NRT-INFEWS: The DataFEWSion Traineeship Program for Innovations at the Nexus of Food Production, Renewable Energy and Water Quality

Program Theme and Goals

Sustainable provision of food, energy and clean water requires understanding of the interdependencies among systems, as well as the motivations and incentives of farmers and rural policy makers. Agriculture lies at the heart of interactions among food, energy and water systems (FEWS). It is an increasingly energy intensive enterprise, but is also a growing source of energy. Agriculture places large demands on water supplies while poor practices can degrade water quality. Each of these interactions creates opportunities for modeling driven by sensor-based and qualitative data collection to improve the effectiveness of system operation and control in the short term, as well as investments and planning for the long term. The large volume and complexity of the data collected create challenges for decision support and stakeholder communication. The DataFEWSion National Research Traineeship (NRT) program aims to build a community of researchers that explores, develops and implements effective data-driven decision-making to efficiently produce food, transform primary energy sources into energy carriers, and enhance water quality.

The goals and associated objectives are:

G1. Foster interdisciplinary research based on data-intensive methods.

- O1.1. Increase collaboration between researchers in FEWS domains and those in decision modeling and analytics.
- O1.2. Expand research that leads to workable, synergistic solutions for food production, renewable energy and clean water in the social, economic and geographic context of Midwest agriculture.

G2. Educate STEM graduate students for a range of research, research-related and entrepreneurial careers employing data-driven modeling at the FEWS nexus.

- O2.1. Train students in the effective use of systems modeling to understand the interactions among food production, renewable energy generation and water quality along with their business and policy contexts.
- O2.2. Improve decision science and analytics skills in FEWS researchers to improve their use of heterogeneous data from biological, hydrological, chemical, thermal, social and economic processes.

G3. Prepare STEM graduate students to work effectively in multidisciplinary teams, communicate effectively with stakeholders, and identify economically sustainable innovations.

- O3.1. Develop and test mechanisms and structures for mentoring, social support and team-building that aid retention, productivity and timely degree completion of STEM graduate students.

- O3.2. Develop and test mechanisms and structures for providing professional and communication skills relevant to careers in academia, government, or industry, including startups.

Elements of the Traineeship

The structure of the DataFEWSion Traineeship is based on Golde and Walker's "Stewardship framework" for doctoral education [1], which posits that PhD holders (in industry, academia, or elsewhere) act as stewards of their particular disciplines, with their stewardship activities described as: *Conservation, Generation,* and *Transformation. Conservation* of disciplinary knowledge is passed to students through coursework and other foundation-laying academic inquiry. *Generation* takes place when stewards produce new knowledge that contributes to the field. *Transformation* is the translating of expertise to a variety of audiences. We use the key actions derived from interviews with PhD holders [2] as guidelines for the Traineeship activities (see Fig. 1). In this context, the "discipline" is defined as core competencies in data analysis, synthesis, and decision-making for FEWS.

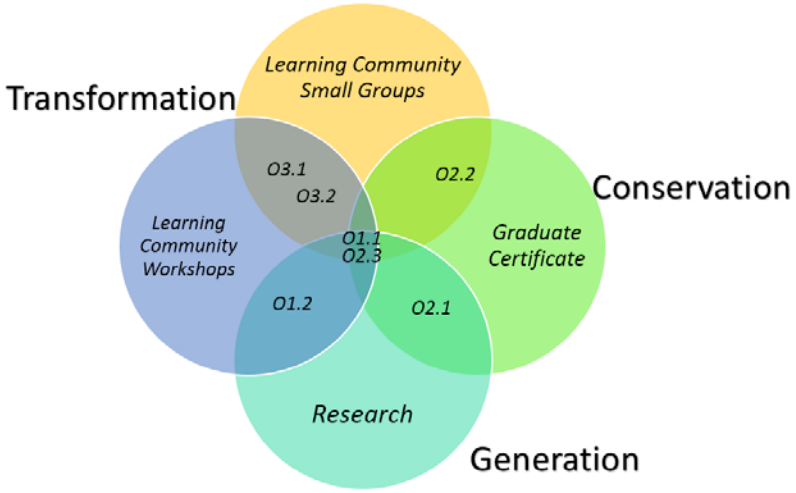

Figure 1. Project objectives mapped to components of the Traineeship under the Stewardship framework.

The key components of the Traineeship are:

1) Dissertation research on a FEWS issue for the *generation* of new knowledge;
2) A graduate certificate in Data-Driven Food, Energy and Water Decision Making, which consists of 3.5 credits of core courses and 9 credits of electives as described in Table 1 that represents *conservation* of knowledge;
3) A Graduate Learning Community [3] for *transformation* of knowledge that includes a two-year series of monthly workshops and weekly small-group activities designed to enhance the trainees' interdisciplinary communication and collaboration skills.

To avoid extending the time to degree completion, the certificate coursework is designed to be flexible enough to integrate seamlessly into each trainee's primary degree program of study. The two years of the workshop series can be taken in either sequence, so that the whole traineeship program can be completed in two years.

Progress to Date

The five-year National Science Foundation NRT project began in September, 2018, with a planning year. Our first cohort of trainees in the 2019-20 academic year includes eight PhD

students: five that represent three engineering disciplines (agricultural & biosystems, chemical & biological, and industrial), as well as two students from the crop production & physiology program in the agronomy department and one from the statistics program. Their research interests include:

- Statistical analysis of satellite imagery for monitoring natural resources and best management practices,
- Quantifying the benefits of diverse crop rotations on environmental, social, and economic scales,
- Data analytic tools that manage supply chain risk in the FEWS nexus,
- Coupling human decision-making with sound agricultural and environmental practices,
- Agricultural practices to improve water quality through agricultural engineering methods,
- Developing pyrolysis plants to effectively convert waste biomass into biofuel and value added chemicals,
- Antibiotic resistance indicators and evaluation of in-field or edge-of-field practices that may reduce them, and
- Combinations of land use and management practices to maintain profitability while improving water quality.

We anticipate three more cohorts of trainees, with pairs of successive cohorts overlapping in each of the next three academic years.

Table 1. Requirements for the graduate certificate in Data-Driven Food, Energy and Water Decision Making

Knowledge Area	**Requirement**	**Courses**
Fundamental understanding of interactions in the FEW nexus	Core Course	A B E 690X: *Biosystems for Sustainable Development* (2 credits)
Communication	Core Course	GR ST 566: *Communications in Science* (0.5 credit)
Entrepreneurship	Core Course	*BCB 590 / EE 690X: Entrepreneurship for Graduate Students in Science and Engineering* (1 credit)
Data acquisition, visualization, and analytics	Elective (Choose One)	6 options in Engineering or Statistics (3 credits)
Complex systems modeling for decision support	Elective (Choose One)	6 options in Engineering or Agronomy (3 credits)
Economics, Policy, or Sociology of FEWS	Elective (Choose One)	6 options in Engineering, Sociology or Economics (3 credits)

The first year of workshops focus on "Your role in the FEWS nexus." In Fall, 2019, they focused on Career Paths and Planning; Establishing Your Brand; and Interdisciplinary Communication. In Spring, 2020, they consist of listening sessions with stakeholders concerning Agriculture & Water Quality, Agribusiness & Bioenergy, and Policy Impacts. The second year of workshops will address the theme of "Effecting change in the FEWS nexus" and will focus on stakeholder

communication, entrepreneurship, and interdisciplinary collaboration. An annual symposium each spring will bring trainees and faculty together with our industry advisory board.

The weekly small-group meetings are led by the trainees on a rotating basis. In the first semester they incorporated peer-review activities similar to those described by Cunningham [4]. Based on trainee feedback, in the second semester they include more opportunities for trainees to present their research and identify collaboration possibilities. In Fall, 2020, the trainees plan to take turns sharing areas of expertise such as data analytics methods and familiarity with databases or software tools.

Recruitment and Evaluation

To recruit diverse and highly qualified trainees, we formulated a recruitment plan in consultation with our diversity advisory board. It includes marketing the program to graduate programs and faculty, as well as student organizations and professional societies organized around the relevant disciplines as well as underrepresented populations. Our program coordinator works closely with academic programs as well as diversity program staff in the Graduate College and the academic colleges to identify potential trainees.

An external evaluator collects evaluation data on each cohort and each component of the traineeship according to our logic model-based evaluation plan. At the time of paper submission we do not yet have results of the first year's evaluation.

Acknowledgment

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[1] E. Golde and G. Walker, Eds., *Envisioning the Future of Doctoral Education: Preparing Stewards of the Discipline*. San Francisco: Jossey-Bass, 2006.

[2] C. G. P. Berdanier, A. Talley, S. E. Branch, B. Ahn, and M. F. Cox, "A strategic blueprint for the alignment of doctoral competencies with disciplinary expectations," *International Journal of Engineering Education,* vol. 32, pp. 1759-1773, 2016.

[3] V. Tinto, "Learning Communities: Building Gateways to Student Success," *The National Teaching and Learning Forum,* vol. 7, pp. 1-11, 1998.

[4] K. J. Cunningham, "Graduate Engineering Peer Review Groups: Developing Communicators and Community," presented at the ASEE 2019 Annual Conference, 2019.