staff, and staff representing state commodity organizations and the Conservation Technology Information Center. Two CCSI agronomists and a newly hired program manager rounded out the core team. This core team of 10 to 12 people met regularly by conference call or in person, over the duration of the project.

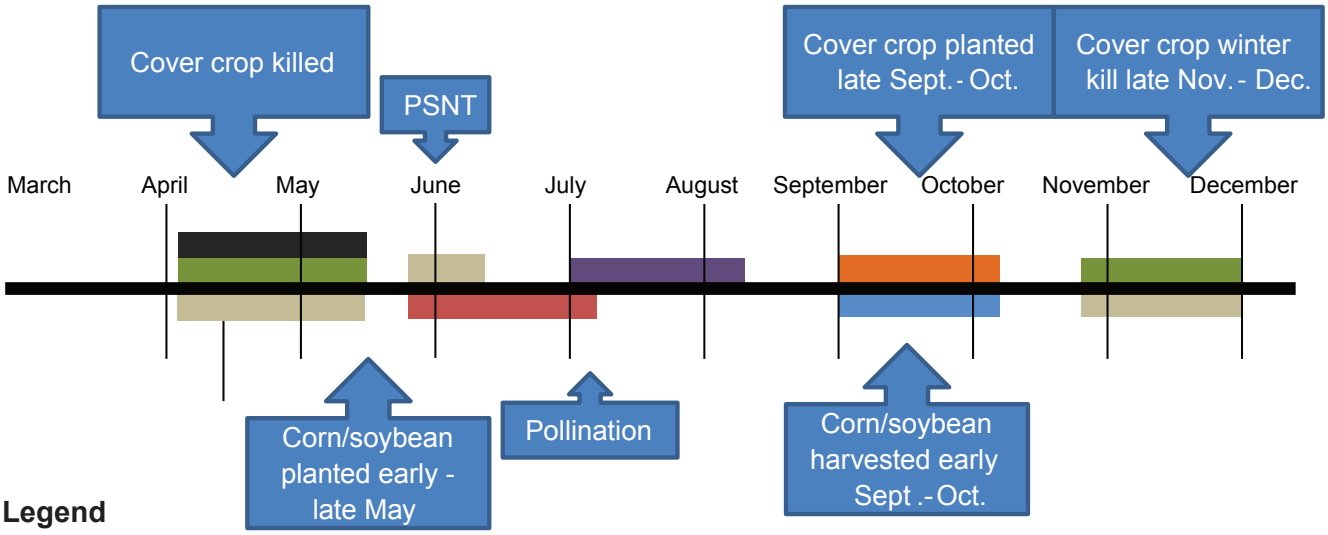
The four quadrants of the state were identified as "regional hubs," serving as focal points for the demonstration/research assessments, along with educational outreach and training activities. The project was initially designed to include 13 sites, consisting of 8 farmer-cooperators, 2 soil and water conservation district (SWCD)–managed sites, and 3 Purdue Agricultural Centers.

Criteria for potential farmer-cooperators for this project included active no-till or strip-till, yield monitoring/mapping capabilities, access to field records, ability and willingness to conduct a replicated strip trial on one field for three years, and facilities to host field days and trainings. Desirable attributes included long-term experience with conservation cropping systems, a track record of promoting conservation, and effective communication skills. A list of 39 potential farmer-cooperators was generated from personal knowledge of the core team plus input from two partnering organizations: Indiana Soybean Alliance and Indiana Corn Marketing Council. Potential cooperators were vetted for interest, required criteria, and desirable attributes.

Because of the number of highly qualified candidates and to increase the geographic breadth of the outreach loca-

Figure 1

Timeline for field soil sampling at Indiana Conservation Cropping Systems Initiative sites. PSNT = Pre-sidedress nitrate test.



Legend

- Soil fertility
- Cover crop biomass
- Soil nitrate, moisture, and temperature
- Soil penetration resistance, soil moisture, soil aggregation, and soil health sampling (intact cores – water holding capacity)
- Chlorophyll reading
- Stalk nitrate and hand harvest for nitrogen availability
- Yield monitor

Soil health tests include the following:

- Ward Labs – PLFA test (fatty acids)
- Earthfort – soil food-web analysis
- Cornell Soil Health Assessment – suite of biological, physical, and chemical tests
- Haney Test – suite of chemical tests and Solvita CO_2 burst to give a soil health score

tions, the project scope was enlarged to include 12 farmer-cooperators, 3 for each hub region. Participating farmers were required to (1) conduct field trials comparing a current practice to a new practice, and (2) serve as host/mentor/advisor/resource for field days, for staff trainings, and for farmers to call or visit when considering adopting conservation systems. Members of the core team then worked with the farmer-cooperators to select an appropriate field for the strip trials, design "treatments," and further review project requirements.

Concurrently, the core team reached out to field-level ICP staff to establish four working groups, one per regional hub. Some working group members were initially appointed by their state- or area-level leadership, including members of the recently formed Indiana NRCS regional soil health teams. These four working groups were intended to (1) assist with planning and hosting the regional hub field days, workshops, and trainings; and (2) conduct field soil and plant sampling on farmer-cooperator and SWCD-managed sites. Those two activities became a team-building exercise, serving to strengthen the local collaboration among ICP staff for soil health understanding, outreach, and education.

Sampling protocols were developed from the list of measurements identified in the CIG proposal and were the consensus of the two CCSI agronomists, the NRCS soil health specialist, and the university researcher. Details on depths, timing, commercial lab requirements, and other important aspects were written up in outline form, and then later improved to include more details and photos. The general timeline of the different samplings is shown in figure 1.

As the full extent of sampling details became apparent, one person was selected as the point of contact for each of the farmer-cooperator and SWCD-managed sites. This person was responsible for keeping in contact with the farmer about timing of field operations, crop status, and other factors that determined the timing of sampling events. The contact person would then solicit assistance from the regional working group for the actual field sampling events.

Field records and other metadata associated with farmer-cooperator operations were collected as part of a partnering economic study. The wide variety of practices, systems, and soils across the state and relatively few numbers of sites did not provide sufficient information for rigorous economic analyses; however, the preliminary data were used to redesign and focus future economics work. In lieu of the planned in-depth analysis, eight economic case studies were conducted and published and have been used often at workshops and other venues. These are available on the CCSI website (CCSI 2018a).

Initial plans for outreach and education events included one "train the trainer" and two farmer-oriented workshops/field days per hub region per year, aiming for one field day per farmer cooperator (originally planned as eight) per year. Due

to geographic locations and logistics, not all farmer-cooperators served as the host farm for an event; however, all participating farmers took part in multiple events at other locations, providing their expertise to attendees. Involving our participating farmers as part of the teaching cadre was very effective in helping other farmers learn practical details about making soil health systems work well, and in understanding *why* they might wish to adopt similar systems. In addition to technical education, presentation and media skills training was added to help ICP staff and some farmers improve their soil health communications skills. During the CIG period, 290 CCSI-associated education events were held. Since 2011, CCSI workshops have reached over 25,500 attendees; over 750 unique individuals have attended at least one soil health training for staff and agricultural professionals.

Many written materials and press releases were produced during the project, including 11 NRCS Fact Sheets, 6 Purdue Extension publications, 3 master's degree theses, and 23 news releases. A full list of these is available on the final CIG report (CCSI 2016). Individual farmer reports are available on the website (CCSI 2018b).

The project served as training and experience for at least 10 graduate students who helped with sampling at farmers' fields, participated in workshops, and met farmers and conservation field staff involved with the project. The project also helped several new faculty members become involved in the ICP efforts. These networking and learning opportunities were invaluable for the students and new faculty.

CHALLENGES ENCOUNTERED

A number of operational challenges were encountered that affected data collection, the ability to detect soil health differences among treatments, and the communication of results to all partners.

Sites and Treatments. Treatments on some farmer sites were not very different from each other; therefore we might not expect measurable differences in soil health, at least over the short term. Examples include no-till vs. strip-till (both with cover crops), strip-till vs. vertical till (both with cover crops), wheat (*Triticum aestivum* L.) vs. cereal rye (*Secale cereale* L.) cover crops, or cover crops with different rates of fertilizer nitrogen (N). Other farmer sites had true cover crop vs. no cover crop comparisons, but they were planted on fields with long-term history of no-till. The impact of a few years of these treatments was not very large on this strong base of no-till.

Treatment comparisons were not the same among any of the farmer cooperators, which made it more difficult to discern trends across multiple soils and locations. There were different soil types and locations, as desired, but there were also different cover crops, cash crops, crop rotations, degrees of tillage or no-tillage, and many other factors.

Partner Support and Organization. Initially, some ICP field staff were not very supportive of the project, in part because they were unaware of their potential involvement and were not part of early planning, including suggestions of potential farmer-cooperators. This took some time on the part of the core CCSI team to take a step back and provide better explanations and invitations for improved partnering on the project.

Metadata collection from all farmer-cooperators was difficult. Most farmers provided partial information of the detailed data that was requested, and some did not readily respond to emails. In addition, overlapping projects and confusion about which team members were gathering data sometimes led to two or three team members contacting the farmer to collect the same information, which became annoying to the farmers and another source of confusion and frustration for the team members. These issues affected both the agronomic and the planned economic analyses.

Data Analysis and Communication of Results. Timely communication about results and their meaning was a difficult challenge for several reasons, including volume of data, complexity of analysis, and reporting processes. First, there were many tests, done at several times per year, on many sites. None of the team had prior direct experience with commercial soil health tests, which was precisely why we wanted to measure these. The soil health data from commercial soil health labs were complicated, and no team member had the time nor expertise to fully analyze those data, interpret them, and make sense of them for our farmer and field staff cooperators. This became a source of frustration for all. The baseline (2013) results were analyzed by a postdoctoral researcher from another group at Purdue, and results were presented to the teams in late 2014. The next rounds of soil health samples were not taken until 2015 and were not fully analyzed until 2017 upon arrival of a postdoctoral researcher, funded by NRCS (CESU Agreement No. 68-3A75-18-037) to be dedicated to analyzing data from this project.

Some of these data (cover crop biomass and N content, soil nitrate [NO_3^-], stalk NO_3^-, and some detailed soil physical properties at selected sites) were part of graduate student theses, and the students analyzed them at the end of each year. Reports were prepared but were not always distributed very widely.

Although reports were written and summaries presented to teams in the fall of 2017, the interpretations are not clear cut, and therefore some of the teams were discouraged that more distinct results were not obtained. Although results that show little difference between cover and no cover for long-term no-till plots are valid and useful findings and can help inform future efforts, it is often discouraging to team members who are not as familiar with research results nor the slow path of developing and identifying useful new measurement techniques for soil attributes that are not as well understood, like soil biology.

Another factor contributing to the frustration of team members was the apparent lack of comparability of results from different labs, on tests that purportedly were measuring the same thing. Soil respiration is one example, where two different labs used two different time periods (96 hours vs. 24 hours), which then led to different results and interpretations. Other examples include different methods for attributes given similar interpretations (e.g., availability of carbon [C] to microbes) but quite different results (e.g., active C vs. water extractable organic C). These all point to the continuing need for some standardization of methodology, including sampling procedures.

SOLUTIONS DEVELOPED

For some sites, tilled fields without cover crops were located as comparisons for 2016. These conventional neighbor fields were not perfect comparisons as they were not adjacent fields in most cases, and often had a different cash crop at the time of sampling than the main CCSI fields, but they were similar soils. The tillage intensity on comparison sites varied. In general, more differences in soil health were detected between the cover cropped, no-till CCSI field and the conventional neighbor, than between the cover crop vs. no cover crop, no-till treatments on the CCSI field.

Obtaining farmer metadata improved by the program manager calling each farmer multiple times per season after anticipated field operations to collect data, i.e., when was cover crop terminated and how; what crop was planted, when, and at what seeding rate; fertilizer products, rates, and dates; pesticides, rates, and dates; harvest dates, yields, etc. This was time consuming but was successfully completed for one of the years. For economic analyses fields (usually different fields than the strip trial fields), the graduate student was able to get appointments with many, but not all, of the farmers to obtain their data. Although somewhat easier with those farmers with good record-keeping systems (whether computer or paper records), this was still not straightforward. This whole area needs further streamlining and techniques to obtain the needed data, while minimizing the burden on the farmers and project personnel.

LESSONS LEARNED AND FURTHER RECOMMENDATIONS

The project team learned many lessons as we progressed through the challenges and opportunities of this collaborative effort. We offer our reflections and recommendations to hopefully help others who may be initiating on-farm studies for soil health improvement.

Farmer and Site Selection. Based on our experiences, we recommend the following considerations when selecting farmer-cooperators and field trial sites for similar projects:

- Develop and follow rigid criteria for selection of farmers. Assure that their record keeping skills and technology are exemplary. Possibly provide them with software and/or training.
- Solicit suggested potential farmer names from conservation field staff, as well as from core team members and commodity groups, to provide a broader range of potential cooperators and to increase buy-in of the project.
- Consider pairing an experienced conservation system farmer cooperator with a farmer who is just starting or wanting to start conservation systems. This provides expertise and mentorship to the farmer just beginning in these systems, as well as potential comparison sites if soil types are similar. In addition, it expands the potential reach of educational events, as the attendees can learn the benefits of long-term use but also hear the experiences of someone just starting who may be more relatable to them in their own concerns and constraints.

Research Design and Sampling. To increase the probability of detecting differences in soil health with different management practices and over time, we suggest focusing on large management changes, maintaining consistency in sampling and analysis, and restricting the number of treatments and measurement types. Specifically, we recommend the following:

- For the on-farm research, start with fields that are more "conventional" and then implement a conservation cropping system, preferably with multiple practices (e.g., cover crops and no-till and the associated nutrient and pest management practices needed for those), but maintain a "control" plot with the original practices as a comparison. Generally, improvements will be measurable faster when starting from a more conventional system. Even those farmers who have long-term experience with conservation cropping systems may pick up new fields that have not yet had such systems in place.
- Consider a narrow range of treatments to be repeated across all cooperating farms. Inferences from this study were limited in part by the wide range of treatments used by the different farmers. Perhaps local or regional groups of farmers wanting to evaluate one cover crop vs. no cover, or one cover crop vs. a large, multispecies mix, who would all do the same treatment for multiple years on the same field, would allow stronger conclusions to be made. Groups like Practical Farmers of Iowa (PFI 2018) have taken this type of approach on other agronomic research, allowing for better learning and data.
- Monitor the soil health over a longer time period, preferably a minimum of five years. Soil health is a long-term improvement process.
- Be consistent in the sampling, including sampling at the same time of year, the same cash crop, same relative row position, same depth, and same soil health test/lab. This also means sampling the same locations in a field for subsequent years. See Purdue Extension publication by Zuber and Kladivko (2018) for details.
- Provide required annual training for all volunteer samplers to clarify procedures and emphasize important points. Not all conservation staff and volunteers have taken soil samples, used a penetrometer, sampled cover crop biomass, etc., and many are unsure of correct procedures. Written procedures, with photos, are necessary, but in-person training is also very helpful. This improves data quality, helps educate and reassure the sampling crews, and helps build even greater buy-in with the project. This training could also include a primer on research, why the specific data are being collected, why the metadata are so important, and how data will be analyzed and interpreted.
- Consider contracting sampling to an agronomist or extension educator with experience in field research and soil sampling, rather than requesting volunteer sampling from conservation field staff. This may improve sampling consistency and reduce training needs; however, it also takes away the potential "team-building" benefit of local staff collaborating on sampling and seeing the same farmer's field through all the stages of the season.
- Acknowledge the limitations of working with farmers on on-farm trials and adjust expectations accordingly. Even

with well-planned field trials of two treatments, farmers manage dynamically and often adjust or change things to manage their system. It is difficult to evaluate and analyze the system as they would really want to manage it, within the constraints and "rules" of strip trials in a field, but it is also difficult to compare different fields managed with different complete systems and obtain statistically rigorous data.

- Consider restricting the numbers and types of measurements made on these types of farmer strip trials to a few key measurements in a few well-defined areas of the field. Although this conflicts with the ideas of taking many measurements, such as all the Tier 1 measurements recommended for soil health monitoring by the Soil Health Institute (SHI 2017), it may be better to select a few measurements and take more soil samples to characterize these.

Metadata. Metadata collection is a difficult challenge. Although farmers agree to provide the needed information, it can be difficult to obtain due to the time required on their part. Some suggestions to improve metadata collection include the following:

- Make use of agronomic software packages that collect field data and organize record-keeping. A challenge is that every farmer has a different combination of software, equipment, and precision farming applications. Often, data are not compatible across companies and platforms.
- Even if a software solution is possible, schedule time for the project data person to sit down with the farmer (and main farmer contact person), show them the features, explain why these metadata are needed, and build the relationship. This is especially important the first year, but might need to take place annually, depending on the process.

Interpretation and Communication of Results. Prompt data analysis, interpretation, and communication are essential for maintaining the interest and engagement of project partners and cooperators. To deal with the data analysis challenges discussed earlier, we recommend the following:

- Consider hiring a full-time or nearly full-time person to handle the data, manage it in a database, and analyze and interpret the data for a study of similar size and scope. For soil health data analysis and interpretation, a PhD-level scientist is needed, with expertise in a range of statistical analysis techniques along with technical knowledge of soil health. Database management could be done by a different person, who collects, enters, curates, and manages the data. Separation of the database management and the data analysis would be critical for studies any larger than the one we did, meaning at least a full-time data analyst and a part-time database manager (i.e., someone who spends a significant portion of their time on managing the data from the project).
- Send periodic short newsletters to the farmers and local team members about the types of results they will be receiving directly from the lab (e.g., biomass and soil NO_3^- in spring), along with general interpretations of the data (e.g., pounds of N in the biomass is N protected from leaching losses). This serves to provide feedback several times per year in a way that is general and not specific to each site's results, and it can be done before overall project data are analyzed.

Engaging a Diverse Group of Cooperators. Capitalize on the network and sense of community that develops as a result of working together on a true partnership project. Many of the people involved, including farmers, conservation field staff and crop advisers who assist with sampling and participate in workshops and field days, students, and core team members, may develop new and/or deepened relationships through the common purpose and sharing of ideas and experiences. Further development of ways to keep everyone engaged and interested for the duration of a project would be helpful, building on that sense of community.

CONCLUSIONS

The Indiana CCSI project on soil health demonstration/research, assessment, and education/outreach has been an important contribution to facilitating further adoption of conservation cropping systems in Indiana and neighboring states. The project included numerous partners from around the state and received funding from NRCS and other partner organizations and entities. The project built upon the strong, state-wide ICP and strengthened partnership efforts at the local level to educate farmers about how and why to integrate cover crops, no-till, and associated practices into their farming operations. Outstanding conservation farmers were an integral part of the teaching cadre, educating conservation staff and farmers about the practical aspects of integrating conservation practices into their systems. Outreach included training of field staff, workshops and field days for farmers and field staff, many types of written and web materials, and small group and one-on-one discussions. Research/demonstration activities were conducted at Purdue research centers and on cooperating farmers' fields and involved local conservation staff in the collection of the field samples. The CCSI has won several awards (No-Till Innovator from No-Till Farmer, January 2016; Soil and Water Conservation Society 2014 Merit Award; and 2017 Conservation Accomplishment Group Award from Indiana Soil and Water Conservation Society), recognizing the work and effectiveness of the overall program. The program has continued to learn lessons, change, and grow over time. It is our hope that some of these lessons learned and recommendations will be helpful to others who are considering initiating on-farm studies aimed at soil health improvement.

ACKNOWLEDGEMENTS

This project was originally funded through a USDA Natural Resources Conservation Service Conservation Innovation Grant, grant #69-3A75-12-215.

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