# FEW: A Workshop to identify interdisciplinary Data Science approaches and challenges to enhance understanding of Interactions of Food Systems with Energy and Water Systems.

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PROJECT SUMMARY

In coming decades, the world population is projected to grow significantly increasing the demand for food, water, energy, and other resources. Furthermore, these resource challenges may be amplified due to climate change, urbanization, and the interdependent and interconnected nature of food, energy and water (FEW) systems, which were traditionally analyzed and planned independently. Such piece-meal approaches (e.g., bio-fuels) to solving problems in one system (e.g., energy) have led to unanticipated problems (e.g., increase in food prices) in other systems. The goal of the nexus FEW security approach is to reduce such surprises by understanding, appreciating and visualizing the interconnections and interdependencies in the FEW system of systems at local, regional and global levels.

However, the nexus approach for sustainable management of global resources faces significant challenges due to differences in data collection protocols, data representation standards, access to complete data and data analysis tools. In addition, the FEW system of systems provides major challenges and opportunities for novel data science research. Although data science analysis methods extensively applied to large and complicated systems, such as social networks, data science efforts in complex physical systems (e.g., system of FEW systems) have been far more meager. Given FEW systems' rich data-driven history, there is a tremendous opportunity to systematically integrate novel large-scale data analysis methods with the physical, experiential, process oriented, and even conceptual knowledge that the broad climate, water, and energy research communities have developed. In addition, data science methods need to account for dependence between models, variables, locations and seasons (of food, energy and water systems) to reduce the risk of yielding misleading results.

Intellectual Merit: There is a tremendous need to significantly advance data science and realize the promise of the nexus approach to meet societal challenges in the face of population growth, urbanization and climate change. The proposed workshop will gather thought leaders from both data science and the relevant areas of system of food, water, and energy systems. This workshop will use both FEW nexus pull and data science technology push discussions to identify data science challenges in understanding, appreciating and visualizing the FEW systems. The first two successive sessions will explore these opposing directions. The second day will identify FEW inspired data science grand challenges in a synthesis session. Specifically, the goal of this workshop will be to create a vision of how data driven methods could make a significant contribution to understanding interactions between FEW systems and what research is needed to realize that vision. This proposal provides a detailed schedule of milestone and tasks including this team's resume for leading visioning workshops.

Broader Impact: The proposed workshop will facilitate and enable interdisciplinary partnerships between data scientists and FEW nexus researchers from academia, industry and federal agencies to develop innovative, interdisciplinary research approaches enhancing the understanding, appreciation, and visualization of the interactions between FEW systems. It has potential to formulate next generation data science research agenda towards better understanding, appreciation and visualization of the interactions and interdependencies among FEW systems. Workshop report will be included in reading lists of graduate courses on data science in Ph.D. to integrate the results in education. The report will also be used in professional graduate data science degrees for workforce training. A key goal will be to diversify participation across career stages, under-represented groups, geographies, and disciplines (e.g., machine learning, data mining, geo-spatial analytics, and nexus of food, water and energy systems).

# PROJECT DESCRIPTION

## 1. Introduction

By 2050, the world's population is projected to have reached 9 billion and global agricultural demand is projected to grow by 70-100% [Andrews-Speed 2015, MPS-AC 2014] due to the growing impacts of climate change, concerns over energy security, regional dietary shifts, and the Millennium Development target of reducing world poverty and hunger [Conway 2012]. In addition, agriculture is a major consumer of fresh water, and the increasing food production for the growing population will demand more water for irrigation as well as better water management. These resource challenges are amplified due to climate change [AgMIP, Ericksen 2008] and urbanization in the developing world.

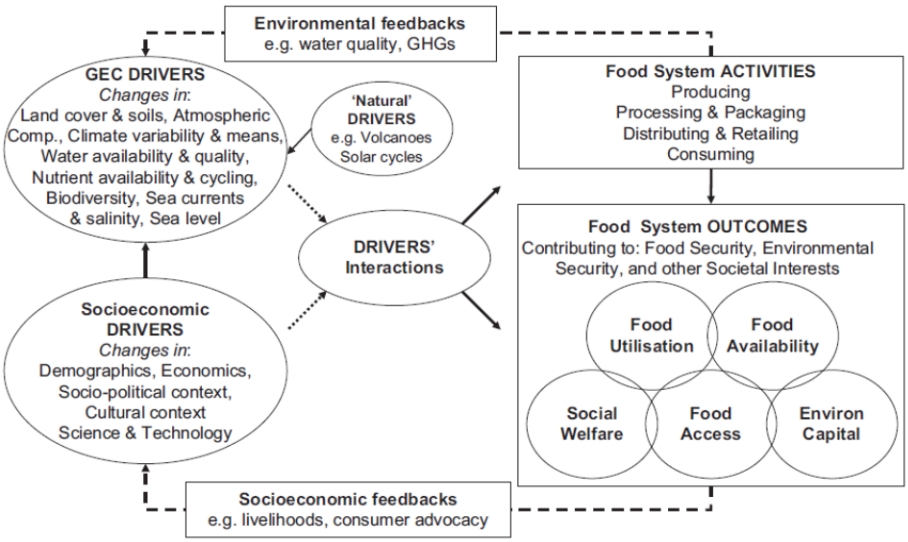


*Figure 1. Food systems and their drivers [Ericksen 2008].*

The food system consists of a number of components as shown in Figure 1. In particular, we can categorize the food system as consisting of four major components: food production, processing, distribution and consumption. Food production can be characterized by three broad categories of food: fish, meat, and crops (e.g., grains, vegetables, fruits). As noted in [Ericksen 2008], it is not sufficient to consider the food system in isolation since, "A host of other economic, social, and environmental drivers affect food security as well, and the interactions among these drivers, activities and outcomes are complex." The drivers include energy, water, climate land use change, urbanization, population growth, and energy. For example, impacts of climate change and water scarcity on food availability will occur throughout the food chain, but will generally be strongest for agriculture, given its sensitivity to climate and its primary role in food supply and in the provision of livelihoods to poor people [Vermulen 2012].

Significant challenges arise from the interdependent and interconnected nature of food, energy and water (FEW) systems, which were traditionally analyzed and planned independently, leading to unintended consequences such as the rise in food prices due to the promotion of bio-fuels to address concerns about the sustainability of fossil fuels. The goal of the nexus approach [EFW 2014, Hoff 2011, Mohtar 2012, Scott 2015] is to reduce such surprises by understanding, appreciating and visualizing the interconnections and interdependencies in the food, energy and water system of systems (Figure 2) on three planes: biophysical resources, institutions and security [Scott 2015]. For example, a more efficient and sustainable food sector (e.g., precision agriculture [Ag 2015]) may reduce the demands for energy and water [Sumer 2015] as well as improve the water quality by reducing fertilizer runoffs. Similarly, cheaper and abundant energy may improve the production as well as the distribution of food and improve the availability of fresh water via desalination. Moreover, the increased availability of water in dry regions may reduce the energy used to transport bottled water and food from remote locations [EW 2013, EW 2014, Holdren 2014].

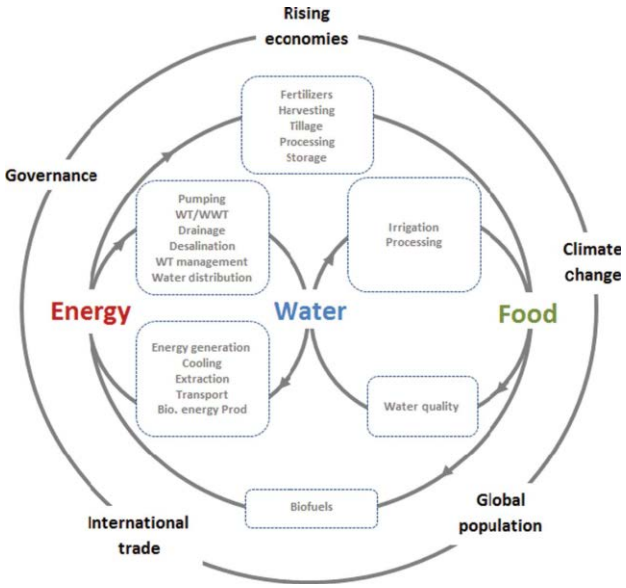


*Figure 2. Interaction of food system with energy and water systems [Mohtar 2012].*

Data and data science are crucial for the success of the nexus approach for many reasons. First, there is a need to "better understand the problem, the connections, and the impacts by generating, using, and openly sharing [GEOSHARE] improved sources of data" [Sumer 2015]. This is needed for monitoring [GEOSS, NexusObservatory] a variety of Earth resources (e.g., agriculture fields, fresh water lakes, energy needs for cooling or heating, etc.), and trends (e.g., deforestation, pollution, etc.) for a timely detection and management of risks, such as impending crop failures and crop-stress anywhere in the world. In addition, the need for data science also arises from the significant gap in data-availability to support decision making across data-rich and data-poor regions, and the differences in data collection protocols, data representation standards, monitoring frameworks, access to complete data, and data analysis tools [GIBBS, WEFPlatform].

Data science is also critical for efficiently managing Earth's natural resources by addressing issues such as: How do the population growth, climate change [AgMIP] and urbanization impact the resources of our world? How might we better observe [GEOSS], analyze, and visualize the interaction of the food system with the energy and water systems? Is there a spatial or seasonal variability in the interactions of food systems with energy and water systems? Where are the hotspots of most sensitive areas? How are these hotspots evolving due to climate change?

Example: Data Science tools, e.g., Geographic Information Systems (GIS) [Shekhar 2008] linking a great diversity of data to positions on the Earth surface, are increasingly used in food production [NRC 2014] and consumption [NRC 2015] systems. The ability GIS provides to capture, store, check and display spatial datasets -- providing farmers a much more intimate view of their own fields -- has unleashed game-changing capabilities in precision agriculture [Ag 2015], including enabling farmers to optimize farm returns, reduce unnecessary applications of fertilizers and pesticides, preserve natural resources, and contend with impending weather events.

Precision agriculture [PrecisionAg 1997] uses a blend of data science components such as the following:

- computerized map visualization to understand inter- and intra-field variability [Nielsen 1985];
- spatial databases [Shekhar 2003] to collect and query location-aware data about soil properties, plant properties, farm management practices, and yield;
- path planning and navigation systems to efficiently traverse farms without unnecessary soil compaction
- spatial statistical analysis [Gelfand 2010] to delineate management zones, and
- spatial decision support systems to optimize yield while preserving natural and farm resources.

But while the history of data science in precision agriculture is important, let us consider a few future opportunities that are potentially even more compelling for food security in the face of population growth and rapid urbanization around the world. For example, high-throughput phenotyping technology may help us move from precision agriculture at plot level to high-precision agriculture to nurture individual plants. Spatial data mining and machine learning techniques may analyze UAVs-based Hi-frequency farm monitoring datasets to detect and manage anomalous areas where plants are growing too fast or too slow. Location aware small vehicles (e.g., Huskies, Grizzlies) may safely move between growing plants to deliver individualized care to nurture plants with anomalous growth, and robotic bees may help with pollination to address recent decline in bee populations. Connected and automated vehicles research may lead to self-driving tractors to relieve farmers to attend to more important tasks such as assessing impacts of anomalous plant growth areas on projected yield and to refine management practice toward meeting yield goals.

Why this workshop? The system of interconnected and interdependent food, energy and water systems raises major challenges for current data science methods. Although data science methods have been applied quite extensively to analyze some large and complicated systems [Discovery 2012, NRC 2013], such as social networks, data science efforts in complex natural systems (e.g., systems with physical, chemical and biological elements) have been far more meager. Recent articles in Nature [Butler 2013], Science [Lazer 2014] and PLOS [Olson 2013] noted major failures of Google flu trend. Consequently, a 2014 New York Times article [Marcus 2014] said, "no scientist thinks you can solve this problem by crunching data alone, no matter how powerful the statistical analysis; you will always need to start with an analysis that relies on an understanding of physics and biochemistry" [Marcus 2014]. A 2014 Geo-Physical Letters paper [Caldwell 2014] added: "failure to account for dependence between [Physical]

models, variables, locations and seasons yield misleading results".

Given the rich data-driven history of the system of food, energy and water systems, there is a tremendous opportunity to systematically integrate novel large-scale data analysis methods with the physical, experiential, process-oriented, and even conceptual knowledge that the broad climate, water, and energy research communities have developed [IS-GEO 2015]. Thus, it is timely to organize a workshop to define a research agenda for next generation data science to meet the societal challenge to understand, appreciate and visualize interactions of food systems with energy and water systems.

## 2. Workshop Goals, Metrics and Expected Outcome

The objective of the proposed activities is to formulate a broad research program on next generation data science for understanding the interaction of food systems with energy and water systems and engage the broader community. Focused attention from key leaders in the field will illuminate important areas of research and study for various programs. A key outcome would be a set of critical research issues and a broad research program, which would describe the research directions to understand and address the problems, and describe the benefits to society from this research.

Engaging key participants: We plan to engage about 50 researchers across academia, industry and government in this project. Since participants from federal agencies and major companies as well as local participants may not need travel support, the budget includes travel costs for only 30 participants. A sample of representative participants can be found in section 5. A key goal will be to diversify participation across: career stages, validation methodologies (theory, systems, etc.), and disciplines (e.g., computer science, geography, social science, navigation, remote sensing, and engineering).

We have already started engagement with the food systems community at the recent Capitol Hill reception [Ag 2015] for the House Agriculture Committee. During this event, P.I. Shekhar discussed the role of data science (e.g., soil maps, spatial statistics and Geographic Information Systems) in precision agriculture. It drew interest from professional societies (e.g., Soil Science Society of America), major food companies (e.g., Cargill, Du Pont, Land O' Lakes Winfield) and precision farming technology companies (e.g., Trimble).

We have also started engaging the data science community in investigating the interactions of food systems with energy and water systems at the recent NSF IIS-GEO workshop [IS-GEO 2015]. While the focus of this workshop was on intelligent systems for Geo-sciences, a small group of participants discussed the system of food, energy and water systems as a case study to inspire the next generation of data science methods.

Workshop Venue: The workshop may be organized in Washington D.C. near NSF headquarters. This will facilitate wider participation from NSF and other federal agencies. Alternatively, it may be organized in the Mid-West, e.g., University of Minnesota campus. This will facilitate wider participation from industry, as many large food companies are located in the Mid-West. The University of Minnesota has provided a letter of commitment to help with the engagement of industry via their current relationships. If the proposal is funded, venue choice will be finalized in consultation with the NSF program managers.

Pre-Workshop Activities: We will reach out to major research groups in the area of nexus of food, energy and water security. We propose to issue an open call for short (2-page) whitepapers as part of the process to select workshop participants. The call for whitepapers will be disseminated widely using the workshop web-site and data science mailing lists. We will also explore panel discussion at summer meetings to publicize the workshop.

Workshop Activities: We propose to build a research agenda for next generation data science for understanding interactions of food systems with energy and water systems through a workshop designed after the 2012 Spatial Computing visioning workshop [CCC 2012], in an effort to stimulate innovation from opposing directions: pull (i.e., FEW Nexus data science needs) and push (i.e., disruptive Data Science technology). The first two sessions will explore these directions in successive sessions on the first day. Each session will include a panel, a break out discussion, and reports summarizing breakout discussions. The second day will have a session on generating grand challenges for next generation data science (e.g., physics-constrained data mining) along with a synthesis session which will record the common competency and theoretical needs determined from the previous reports.

Panel on Data Science Trends and Disruptive Technologies: A panel will be organized to identify the key science and technology results expected in the coming decade based on the current state of the art. What are the key anticipated inventions and discoveries that may significantly change the use of Data Science in industry and government? The breakout groups may be organized by phases of data-driven science, e.g., data collection, data management, data preparation, data science modeling, evaluation, visualization, etc. The report from this breakout will identify key science results expected to appear over the next decade based on extrapolation from current work in Data Science.

Panel on Data Science needed to understand the interaction of food system with energy and water systems: This panel will invite leaders from industry and mission-centric government agencies to identify both short and long term needs and opportunities, including core requirements, bottlenecks and stretch-goals. Panelists may address questions such as the following: How can the linkages between food, energy and water systems be understood better via data driven methods? How can more and better information exchange support Nexus actions? This session will be structured to understand common needs across multiple use cases. For example, Physics-constrained Data Mining models may be needed by many use cases. The breakout groups may be organized by the food subsystems [Ericksen 2008], e.g., production, processing, distribution, and consumption. Alternatively, the

breakout groups may be organized on three planes: biophysical resources, institutions and security [Scott 2015].

Synthesis Process: Finally, a synthesis process will be used to identify core findings from earlier workshops to prepare a report to be shared with the wider community for comments and suggestions. We plan to present the report at annual meetings of selected professional organizations for wider feedback. Based on the full set of reports and community feedback, a final report will be put forward for presentation to the NSF and to the wider community.

Post-Workshop Activities: A draft report will be shared with workshop participants in October for comments, which will be used to prepare the final report. We will explore the publication of a blog entry on community blogs (e.g., CCC blog) to share the highlights of the workshop immediately after the workshop.

Education and Workforce Development: The workshop report will be used to introduce the topic of next generation data science to graduate level students by being used as a reading material in both Master's programs (i.e., Master's in Data Science Program at U of M) and PhD level courses (i.e., Spatial Databases Research [CSCI 8715]). The research topics suggested will also help in workforce training by providing projects that can be used in training both undergraduate and graduate level students.

## 3. Timeline

As summarized in Table 1, the effort will begin in the summer of 2015 with an initial organizational meeting between core leaders. An online web presence will be established and a call for Participants form will be drafted as well as publicized. The workshop will be held in early Fall 2015, followed by a summarization and a draft report on the findings in October 2015. Following a peer review among program members and interested parties in November, 2015, we will submit the final report to the NSF in December, 2015.

Table 1: Proposed Timeline

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|---|---|
| May 2015 | Project kickoff, finalize workshop date and city, create workshop website. |
| June 2015 | Open call for participation & position paper<br>(with a short reading list on FEW nexus and system of systems approach) |
| July 2015 | Finalize list of participants, Agenda, Facilities, Catering, etc. |
| August 2015 | Travel arrangements |
| September 2015 | Potential Symposium Date, e.g., 2nd-3rd or 15th-16th |
| October 2015 | Prepare Report Draft |
| November 2015 | Peer review of draft report |
| December 2015 | Revise and finalize report |

## 4. Team Qualification

An ideal team to organize the proposed interdisciplinary symposium needs a variety of skills including broad representation, intellectual leadership, interdisciplinary collaboration, catalyzing research visions, and community engagement. Our team has all of these skills.

The workshop advisory committee will provide a broad representation via three sub-committees in charge of data science, FEW and diversity. The data science sub-committee will include leaders from Machine Learning (e.g., Prof. Padhraic Smyth, University of California, Irvine), Statistics (e.g., Prof. Alan Gelfand, Duke University), Data Mining (e.g., Prof. Vipin Kumar, University of Minnesota) and Geo-spatial analytics (e.g., Dr. Erik Hoel, ESRI). The FEW sub-committee will include community leaders from nexus (e.g., Prof. R. Mohtar, Texas A&M University; Prof. Matthew Kurian, Nexus Observatory) and food systems (e.g., Prof. Raj Khosla, Colorado State University. The diversity committee will include representatives from industry (e.g., US Chamber of Commerce; Cargill), federal agencies (e.g., USDA, NSF, EPA, NOAA) and community groups (e.g., Computing Community Consortium, ACM SIG-Spatial, SIG-KDD, SIGMOD).

Intellectual leadership: P.I. Shekhar is a thought leader in the area of spatial data science. He is serving on the Computing Community Consortium (CCC) council (2012-2015) and recently organized a CCC workshop to catalyze research visions in spatial computing. Co-P.I. Mulla is a thought leader in the area of precision agriculture as well as watershed management and modeling. His research has affected state and national policies relating to agricultural drainage, fertilizer use efficiency, animal agriculture, TMDLs, and Gulf hypoxia. He has collaborated with USDA-NRCS, USGS, state departments of Natural Resources, Agriculture, and Pollution Control, local government joint powers boards, commodity groups such as the corn research council and pork producers, and NGOs such as Clean Up our River Environment.

Interdisciplinary Collaboration: Shekhar and Mulla have collaborated for a number of years in a variety of forums as their research interests in the areas of spatial data mining of precision agriculture soil maps for discovering spatio-temporal patterns such as hotspots of abnormal plant growth or portioning a field into contiguous management zones. Both are fellows of the Institute on Environment (IonE) and participate in the IonE activities. In addition, they have collaborated on interdisciplinary projects on precision agriculture including a recent presentation at the "Deconstructing Precision Agriculture" reception for the House Agriculture Committee.

Catalyzing Research Visions: Team members have organized workshops and conferences. P.I. Shekhar organized a visioning workshop [CCC 2012], and delivered keynote addresses providing knowledge-gap analysis. Co-P.I. and P.I. have served on the committee of the National Research Council to perform gap analysis and set research agendas.

## 5. Acknowledgements

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# Facilities, Equipment, and Other Resources

The National Center for Food Protection and Defense (NCFPD) was officially launched as a US Department of Homeland Security National Center of Excellence in July 2004 led by the University of Minnesota (UMN). Developed as a multidisciplinary and action-oriented research consortium, NCFPD (www.ncfpd.umn.edu) addresses the vulnerability of the nation's food system to attack through intentional contamination with biological or chemical agents. NCFPD takes a comprehensive, farm-to-table view of the food system, encompassing all aspects from primary production through transportation and food processing to retail and food service.

UMN global food ventures initiative (mndrive.umn.edu/food) is developing holistic and integrated approaches to ensuring a sustainable, safe and resilient food system. Minnesota is the sixth largest producer of agricultural products in the nation and about one-fifth of Minnesota's economy is attributable to agribusiness. In addition, there are more than 200 food headquarters (e.g., Cargill, General Mills, Mosaic, Land O'Lakes, Hormel, SuperValu, Schwan Food Company, Target Corp., and C. H. Robinson are among 20 fortune500 companies headquartered in MN) in the state and 2,300 food companies. The university is leveraging its expertise and investments in food, agriculture and public health and partnerships throughout the state to enhance agriculture research, boost critical analysis of current systems and apply newfound knowledge to address food contamination, human, plant and animal diseases and supply threats. It aims to advance industry practices and public policy to promote global food protection and grow consumers' confidence in the food they buy, develop new markets for sustainable development to address resource constraints on water and energy and train the next generation of food scientists.

Authorized by Congress as one of the nation's 54 water resources research institutes, the UMN Water Resources Center (wrc.umn.edu) provides leadership in freshwater management through cutting-edge research, educational opportunities for students and professionals, and community outreach. For students, WRC provides a critical link to water-resources professionals and access to all the University's water-related programs. For citizens and professionals, WRC provides oversight of community-based programs and training and assistance with issues related to impaired waters, storm-water management, agricultural practices and global water issues. It also connects the research expertise at the University to research problems at the national level. The center is affiliated with the University's College of Food, Agricultural and Natural Resource Sciences, University of Minnesota Extension and the Minnesota Agricultural Experiment Station.

Co-P.I. Mulla directs the UMN Precision Agriculture Center (www.precisionag.umn.edu), which fosters the use of site specific management techniques through collaborative research, education, and outreach programs. Since 1995, the center conducts research on a variety of issues through multi-disciplinary on-farm studies conducted in many states and around the world. Graduate students use and develop innovative techniques to study spatial and temporal variability in crop yield and quality, soil and landscape attributes, and precision crop management practices to increase yield while reducing environmental impact (e.g., runoffs). Our researchers have access to top of the line

equipment and facilities including both hardware and software.

P.I. Shekhar and Co-P.I. Mulla are fellows of the UMN Institute on Environment's (environment.umn.edu), whose mission is to discover solutions to Earth's most pressing environmental problems by conducting transformative research, developing the next generation of global leaders and building world-changing partnerships. It investigates approaches to move towards a future in which sustainable agriculture feeds the world; renewable energy powers the planet; every person has access to food, clean water and shelter; oceans, lakes and rivers are unimpaired; cities have vibrant economies, neighborhoods and cultures; and thriving ecosystems support thriving economies and societies. It believes that complex environmental challenges can't be solved with business-as-usual thinking. Its activities include discovering research based solutions, educating next generation of environmental leaders, and engaging partners. With some 20 Fortune 500 companies and many other players in the global economy, Minnesota is an ideal setting for creating collaborative change. By linking our work with that of leaders in the business, investment, media and nonprofit sectors, we're building synergies and creating conduits for sharing Minnesota innovation with the world while growing new opportunities at home.

Education and Mentorship: The Institute on Environment provides leadership and education programs to prepare the next generation of environmental decision makers to lead amazing lives. From unique learning opportunities to global competitions, it empowers emerging leaders with the knowledge and skills they need to create positive change on a global scale. Current programs include the sustainability minor as well as two Leadership programs named Boreas and Acara. The *Sustainability Minor* program provides undergraduate and graduate students with opportunities to reach across disciplines with a focus on the connections between society and the environment. The curriculum includes a core course titled "Sustainable People, Sustainable Planet," interdepartmental electives, and a project-based capstone course in which students address a community's environmental, social and economic sustainability from a systems perspective. The *Boreas Leadership Program* equips graduate and professional students and postdoctoral fellows with the communications and media skills, leadership expertise, and trans-disciplinary tools they need to become environmental leaders. Drawing on expertise from across the University, Boreas connects participants with environmental leaders in many sectors and enhances leadership skills in three areas: communications and media, integrative leadership, and systems thinking. The program also offers valuable professional networking opportunities for students. The *Acara program* mentors university students from around the world as they form international collaborations and envision and launch successful social businesses through education and competition.

UMN Conference Planning and Facilities (cce.umn.edu/conference-planning) provides conference management services such as facilities (e.g., high-tech classrooms, computer labs), audio-visual media systems, housing, meals, preparation of participant packets, proceedings, etc. Recently, it helped us organize the 2011 Intl. Symposium on Spatial and Temporal Databases on campus.

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National Science Foundation
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Dear Colleagues,

The Office of the Vice President for Research (OVPR) supports and guides faculty in their research efforts including identification of research opportunities and challenges, as well as strengthening ties with business and industry partners. The Upper Midwest is considered the silicon prairie of the food industry with headquarters of some of the largest and most innovative food companies (e.g., Cargill, General Mills, Land O'Lakes, SuperValu, ADM, John Deere, etc.). The University of Minnesota's MnDRIVE) program (https://mndrive.umn.edu/food) has elevated global food as one of our highest research priorities, with a focus on developing holistic and integrated approaches to ensuring a sustainable, safe and resilient food system. This program and our researchers aim to advance industry practices and public policy to promote global food protection, grow consumers' confidence in the foowhether wed they buy, develop new markets for sustainable development to address resource constraints on water and energy, and train the next generation of food scientists.

The University of Minnesota offers additional capacities including the Water Resources Center (wrc.umn.edu), one of nation's congressionally authorized water resources research institutes, which is affiliated with our College of Food, Agricultural and Natural Resource Sciences. The NorthStar Initiative for Sustainable Enterprise (NiSE) (northstar.environment.umn.edu), a program at the Institute on the Environment, works with the private sector to understand and act on sustainability challenges facing our world's rapidly expanding economic systems. Finally, the OVPR's new Convergence Colloquia (www.research.umn.edu/about/convergence.html) series facilitates multi-disciplinary action-oriented think tanks focused on critical issues for our communities. Fall 2015 Colloquia will addresses alternative energy sources, improving water quality, and food systems, and will bring together researchers with private, public and nonprofit experts to identify strategic collaboration opportunities that can lead to significant impact at the local, state, national and global scales.

Due to the significant overlap with our research priorities and investments, we are very enthusiastic about the NSF initiative on interaction of food systems with energy and water systems (FEW) and the workshop proposal by Prof. S. Shekhar and Prof. D. Mulla. If the proposal is funded, we commit to help engage the researchers from food industry (e.g., Cargill, General Mills, Land O'Lakes, Super Value, etc.).

Sincerely,

Brian Herman
Vice President of Research
University of Minnesota