**Building Collaborative Research Networks to Advance the Science of Soil Fertility:**

**Fertilizer Recommendation Support Tool (FRST)**

**A. *Statement of Issues and Justification:***Soil testing and the recommendations derived from laboratory analyses provide the backbone for nutrient management in modern agricultural production systems. However, most science-based soil fertility recommendation systems for phosphorus (P) and potassium (K) fertilizer guidance are based on decades-old soil-test relationships that were developed within states in the 1950s-1970s (Spargo et al., 2022). While soil testing has the common goal of determining which nutrients are needed and how much fertilizer to apply, soil-testing laboratories in the U.S. use different analytical methods, interpretations, and philosophical approaches when making fertilizer or nutrient recommendations. The NIFA soil test regional work groups (NCERA-13, NECC-1012, SERA-6, and WERA-103) have provided good guidance for analytical methods and today, five soil test extractants are used to analyze P and/or K of most soil samples in the USA (Spargo et al., 2022). Additionally, all university labs participate in either the North American Proficiency Testing (NAPT) Program or the Agricultural Lab Proficiency (ALP) Program to assure the accuracy and precision of soil test results. Thus, the differences in soil-test-based nutrient recommendations among labs across states with similar physiographic areas and soils are most often due to older calibration and correlation study results and interpretations of the results (e.g. philosophical choices).

Conflicting and outdated recommendations across state boundaries lead to end-user confusion and reduced confidence in soil testing, which ultimately proves detrimental to research and educational efforts that encourage 4R Nutrient Stewardship. The 4R Nutrient Stewardship program is the backbone of USDA-NRCS Nutrient Management Standard designed to optimize nutrient use while minimizing off-site impact of nutrients on water quality. Despite long-standing regional efforts to maintain communication and coordination across soil testing programs, Zhang et al. (2020) demonstrated that land grant recommendations from university or state labs within the Southern region using the same soil test extractants had P recommendations that varied by a factor of 2.5. These differences across state lines were primarily based on best professional judgment rather than empirical evidence. Scientifically defensible soil-test recommendations are fundamental to agricultural production and environmental protection.

To advance the precision of soil test recommendations and, where appropriate, dissociate them from state boundaries, we developed the Modernizing Fertilizer Recommendations: Fertilizer Recommendation Support Tool, or “FRST”, project, which we believe is foundational to farmers and nutrient management conservation efforts nationwide. By optimizing nutrient use and decreasing nutrients at the source, and thereby increasing the effectiveness of conservation practices, both farmers and taxpayers will save millions of dollars annually and protect the environment by reducing off-site nutrient loss. While the responsibility of interpreting soil test results and developing recommendations will remain with land-grant soil fertility faculty of each state, FRST aims to stimulate cooperation among states and across regions, providing valuable data and resources for up-to-date and science-based fertilizer recommendation systems, including standardizing the equations for the relative yield value and critical soil test value, in order to reduce differences in recommendation philosophies.

State-based, soil-test correlation databases seldom have enough site-years and diversity to develop recommendations based on factors other than soil-test P or K. Development of the national soil-test correlation database for legacy, current, and future research results will be instrumental in developing recommendations that consider covariates that can make nutrient recommendations specific for production systems with different crop yield potentials, soil properties that influence nutrient availability (e.g., soil pH and clay content), and factors like drainage and slope that influence nutrient movement. It is possible that analysis of the large, diverse database may show that soil test critical nutrient values and the resulting fertilizer-nutrient rate recommendations should be different among geographic regions.

Standardization of soil-test-based nutrient use recommendations is one possible outcome when data from multiple states are analyzed together, but standardization of recommendations is not the end goal of this project. The most important outcomes of the FRST Project are making soil-test-based fertilizer recommendations more scientifically defensible and more accurate, increasing end-user confidence in fertilizer recommendations, and developing a consistent soil-testing vocabulary and with clear definitions of the term used in the soil-testing industry. All of these goals require extensive research to analyze data and open conversations with all stakeholders and industry segments to develop a consensus and seek out all educational opportunities to disseminate the information.

The FRST project is composed of over 100 individuals representing 41 land-grant (40 states and one territory), two state universities, one private university, three USDA divisions (Agricultural Research Service, Natural Resources Conservation Service and Farm Service Agency), three not-for-profit organizations, and one State Department of Agriculture. The collaborative nature of the FRST project is at its core. Many of the FRST collaborators are members of one of the four existing multi-state soil testing projects: NCERA-13, NECC-1012, SERA-6, and WERA-103. Additionally, SERA-17 has been engaged in the FRST effort. The need for a national project like FRST was discussed at a joint meeting of the Regional Soil Testing Multi-state groups held at Penn State (July 2016).

There are eight FRST activities leading to the development of the FRST decision tool that will initially provide critical soil test values based on selected parameters such as region, soil classification, crop, and other metadata. Longer-term, the FRST tool will provide recommendations, again based on user criteria selection.

Activities include:

1) Surveyed soil fertility faculty at land grant universities on current soil fertility practices and recommendations to better understand the current status of soil testing across the U.S. and identify opportunities to harmonize nutrient management guidelines (Spargo et al., 2022);

2) A team of land grant soil fertility faculty developed a minimum dataset for future soil test correlation and calibration trials to guide research in the U.S. (Slaton et al., 2021);

3) Developed the FRST database to preserve legacy data and add new soil test correlation and calibration P and K data (Lyons et al., 2021);

4) Explored and determined the most appropriate relative yield calculation for use in the FRST decision support tool (Pearce et al., 2022);

5) Supported state-level soil test correlation and calibration trials during 2021 funded by FRST;

6) Developing a multi-state analysis of soil sampling depth influence on soil test outcomes in order to translate between different soil depths;

7) Determined the soil test correlation model most appropriate for the FRST decision tool (Pearson et al., 2022 in review), and;

8) Developing a user-friendly decision support tool to provide soil test user information for a soil-test and crop-response-to-fertilization searchable web-based decision tool. This tool will provide more consistent, transparent, and science-based decisions for nutrient recommendations.

Activities 2, 4 and 5 have been completed, while activity 1 and 7 are almost complete. We have started activities 6. Activity 3 and 8 will be ongoing during the life of the project and require long-term support for the success of this initiative.

Project activities are not fixed. Some activities were started at the beginning of the project while others began through collaborator group discussions around specific topics, such as the appropriate definition for relative yield. Other activities have been added as individual interest has aligned with need, like a sub-committee looking into updating lime recommendations. A new activity suggested by faculty collaborators is to compare P and K nutrient recommendations within the Western and Mountain regions similar to what a southern regional group did (Zhang et al., 2020). Another suggestion was to possibly add sulfur to the database. We expect new activities to be suggested from collaborators, accepted or declined based on need and funding, and if accepted, brought to fruition. The large collaborator group allows for new activities to be nominated and added as resources allow.

We have two primary stakeholder groups: the soil fertility research community and agricultural practitioners, such as producers, certified crop advisors (CCAs), fertilizer dealers, etc. The soil fertility community, both researchers at land grant universities and USDA-ARS, as well as practitioners in the federal government, primarily NRCS, are our soil fertility research community stakeholders. The farming community will be both primary and secondary stakeholders, as they will not only have direct access to the FRST tool, but will also benefit from improved fertilizer recommendations developed by the research community supported by FRST. USDA-NRCS 590 Nutrient Management Standard is foundational to conservation practices and FRST should support a more robust 590 standard to optimize nutrients for the producer while minimizing the off-site environmental impact.

As mentioned, the soil fertility research community is actively involved in monthly meetings, current activities, and proposing new activities. By forming a community of practice, we are increasing the knowledge of the collaborators and working on research topics of interest to many. When the database is sufficiently robust, we will allow the research community to access the data for further exploration of soil test correlation and calibration trials. Access to the database will support work by many types of researchers and extension scientists, beyond soil fertility, such as crop physiologists, agro climatologists and modelers. The minimum dataset will ensure that the database is populated with all relevant data that could be used to further the investigation of topics around soil fertility, including soil texture, soil sampling depth, and other environmental parameters (Slaton et al., 2021).

Once there is a beta version of the FRST decision tool, our stakeholder community expands to include additional users – farmers, CCAs, private soil test laboratory professionals, and others. We have begun to interact with the private soil test laboratory professionals, who are eager to participate and believe this will help the credibility of recommendations. We will solicit participation from these groups to provide feedback and suggestions regarding the functioning of the tool and the usefulness of the output. This will be a highly interactive process.

***B. Objectives and Projected Outcomes****:*

**Goals**

The **primary** **goal** of FRST is to address the national issue of soil testing transparency and accuracy by promoting clear and consistent interpretations of fertilizer recommendations by removing political and institutional (public and private) bias from soil test interpretation and providing the best possible science to enhance end-user adoption of nutrient management recommendations. A **secondary goal** is to provide a catalyst for innovation in soil fertility – useful to those making recommendations as well as those evaluating those recommendations.

**Objectives**

The primary objectives of the FRST project that the National Research Support Program (NRSP) funding will support are as follows:

1. Develop a community of practice to galvanize interest and participation around soil fertility.
2. Develop a searchable tool that provides soil test correlation and calibration graphs with statistical confidence intervals for the geographic area(s) of interest (general users). The first step will be to identify the critical soil test level above which there is no response (correlation) and the next step will be to provide fertilizer-nutrient rate recommendations when a yield response from fertilization is expected (calibration).
3. Provide data to nutrient management scientists and modelers for in-depth analysis of soil test correlation and calibration data (researchers).

The FRST project has been in existence for four years and follows an activity-based program. The activities have varied end points, which will be listed here. Some of them have been completed while others will be ongoing for the life of the national project.

1) Soil fertility faculty at land grant universities were surveyed on current soil fertility practices and recommendations to better understand the status of soil testing across the U.S. and identify opportunities to harmonize nutrient management guidelines. The survey and all data have been published in Ag Data Commons (National Ag Library; Spargo et al., 2022). A synthesis paper has been written and submitted for publication. There are many other papers that can be developed from the national survey data by whichever collaborators want to work on them. Finally, the data are being shared with stakeholders, such as NRCS, to help them understand how underfunded soil test correlation and calibration has been in the U.S during the past 40 to 50 years.

2) Developed, with a team of land grant soil fertility faculty, a minimum dataset for future correlation and calibration trials to guide research in the U.S. After two years of frequent meetings, the minimum data set for soil test correlation and calibration trials was published (Slaton et al., 2021) and an Excel spreadsheet template developed that allows researchers to easily capture the necessary data that meets the minimum data requirements. Data for FRST will be spooled from the minimum dataset to the Excel file into the relational database.

3) Development of the FRST database to preserve legacy data and add new soil test correlation and calibration P and K data. The database was developed in Excel then transformed to a relational database structure that includes the legacy data as well as the minimum data set components. Currently the database contains over 1400 K or P trials that represent 26 crops.

The database will be tied to and accessible by the FRST decision tool (Lyons et al., 2021). Data will continue to be collected and added to the database over the life of the project. We anticipate that the database will be used extensively by researchers to model and publish soil test correlation results.

4) Explored and determined the most appropriate relative yield calculation for use in the FRST decision support tool by a group of FRST collaborators who volunteered. This was a new activity proposed by the collaborators. After a year of work by the committee, there was consensus around the equation selected for the relative yield calculation, which will be used in the FRST tool. In addition, a journal article was written as there was no literature comparing different relative yield definitions with each other (Pearce et al., 2022).

5) Supported state-level soil test correlation and calibration trials during 2021 funded by FRST. The data derived from these soil test correlation and calibration trials (18) were delivered and entered into the FRST database. A number of these trials also received Ag Data Commons citations (https://soiltestfrst.org/resources/). We will continue to encourage trials as we have resources available.

6) Developing a multi-state analysis of soil sampling depth influence on soil test outcomes to translate between different soil depths. Different states and cropping systems utilize different soil sampling depths. As there was no peer-reviewed publication providing translation soil test values between depths regionally, we began this work during 2021. Scientists from over two-thirds of land grant universities in the U.S. have participated in this study with a total of 2936 samples from 197 unique sites. The protocol was very rigorous and was vetted and approved by all collaborators. Multiple depths were collected, and the soil was analyzed for Mehlich-3 extractable nutrients, pH, organic matter and depending on the geographical location from which it was collected, also Olsen P (western states with pH > 7.2) or Modified Morgan P (northeastern states). Collaborators also provided metadata to be able to associate cropping systems and soil characteristics, including texture, with the depth translation. The data are currently being analyzed. The output from this activity will provide translation equations for soils under various cropping systems at different sampling depths in the FRST decision tool. Therefore, we expect multiple translation equations relative to the system and depth sampled.

7) Selecting the soil test correlation model appropriate for determining the critical soil test value is essential for the FRST decision tool. As there are several available models, it is important to consider their strengths and weaknesses, analyze them statistically, and then determine the appropriate model for use in the FRST decision tool. FRST collaborators volunteered to work on this very important committee and after approximately one year of work, the committee selected

8) Development of a user-friendly decision support tool to provide soil test user information for a soil-test and crop-response-to-fertilization searchable web-based decision tool. The output from the tool is the ultimate goal of the project. Users, which include the private sector (e.g. soil test labs, CCAs, etc), will be enlisted to help beta-test the FRST decision tool. Discussions are already underway with a large association of private soil test labs.

Every activity proposed in the FRST project has been assessed based on the outcomes we established. For instance, the minimum dataset was considered successful when the journal article was published, the data entry template for the FRST tool was developed and placed at soiltestfrst.org, and the minimum dataset was used for state-level soil test correlation and calibration trials. Completion of identified details within the activities is important to the collaborators and the success of this project. The executive team meets bi-weekly to assess each activity and ensure that timelines and deliverables are being met. The outcome of all objectives and activities are assessed by participant involvement and the publication and citation of fact sheets and peer-reviewed journal papers. (See section C for more details on the executive team.)

***C. Management, Budget, and Business Plan****:* The FRST project has a nine-person executive team composed initially of a self-forming group that volunteered when this project was established. More recently there have been changes in the composition of the group. There are five faculty (professors from NC State, Penn State, University of Arkansas, University of Minnesota, and Utah State University), one ARS researcher, one data scientist/programmer (NC State), and one research scholar. Dr. John Spargo from Penn State represents the Northeastern region (NECC-1012), Drs. Deanna Osmond (NC State University) and Nathan Slaton (University of AR) represent the Southern region (SERA-6), Dr. Dan Kaiser (University of MN) represents the North Central region (NCERA-13), while Dr. Matt Yost (Utah State University) represents the Western and Mountain regions (WERA-103). Drs. Kleinman and Osmond represent SERA-17. As representatives from WERA-103 and NCERA-13 are newly added, those organizations will determine who and how representatives are rotated onto and off the executive team, but their tenure must be a minimum of two years. Penn State will continue to represent NECC-1012, which is a very small group, and the SERA-6 representatives will continue as the FRST project started in that region and anyone that wanted to serve could volunteer. The executive committee meets twice a month to ensure the timely completion of current activities. They also discuss new funding and activity opportunities and different management components as they arise.

**Budget**

The project is currently funded by USDA-NRCS through March 2024, with the spending categories provided below. This will represent four years of funding and we had an additional three years of prior funding from USDA-ARS that overlapped with NRCS funding, which paid for one each post-doctoral and research scholar salaries. The post-doctoral associate, Dr. Austin Pearce, who left in October 2022, led the activities to determine the relative yield definition and the critical soil test value model. The research scholar, Dr. Sarah Lyons, developed the Excel database as she curated and added legacy data. She also has worked on data configuration for the survey data and provided support for colleagues submitting data to Ag Data Commons for publication. She will continue this activity as collaborators ask. The programmer has developed the relational database and is programming the FRST decision tool. Supplies and materials are primarily for computers and other necessary software costs. Current services have paid for state-level soil test correlation and calibration trials (2021) and laboratory costs associated with the soil depth translation project. Journal publications are also charged to Current Services. Travel has and will pay for travel to scientific meetings for those presenting information on FRST.

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| **USDA-NRCS Description (April 2020-March 2024)** | **Current Budget** |  |
| EHRA Non-Teaching Salaries | 487,404.00 |  |
| Staff Benefits | 149,714.00 |  |
| **Total Personnel Expenditures** | **$637,118.00** |  |
| Contracted Services | 1,000.00 |  |
| Supplies and Materials | 13,091.00 |  |
| Travel-Domestic | 50,882.00 |  |
| Current Services | 204,000.00 |  |
| **Total Direct Costs** | **$909,091.00** |  |
| Total Indirect Costs | $90,909.00 |  |
| **Total Expenditures** | **$1,000,000.00** |  |

Since application to the NRSP is for five years, we will use resources provided by NRCS for the next two years, while we continue to try to find resources from federal agencies, not-for-profit organizations, and corporations. We are also asking for NRSP funding of $212,000 ($70,667 per year) from 2024-2027 as follows:

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| **NRSP Description (2024-2027)** | **Current Budget** |
| SHRA Non-Teaching Salaries | 150,000 |
| Staff Benefits | 50,000 |
| **Total Personnel Expenditures** | **200,000** |
| Current Services | 12,000 |
| **Total Expenditures** | **212,000** |

The funding for salaries will pay for a part-time programmer for the FRST decision tool and current services will pay for journal publication (two per year). We recognize that NRSP funding is not on-going and we will continue to look for funding from both the public and private sectors, as we have continued to do throughout the life of the project.

***D. Integration:*** By its very nature, the FRST project is well-integrated. Many collaborators maintain a mixture of extension, research, and/or teaching appointments. The development of the FRST tool is based on research, some of which has been performed during this project, but the execution of the decision tool is an applied outreach tool. Expectations are that faculty will include some of the published work from FRST into class discussion; for instance, inclusion of the Minimum Dataset paper, to provide guidance on best practice in soil correlation and calibration trials, would be an excellent teaching tool for a graduate-level soil fertility course. Demonstrations of the FRST tool would also be an excellent source of material for extension outreach and presentations and could provide valuable material to an international audience for similar projects to take place worldwide.

***E. Outreach, Communications, and Assessment****:* Because FRST is heavily skewed by many extension specialists that are part of the project, extension was baked into the project from the beginning. The elements expected for this project are described below.

1.There are several different intended audiences of FRST as discussed in the objectives. The initial audience is soil fertility faculty at land grant universities where the intent is to develop a community of practice to galvanize interest and participation around soil fertility, particularly as the number of faculty in the field is declining and administrators are reluctant to continue funding this work. This community has formed and stays connected through monthly meetings that engage faculty. Collaborators are and will continue to be asked for feedback on whatever activities are current in addition to providing data for the database when available. Additionally, subsets of volunteer collaborators are more directly involved in activities as they come about. Widespread participation from the soil fertility community in project activities is intended to provide consistent nutrient management decision making. A second intended audience is end users, including producers, CCAs, commercial soil test laboratories, and soil and water district and NRCS employees, who can access and use the FRST decision tool to help them determine the soil test critical value above which additional nutrients will not increase yield.

2.. The executive team (FRST stakeholder advisory committee) is committed to engagement of the multiple stakeholder groups by ensuring that the project stays focused, on-schedule, and representative of all geographical regions in the U.S.

Engaging the private sector will be critical for the success of FRST so we have been meeting with ALTA (The Agricultural Laboratory Testing Association), an organization of professionals dedicated to quality soil testing, accurate reporting, sound management advice, and information sharing. Many in this group manage private-sector soil test labs and the leadership of ALTA is very interested in working with the FRST team. We will be interacting with them by attending their annual meetings and other activities. Discussions with ALTA have already been instrumental to our work as we have learned that many soil test labs no longer make recommendations; they simply provide analytical results to the advisors who then make the fertilizer recommendations. Working with ALTA on the FRST project and decision tool will be iterative and critical to the integration of the private sector. We will also pursue other private-sector opportunities.

Once the decision support tool is ready for beta-testing, another 11-member stakeholder advisory committee will be developed consisting of two farmers, two CCAs, two commercial soil test lab personnel, two collaborators from FRST, two executive team members from FRST, and the programmer to provide continuous feedback on the development of the FRST decision tool. It will be critically important to also provide all collaborators the opportunity to provide feedback on the decision tool; the national soil fertility faculty must support the outcomes of the tool or it will not be promoted and/or used.

When the decision tool is developed, we will urge collaborators to provide local outreach to their farmers, CCAs, agency personnel including NRCS, private labs, and any other group involved in nutrient decision making. Assuming that many land grant institutions choose to use FRST in P and K fertilizer recommendation rates and promote the tool to user groups, we cannot assure that the outside user groups will use the tool, although there appears to be industry interest. This project is focused on harmonizing recommendations across land grant universities for soils within similar physiographic regions as a starting point.

3. The most obvious measures of accomplishments are the large national community of practice we have developed, the peer-reviewed journal articles published, the two symposia we were invited to present at Soil Science Society of America International meetings, and programming of the decision tool. These outcomes are and will continue to be available on our website (soiltestfrst.org). We expect to continue publishing and potentially providing more symposia. Once complete, the transference and use of the FRST decision tool will provide both the most important outcome and impact. The impact of journal articles will be followed by documenting the number of citations, downloads, and Altmetric Attention Score, which includes media mentions (e.g., social networks, mainstream news, public policy documents). To date, the FRST Project has published five papers in refereed journals, been featured in CSA News (the official member magazine for the ASA, CSA, and SSSA), and the CSA News developed a short promotional video for social media. Based on Altmetric scores, all articles have received outstanding attention (see summary below).

* Pearce et al. (2022) Defining relative yield for soil test correlation and calibration trials in the fertilizer recommendation support tool. <https://doi.org/10.1002/saj2.20450>
	+ Altmetric Score of 9 (<https://wiley.altmetric.com/details/129290529>)
	+ In the top 25% of all research outputs scored by Altmetric
	+ High Attention Score compared to outputs of the same age and source (88th percentile)
	+ #6 of 45 outputs of similar age from Soil Science Society of America Journal
* Slaton et al. (2022) Minimum dataset and metadata guidelines for soil-test correlation and calibration research. <https://doi.org/10.1002/saj2.20338>
	+ Altmetric Score of 10 ( <https://wiley.altmetric.com/details/116200503>)
	+ In the top 25% of all research outputs scored by Altmetric
	+ High Attention Score compared to outputs of the same age and source (90th percentile)
	+ 4 of 30 outputs of similar age from Soil Science Society of America Journal
* Lyons et al (2021) Development of a soil test correlation and calibration database for the USA. <https://doi.org/10.1002/ael2.20058>
	+ Altmetric Score of 4 (<https://wiley.altmetric.com/details/119018070>)
	+ Good Attention Score compared to outputs of the same age and source (65th percentile)
* Zhang et al. (2021) Variation in soil-test-based phosphorus and potassium rate recommendations across the southern USA. <https://doi.org/10.1002/saj2.20280>
	+ Altmetric Score of 16 <https://wiley.altmetric.com/details/108142254>)
	+ In the top 25% of all research outputs scored by Altmetric
	+ High Attention Score compared to outputs of the same age and source (88th percentile)
	+ #4 of 25 outputs of similar age from Soil Science Society of America Journal
* Lyons et al. (2020) FRST: A national soil testing database to improve fertility recommendations. <https://doi.org/10.1002/ael2.20008>
	+ Altmetric Score of 12 (<https://wiley.altmetric.com/details/79000951>)
	+ In the top 25% of all research outputs scored by Altmetric
	+ High Attention Score compared to outputs of the same age and source (81st percentile)
	+ #41 of 187 outputs from Agricultural & Environmental Letters
* McCauly (2020) The FRST National Soil Fertility Database. Published in CSA News, June 2020
	+ Altmetric Score of 18 (<https://acsess.onlinelibrary.wiley.com/doi/10.1002/csan.20218>)
	+ Article received 28 tweets from 24 users with 82,011 total followers
	+ 2-minute promotional video was circulated on social media.

4. Early into FRST we developed a robust website (soiltestfrst.org) that provides a robust repository of outreach and outcomes; it provides communications describing the activities, accomplishments, and impacts of the NRSP.At soiltestfrst.org, access to all our collaborators, many FRST presentations, two-page fact sheets and short videos that have or will continue to be developed for each relevant activity, links to our peer-reviewed publications, and a link to our decision tool when it becomes available are available. The soiltestfrst.org communicates the breadth and scope of this national soil fertility project as a NRSP. The impact of the FRST website will be tracked with Google Analytics. Journal and land grant university communications departments have been and will continue to be used to promote project efforts and accomplishments.

5. Mechanisms for distribution of project results are similar to the communication of project activities, accomplishments and impacts as we are distributing project results through the website (soiltestfrst.org) that archives activities into specific outputs: goals and objectives, funding, project team and collaborators, presentations, resources, and contact. The FRST project has already provided two symposia at two annual Soil Science Society of America meetings (2019 & 2021), as well as presentations at several other professional meetings, including CCA training, regional NIFA soil test meetings, and private sector venues, such as The Fertilizer Institutes annual meeting. Many of these presentations are available through the website as are all our publications. We will continue to seek international, national, and regional symposia opportunities and use social media resources to promote project highlights. Currently, we are planning a series of webinar presentations for CCAs and soil test labs regarding FRST - the algorithms we are standardizing and the tool we are developing.

Every paper, presentation, and the website acknowledge our sponsors. Should we obtain NRSP support from Hatch MRF via SAES and NIFA, we would acknowledge them just as we have our current funders.

6. Data management has been central to the conceptualization and development of FRST. Our data storage, FRST decision tool, and collaborator data papers are within Ag Data Commons, which is part of the National Ag Library. AgCROS (Agricultural Collaborative Research Outcomes System), a USDA-ARS website that “provides information, data, and data resources links to some of the USDA Agricultural Research Service (ARS) Natural Resources, Genomics, and Nutrition efforts’, is under the umbrella of Ag Data Commons. AgCROS is designed with the intent to provide agricultural research data to the public research and development community (https://agcros-usdaars.opendata.arcgis.com). Once the FRST legacy database is fully developed, it will be accessible to agricultural researchers.

Further we believe that data quality and curation is critical to the integrity of the FRST database. Since the beginning of FRST we have worked with Dr. Sylvie Brouder and the National Agricultural Library to ensure that our database ontology was appropriate. The majority of legacy data entered into the FRST has been obtained from refereed journals and other publications; we have to assume that the researchers have inspected their data prior to publishing for errors. The FRST team has taken every effort to ensure the data has been correctly copied and imported into the FRST database.  For raw datasets that have been submitted, we also need to assume (and try to ensure by asking) researchers to only submit clean and correct data to the database. The legacy data is typically less complete than current data we are entering that ascribes to the minimum dataset categories that the FRST project delineated (https://doi.org/10.1002/saj2.20338). For data collected from ongoing and future trials, the minimum dataset guidelines for “required data” include measures of variance for the required soil test P and K values and yield data. The minimum dataset stablishes a protocol for scientists to share and publish raw data which will enable database users (e.g., researchers) to vet data quality with statistical analyses. We will continue to promote the minimum dataset as a set of guidelines for soil-test correlation and calibration research as one strategy of promoting and assessing data quality. We will register the FRST database with Ag Data Commons (National Ag Library), which will provide a citation under FRST authorship.

The FRST software engineer is performing checks in the program to ensure all datasets that are entered contain the minimum data required for inclusion, the data is entered in the correct format, and the metadata (county names, state postal codes, soil series, soil map units, soil textures, soil taxonomic names, etc.) are correct.  He is using the SSURGO database to confirm the soil related information.  For location checking, he has location information (state, county and FIPS codes) stored in the database which he pulled from U.S. Census Agency.  Most of the checks are to ensure the data can be properly filtered/grouped and analyzed within the program.

We have discussed rating datasets to signify data quality. However, we are not sure how that information will be applied to the tool results other than reporting how many datasets are the top tier versus lower tiers. At this point, we need as much data as we can obtain. As far as rating datasets, we do not see that currently there is much to be gained.  If in the future, though, we wanted to automatically generate database categories, the categories would probably be: Tier 1 – Datasets that contain all original summary and rep data; Tier 2 – Datasets that contain all original summary data, and; Tier 3 – Datasets that contain data that has been estimated (interpreted from graphs).

Finally, as stakeholders use the tool and filter datasets, they will have the ability to control which datasets they include.  If an individual decides a dataset appears to contain data inconsistent with the related datasets, they will have the option to exclude it.  At this point, it is their responsibility to justify the exclusion and we can offer them an option to report it to FRST so the dataset can be checked.

**References**

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