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Innovations in Research and Extension: The DIRECT^{4}AG Project, Part 1; An Introduction

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On the dust and winds of Midwestern October, combines roll through an annual rite of passage. In 2024, a hotter and (mostly) drier fall is capping off a strong growing season helping speed the harvest of an expected bumper crop (Thiesse, October 10, 2024; Pope, October 9, 2024; Barnett, September 24, 2024). In the cab, many farmers are also likely planning for next year; like scientists, they use data, observations, and experience to tweak the formulas for optimal outcomes. Farmers rely on the results from their fields and the collective knowledge of agriculture writ large. For researchers, this all can feed the imagining of a digitized repository of field experiments and information on crop performance, coupled with weather and management practices, accessible for critical on-farm decisions, further research, and public policy. To those ends, this article introduces a series discussing innovations in research and extension by the DIRECT[4]AG project (USDA-REEIS).

Background

The proposed project is to design and implement a "Digital Infrastructure for Research and Extension on Crops and Technology for Agriculture" (DIRECT4AG). It is funded by USDA's National Institute for Food and Agriculture (NIFA), via the Agriculture and Food Research Initiative's (AFRI) competitive research grants, Data Science for Food and Agricultural Systems (DSFAS) program area priority (USDA-NIFA, DSFAS). Led by researchers and Extension educators at the University of Illinois and Tuskegee University, the project seeks to contribute significantly to the future of digital Extension. The interdisciplinary research and Extension team leverages the National Center for Supercomputing Applications (NCSA) at the University of Illinois to build the data infrastructure and web-based applications that will serve as the interface for communicating research on crop improvement and technology to both researchers and producers. In time, the data and capabilities of DIRECT[4]AG will enable innovative approaches to delivering digital agriculture to both large-scale farms in the Midwest corn belt and to limited-resource, small-scale and Socially Disadvantaged Farmers within the Black Belt Counties in Alabama. The discussion that follows introduces this project and places it in a longer history of investment in agricultural research, development, and Extension.

Discussion

DIRECT[4]AG is the product of the 2018 Farm Bill, the Agriculture Improvement Act of 2018; in Section 7505, Congress authorized an extension design and demonstration initiative (P.L. 115-334). Congress placed the initiative in the Competitive, Special, and Facilities Research Grant Act of the statute (7 U.S.C. §3157). Historically, this authorization was first created in the Food and Agriculture Act of 1977 (P.L. 95-113, Section 1414) but is rooted in the base research grant authority enacted in 1965 (P.L. 89-106). Deeper still, these research authorities and investments trace to the Smith-Lever Act of 1914, and further back to the Morrill Acts of 1862 and 1890, as well as the Hatch Act of 1887 (Kile 1948; Ellison et al. 2017). The Morrill Acts established the land grant colleges and universities, while the Hatch Act established agricultural experiment stations. Extension's foundational concept of using demonstration to translate and apply research outside of the laboratory has been credited to the vision of Seaman A. Knapp in the William McKinley administration of the late 1890's. Knapp, a scientist hired by USDA to help combat the spread of the boll weevil, reportedly explained the concept at the core of applied research and Extension: "What a man hears, he may doubt. What he sees, he may possibly doubt. But what he does himself, he cannot doubt" (quoted in, Benedict 1953, at 152).

Fast forward to the tumultuous events of the early 1970s, when higher food prices and concerns about food crises around the world reinvigorated interest in agricultural research and extension. At the time, the Senate Agriculture, Nutrition, and Forestry Committee reported concerns that the past successes of investments in agricultural research and extension had "resulted in complacency" that meant "agricultural

research began to suffer from neglect" (*S. Rept*. 95-180, p. 159-60). The Committee's concerns followed a series of studies in the era that raised questions about the state of agricultural research at a moment deep into the post-World War II technological revolution. The new authorization for competitive research grants was considered "a new dimension in publicly supported agricultural research" intended to strengthen and modernize it "to meet the new challenges and opportunities" of a "a sophisticated, complex industrial" farming that was "dependent on the continuing infusion of new technology to keep it healthy and economically competitive" (Huang, 1988). An inherent challenge of this approach was that the zero-sum game of budget discipline that took hold in the Eighties would convert the intention for added funding to competing funding and demands that took away from other areas of agricultural research. Review of the new direction a decade later found it had "provided a much needed shot in the arm in support of basic research in the agricultural sciences, particularly in the plant sciences" and opened the entire effort to new researchers into agricultural and plant sciences; timing was fortuitous as well, because the rapid development of biotech helped drive investment (Huang, 1988).

Concerns over, and challenges with, sufficient funding persisted, however. The 1990 Farm Bill increased funding authority through the National Research Initiative Competitive Grants Program, pushing further the competitive peer review grants system, but appropriations failed to keep pace with goals (P.L. 101-624, Section 1615). Despite the funding issues, agricultural research continued to produce significant breakthroughs and some attributed the accomplishments to the competitive grants. Other criticisms also followed, including about whether the country was "effectively applying the accumulated scientific knowledge available," especially for "areas in which information and solutions are needed most urgently," as well as concerns that the peer review process was narrowing research, limiting innovations in research, or even blocking early stage researchers (Kelman and Cook, 1996; see also, Stumpf, 1992).

Leaping ahead again, evaluation and analysis continues to support the importance of agricultural research while noting that it remains underfunded for the challenges from changes in farming and society. Public and private investments in agricultural research and development are both valuable contributors to the long-term growth in agricultural productivity and the economic value of such spending is high (Heisey and Fuglie 2018). The digital era, in particular, has driven views towards the need for an "Extension 3.0" investment and advancements that can "capitalize[] on the network structure of local agricultural knowledge systems" and link knowledge to action or adaptation, especially to "enhance the sustainability and resilience of agro-ecological systems" (Lubell, Niles & Hoffman 2014). DIRECT^{4}AG is intended to help advance the adaptation of agricultural research, demonstration, and Extension to these modern needs and challenges with "user-oriented design methodologies" that make use of continuous feedback informational loops to "identify solutions that are appropriate for the local context" and match "information supply with users' demand and capacities . . . offering what stakeholders need and want to know, in a way that allows them to access relevant, actionable information without extensive prior training on use of the digital service" (Steinke et al., 2022; and 2021).

The project begins with a focus on three to four core areas for translating research results to local farm management needs. These include information about crop rotations, cover cropping practices, tillage practices, and water challenges, including the use of sensors for irrigation. For example, we have installed in-tile nitrate sensors to monitor a long-term study on crop rotations, seeking to translate information about the impact of each rotation practice on crop production and sustainability. These sensors complement data collection at a variety of scales, from satellites and to other aerial and in-field observations, as well as manual ground truthing methods. We are also evaluating reduced tillage practices within different crop rotations.

Another use of this information is to validate a previously-developed cover crop decision support tool using a cover crop field trial coupled with digital simulation to evaluate the model performance (see, *farmdoc daily*, October 1, 2020; February 4, 2021; October 28, 2021). The support tool helps farmers predict cover crop growth, time of termination, and planting of the main crop. Additional metrics can also be predicted, such as carbon and nitrogen accumulation. This experiment is allowing better determination of which environmental variables affect the prediction accuracy of the model, while also providing data for model optimization.

In response to stakeholder inquiries, the DIRECT^{4}AG team, in collaboration with University of Illinois Variety Testing project, planted commercial lines of hybrid corn marketed with and without drought tolerance in yield trials across the state of Illinois. Hybrid seed is the second largest input cost and

selecting hybrid lines with the right traits at the beginning of the season contributes to success or failure at the end of the season. In its third year of data collection, these trials are paired with soil moisture sensors to sample in-field conditions that lead to variable yield outcomes. Weather, soil, and agronomic data are being aggregated to understand the environments in Illinois where it would be economical for growers to plant drought-tolerant lines. These trials will give farmers information about the value of growing marketed drought tolerant hybrid lines of corn in areas with moderate drought risk.

Overall, the DIRECT^{4}AG platform seeks to develop the capabilities for efficient feedback loops that help transform the concept of cooperative Extension for the era of digital agriculture, enabling it to evolve and keep pace with the ever-changing advancements in research and technology. Incorporating the Extension concepts of translation and demonstration in a digital format offers incredible opportunities to better incorporate questions, needs, and feedback from producers, policymakers, and other stakeholders into agricultural and environmental research. Such an effort should also contribute much-needed flexibility and adaptability so that research and information can better keep pace with changes in the fields and across the food system. Future articles in this series will delve deeper into the progress and results to date, with further updates as the project continues in the coming years.

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