CIDA Hackathon: Theme 1

# Data-Driven, Human-Centric Digital Agriculture Innovations


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| Links | The Issue<br>Details<br>Considerations<br>Constraints<br>Resources |

## The Issue

Data science has become a foundation supporting the digitalization of all industries. In the context of digital agriculture, there are two prominent branches:1) the best practice of acquiring, analyzing, and managing agricultural production data for precision management and operation and 2) data-driven approaches specialized to situations with limited sensing and computational resources. Key issues along with the two branches are summarized below:

***Challenge 1: How might we build ethical and reliable AI solutions for agricultural advancement?***

***Challenge 2: How might we streamline reliable production data collection?***

***Challenge 3: How might we assist small-scale farms to make better-informed decisions, using technology?***

***Challenge 4: How might we maximize the impact of agricultural extension/agronomic service provision?***

***Challenge 5: How might Measure, Monitor, Report, and Verify principles be incorporated into the value chain of digital agriculture?***

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## Details

***Production*** data refers to data related to crop management (e.g., crop variety, planting date, fertilize formulation, tillage type, and date, etc.). The use of this data has the potential to assist growers in optimizing inputs and operations on their farms—leading to optimized productivity and virtually no waste in the environment. The first step for implementing the revolution of data-driven agriculture is the collection and management of meaningful, fair, and reliable data. Although crop production data are very important for growers to control and thus optimize productivity, sustainability, and conservation, these data are usually recorded manually by growers or their employees, significantly impairing the reliability and sustainability of farm databases.

***Small-Scale Farms*** account for over 70% of the world's farms. The Food and Agriculture Organization of the United Nations estimates that out of 570 million farms in the world, more than 475 million farms are smaller than 2 hectares, and more than 500 million are family farms. The USDA defines a small farm as grossing less than $350,000 per year, regardless of the farm acreage; 88% of US farms are small. Small-scale farmers, like other small business owners, must manage all farm activities, from planning to production to transportation to marketing and sales. Small-scale farmers are often making decisions about what to plant, when to plant, where to sell, and at what price on marginal lands, with poor water resources, and little access to tech beyond their cell phone—while dealing with changing weather patterns and extreme climate events. Agricultural Extension— run by individual and group educators—provides much needed information and training to farmers. Yet with limited resources and labor hours, many of these educators are challenged to reach a majority of small-scale farmers through traditional one-on-one consulting, or even through group training, and must confront continued obstacles such as poor infrastructure and language barriers. As a result, many small-scale farmers receive limited or inadequate information that they can apply in their farm conditions, even as they face greater pressure to produce more with less.

**Agricultural extension** is the application of scientific research and knowledge to agricultural practices through farmer education. Generally, agricultural extension can be defined as the "delivery of information inputs to farmers." Yet, agricultural extension educators do much more than just share information; they help foster cooperatives and cooperation, communications with outside communities and connections to other types of farmer support (e.g. networks, infrastructure, grants). As such, they have the potential to be strong advocates and voices for farmer needs and interests.

The grand challenge of this theme is complex and crosses the barriers of experimental and controlled research and involves observational data (data from commercial farms). Solutions to this theme need to be developed through interdisciplinary collaborations among agronomists, physicists, engineers, data scientists and other discipline experts. Involving growers and agriculture stakeholders may bring insights for practical solutions and broader adoption.

## Considerations

**— Ethical AI (Explainable AI, Fair AI)—** For food and agriculture systems, untrustworthy AI solutions may introduce cumulative biases and jeopardize our society as a whole at the fundamental level. Despite recent advances in artificial intelligence (AI) demonstrating promising improvements, concerns have been raised regarding the reliability and fairness of AI systems, which are the major barriers for their broad adoption. It is critical and urgent for us to consider and develop "ethical AI" systems for agricultural applications at the beginning of this digital agriculture revolution. Explainable (XAI) and fair AI are particular topics to ensure the trust and fairness of outputs from AI systems. Moreover, AI solutions are only as reliable as the datasets they are based on.

**— Focus on Controllable Factors Data + Sources—** Agricultural production is the result of controlled and controlled factors. Growers need to adjust controllable factors (CF) in order to cope with non-controllable factors (NCF) changing in time and space. The optimization of CF requires detailed information on the NCF, which has been the focus of digital agriculture in recent years, capturing crop, weather and soil data using proximal and remote sensing. Automated and organized collection of NCF data enables conducting AI on large datasets and providing detailed information to the growers for decision making.

The CF data collection is not as organized and rarely autonomous, requiring growers and their employees to manually enter information about crop production data into on-board computers, notepads and Excel spreadsheets for instance. Because the recording of this data is mostly manual, large organized and reliable CF datasets are rare and have not been studied using AI. If these data were available, scientists could help growers optimize decision making on the farm. For instance, if we have sufficient organized and reliable data, we can take a specific task such as soil tillage and compare among all years and all farms where the same set of factors were observed (e.g., similar soil type, precipitations, crop varieties, etc.) and compare all types of tillage (e.g., tillage depth, date, type) in the database. This would allow us to pinpoint which one gave the best results in terms of production and environmental conservation. The same can be done with pesticide or fertilizer application and other tasks.

**— Limited Resources —** Smallholders are the farmers with very limited resource endowment. They own small farming lands (which according to FAO, small family farms average ~2 ha in Asia, Africa, and Europe), and mostly grow basic staple crops along with few cash crops, and primarily based on family labor. A symptom of this challenge is that they are often poor and considerably risk-averse, which deter them to adopt new tools or techniques.

**— Cultural & Educational History —** Often family run and passed down through generations, or ingrained in local socio-cultural ecosystems, small holder farmers may frequently make decisions primarily based on past decisions for previous growing seasons, or around the same cultural practices that have evolved from past ancestors. This can contribute to slow adoption of new tools or techniques.

**— Information Relevance + Delivery —** Easy access of information to guide decision making on suitable crop in the particular soil and environment, as well as market value, best cultural practices, potential disease and insect risk, or success stories of other farmers could all be critical to their success (e.g. what diseases/insect and at what growth stages along with available pesticide/fungicide to effectively treat them)

## Constraints

- Reliable metadata of farming systems are the key to build “ethical AI” systems for agriculture
- Solutions may not need to be overarching for all possible instances of data collection but rather targeted only to one specific task in one specific agricultural context.
- The findability, accessibility, interoperability, and reusability (FAIR) data principles are developed for data management

## Recommended Resources

**Research**

- University of Illinois, Data intensive farm management project: https://publish.illinois.edu/data-intensive-farm-managment/
- ADAS, Agronomics: https://www.adas.uk/Services/agronomics
- Gender in Agriculture: http://www.fao.org/gender/en/
- Agriculture 4.0: The future of  farming technology: https://www.worldgovernmentsummit.org/api/publications/document?id=95df8ac4-e97c-6578-b2f8-ff0000a7ddb6
- The Female Face of Farming: http://www.fao.org/gender/resources/infographics/the-female-face-of-farming/en/
- America’s Diverse Family Farms: 2019 Edition https://www.ers.usda.gov/publications/pub-details/?pubid=95546
- How Racism has Shaped the American Farming Landscape https://www.eater.com/2019/1/25/18197352/american-farming-racism-us-agriculture-history
- Equal Access or Resources and Power Infographic http://www.fao.org/resources/infographics/infographics-details/en/c/180754/
- Building a future with farmers; 2017 Survey results https://www.youngfarmers.org/resource/building-a-future-with-farmers-ii/

**Journal Articles**

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- Vilone, Giulia, and Luca Longo. "Explainable Artificial Intelligence: a Systematic Review." arXiv preprint arXiv:2006.00093 (2020). https://gtr.ukri.org/projects?ref=NE%2FT003952%2F1
- Zambon, Ilaria, Massimo Cecchini, Gianluca Egidi, Maria Grazia Saporito, and Andrea Colantoni. “Revolution 4.0: Industry vs. Agriculture in a Future Development for SMEs.” Processes 7, no. 1 (January 2019): 36. https://doi.org/10.3390/pr7010036.


**White Papers**


- https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Agriculture%204.0%20IoT%20v1.pdf
- http://agecon.okstate.edu/farmdata/files/Managing%20Farm%20Risk%20Using%20Big%20Data.pdf

- https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/ai/ey-bridging-ais-trust-gaps-report.pdf
- Data Driven Agriculture Paper This is a landscape assessment paper examining how smallholder farmers are profiled, how their needs are understood and met, how the impact of agricultural services is measured, how farmer data is shared, and how a global body of knowledge can be built by drawing on typically siloed expertise and data.
- How Digital Tools Impact the Value Chain this document is the result of a meta analysis of 200 documents and reports with evidence demonstrating the value of integrating digital tools into agriculture.
- Digital Innovations in Food Systems: https://bigdata.cgiar.org/evidence-clearing-house/
- Securing the future of the NY Livestock Industry: https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/4/7493/files/2018/11/Cornell-SFP-Livestock-Report-2018-2gmhrp6.pdf
- Precision Agriculture: Bigger Yields From Smaller Farms https://wle.cgiar.org/thrive/2017/03/20/precision-agriculture-bigger-yields-smaller-farms
- Precision agriculture: How can small farmers benefit from large farm technology? https://endeva.org/blog/precision-agriculture-can-small-farmers-benefit-large-farm-technology
- Digital Farmer Profiles: Reimagining Smallholder Agriculture https://www.usaid.gov/sites/default/files/documents/15396/Data_Driven_Agriculture_Farmer_Profile.pdf
- Digital Green: Harnessing Collective Power of Technology and Partnerships https://www.digitalgreen.org/
- Digital Farming: Grameen Foundation https://grameenfoundation.org/solving-poverty/digital-farming
- Developing Local Extension Capacity: Digital Green https://www.digitalgreen.org/usaid-dlec/
- Byte by Byte: Policy Innovation for Transforming Africa's Food System with Digital Technologies https://www.mamopanel.org/resources/digitalization/reports-and-briefings/byte-byte-policy-innovation-transforming-africas-f/
- Digital Agriculture and Small Farmers Infographic: https://www.usaid.gov/sites/default/files/documents/15396/Data-Driven-Agriculture-Infographic.pdf
- **Toolkit: Digital Tools in Agriculture Programming** this toolkit is a comprehensive compilation of all ways USAID implementers and partners can implement digital tools across their agriculture programs.
- Digital and Data Driven Agriculture: Harnessing the Power of Data for Smallholders https://cgspace.cgiar.org/bitstream/handle/10568/92477/GFAR-GODAN-CTA-white-paper-final.pdf?sequence=3&isAllowed=y

**Videos**

Setting up documentation for reliable agronomic data recording

- https://www.youtube.com/watch?v=BiWx9qRLUQk
- https://www.youtube.com/watch?v=Rn9LVSxZwJk
- https://www.youtube.com/watch?v=X8bnb1VzgKg
- https://www.youtube.com/watch?v=5hl8D8qn3Js
- https://www.youtube.com/watch?v=kE1GmkeLd_A
- WeFarm: https://vimeo.com/41066261
- What Urban Farmers Need and How All Service Providers Can Support Them: https://vod.video.cornell.edu/media/What+Urban+Farmers+Need+and+How+All+Service+Providers+Can+Support+Them/1_t20sgeh9
- Cornell Small Farm Program Video: Large collection of background information on operating a small farm in US https://www.youtube.com/user/cornellsmallfarms/videos
- https://www.youtube.com/watch?v=iAITg08loG4
- https://www.youtube.com/watch?v=pJZKYi-OEYg
- Evaluating land and resources for small farms: https://www.youtube.com/watch?v=vkQht_OHDzQ&t=113s
- Sarah Cairns-Smith: Finally, tech solutions to economic development. https://www.ted.com/talks/sarah_cairns_smith_finally_tech_solutions_to_economic_development
- Marcin Jakubowski is open-sourcing a set of blueprints for 50 farming tools that can be built cheaply from scratch. Call it a "civilization starter kit." Farmer and technologist https://www.ted.com/speakers/marcin_jakubowski
- "Dr Hickey has played a pivotal role in developing 'speed breeding', the rapid-generation advanced technology, which enables up to six plant generations per year and provides a powerful tool for crop improvement." https://www.youtube.com/watch?v=B-aXItzqKco

**Data**

- Copernicus Open Access Hub: https://scihub.copernicus.eu/dhus/#/home
- USDA National Agriculture Statistics: https://quickstats.nass.usda.gov/
- Agriculture Data Sets from Data.gov (includes links to APIs): https://catalog.data.gov/dataset?groups=agriculture8571#topic=food_navigation
- Climate Data Online: https://www.ncdc.noaa.gov/cdo-web/datasets
- California Soil Resource Lab: https://casoilresource.lawr.ucdavis.edu/soilweb-apps/
- USGS Earth Explorer: https://earthexplorer.usgs.gov/
- $100 in Azure Cloud Computing Credits available for students. (No credit card required) Go **here** to sign up. This is also renewable for $100 each year for as long as you are a student.

**SDKs (Software Development Kits)**

- Digital Green http://www.digitalgreen.org/coco/

**Others**

- https://www.agworld.com/us/customers/h-and-t-agronomics/
- https://www.precisionag.com/digital-farming/data-management/making-sense-of-the-4-vs-of-big-data-in-agriculture/
- https://www.cc.gatech.edu/~alanwags/DLAI2016/(Gunning)%20IJCAI-16%20DLAI%20WS.pdf
- https://www.datahen.com/blog/big-data-in-agriculture/

**CASE STUDIES / RESEARCH EXAMPLES:**

**Case Studies**

- French National Institute for Agricultural Research (INRA) applies the FAIR data principles to develop a widely-available data hosting platform for high throughput plant phenotyping: https://spj.sciencemag.org/journals/plantphenomics/2019/1671403/
- Remote Observation of Field Work on the Farm: https://www.microsoft.com/en-us/research/publication/remote-observation-of-field-work-on-the-farm/

**Current Research Topics Worldwide**

- (IoT) Internet of Things based sensing systems for automated data collection and management
- (Robotics) Agricultural robots have been developed and are being developed for field and controlled environment agriculture
- (AI) Extensive studies are focusing on the definition and development of "ethical AI" solutions for agriculture and food systems
- (Data Science) Data principles to guide the design and implementation of data acquisition and management system for agriculture
- (Observational research in agriculture) Agronomy and medical science has evolved using experimental research over the last century. With the advent of digital technologies and artificial intelligence, we can now consider using observational research to further advance science.