A Call for Agroecology in the NSF INFEWS Program

Response to the call for white papers to inform NSF's INFEWS funding initiative
from the Agronomy-Crop Science-Soil Science Societies of America

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Transformative research at the food-energy-water nexus is needed to develop new models of agriculture that remain productive and profitable despite increasing strains on water and energy resources, while also reducing the environmental and social consequences of today's dominant systems. The magnitude of this challenge combined with the interconnectedness of food, energy and water issues calls for highly innovative and interdisciplinary science. Recent research has strengthened the case that agroecology, which investigates agricultural practices based on ecological principles, could be applied to meet this challenge by conserving water resources, reducing energy consumption, increasing renewable energy, and serving the public good (Kremen & Miles 2012, Ponisio et al. 2014, Gliessman 2014).

Agroecological research can improve fundamental understanding of how natural and managed systems interact to produce food while protecting and regenerating limited natural resources and other valuable ecosystem services. Agroecology entails a systems-based study of the entire food system - from production to consumption - and draws on the agricultural, biological, environmental, and social sciences to develop ecologically and economically sustainable solutions. Despite the promise of agroecology, this area has been largely neglected in existing research funding programs (DeLonge et al. 2015, Carlisle & Miles 2013, Lipson 1997). Numerous urgent and fundamental questions still require attention to understand the scope of potential solutions available, and the systems science at the core of agroecology offers a unique and high-impact research direction for the INFEWS program.

Importantly, agroecology encourages innovations that produce food for a growing population while also considering the many barriers beyond yields that must be addressed, **including food access and affordability, quality and healthfulness, and waste** (Neff et al. 2015). In pursuit of these innovations, it is imperative to recognize that the right to food, which underlies the need for a productive agricultural system, has been defined as "physical and economic access at all times to sufficient, adequate and culturally acceptable food that is produced and consumed sustainably, preserving access to food for future generations" (UN 2014). In spite of the popular claims that the current dominant system "feeds the world", the right to food is not even currently a reality for many people – a reality that can not be ignored. INFEWS provides an opportunity to seek creative solutions to food system challenges that reach well past yields to include the need for healthy food and environments for the public good.

Key questions in the food-energy-water nexus rooted in agroecology should address designing biologically rich agricultural landscapes that are resilient to extreme events such as water and energy shortages, while providing health and nutrition for all. With these ideas in mind, we outline several research priorities and principles to help guide the INFEWS program.

RESEARCH PRIORITIES

1. **Biologically Diversified Landscapes & Food-Energy-Water Services:** *Can heterogeneous and biologically diverse landscapes improve healthy food yields, optimize renewable energy sources, and support abundant clean water?*

Homogenous landscapes comprised of large-scale monoculture systems have been increasingly linked to problems such as water pollution (Porter et al. 2015, Smith et al. 2015), increased rates of soil erosion (Montgomery 2007), soil degradation that threatens future productivity (Veenstra & Burras 2015), decline of pollinator species (Kremen et al. 2002), and more. Unfortunately, the dominance of these landscapes has only been exacerbated by an increased conversion of perennial lands into corn and soybean production for bioenergy (Wright & Wimberly 2013, Lark et al. 2015). By contrast, biologically diversified landscapes (ones with an assortment of crops, animals, and/or non-crop plants) can produce healthier food with less water, grow bioenergy crops selectively on less productive soils, and enhance ecosystem services. For example, "precision conservation" can protect biodiversity and enhance ecosystem services while reserving the most productive areas of fields for food production (Berry et al. 2003). In one experiment, small buffer strips of perennials in monoculture fields created significant environmental outcomes while having a negligible impact on productivity (Helmers et al. 2012). Ideas like these are needed to help to change the trend of US agriculture toward an increasingly heterogonous landscape, but additional research on landscape structure and related impacts is sorely needed. **A strategic agroecological approach to landscape design could contribute to agricultural systems meeting the multiple services required to ensure long-term ecosystem health.**

Select Research Questions

- FOOD: What are the links between landscape structure, soil biogeochemistry and microbiology, and food quality? How do rotations and diversity affect soil chemistry, biology, pest resistance, and surrounding environments? Can the advancement of perennials grains science (agronomy, food science, plant breeding) produce win-win situations for production and environmental impacts?
- ENERGY: How can bioenergy crops be best integrated in agricultural landscapes to address energy needs while supporting landscape diversification and other environmental services?
- WATER: What crops, animals, and designs can be selected strategically to minimize water needs at the watershed scale? How can soils be managed to improve water-holding capacity? How can improved practices be quantified and modeled at the landscape scale? Furthermore, how can the quality and quantity of wastewater and runoff be addressed at the source?

2. **Resilient Solutions for Climate Change in the Food-Energy-Water Nexus:** *Can INFEWS solutions be developed to improve the long-term resiliency of agroecological farms and ranches while mitigating climate change?*

The effects of climate change are already apparent on many farms and ranches, yet even today most agricultural systems are not that resilient to extreme events. At the same time, agriculture serves as a driver of these exact challenges as the sector continues to be a major emitter of greenhouse gases, contributing about 9% of the emissions accounted for by the US Environmental Protection Agency (EPA 2015). On the flip side, ample evidence demonstrates the ability of agroecological food systems to provide multifunctional benefits, particularly in light of increased risks related to climate and water variability. For example, three pillars of conservation agriculture - no tillage, crop residue management and crop rotation - have been shown to increase crop yields in dry environments (Pittelkow et al. 2015). Also, more diverse crop rotations can reduce yield variability in hot and dry years (Gaudin et al. 2015) and increase yields (Smith et al. 2008, Ponisio et al. 2014) while reducing inputs (Davis et al. 2012). **Identifying innovations that are resilient in both current and future climates and that are not themselves contributing to climate change is key.**

Select Research Questions

- FOOD: What features of agricultural soils make them productive but also resilient, particularly to extreme weather, especially in relation to key physical (aggregate stability, soil water status, and bulk density), chemical (carbon, nitrogen) and biological (microbial communities) properties? Is there a physical limit to the degradation of soils in different regions such that crop productivity can no longer be sustained? What designs enhance resilience while maintaining yields?
- ENERGY: How can the greenhouse gas emissions from agroecological practices be minimized, while reducing inputs and taking advantage of natural processes? Can soil carbon sequestration through soil management or land use changes be maximized to reduce the net climate change impacts of food systems? What are the best data, tools and methods to rapidly sample and determine management driven carbon changes?

- WATER: What foods can and should be grown in a future with new water resources challenges, considering both healthy food needs and energy limitations? How can water be applied not just more conservatively (e.g., through conservation and precision irrigation), but be used more sparingly through strategic crop selection and soil management?

3. **Food Production and Distribution for Public and Environmental Health and Well-Being**: *What innovative public health metrics can more holistically quantify the social and environmental costs of producing food?*

The need to produce abundant food to support a growing population has long been recognized as an agricultural and policy priority. As links have been established between agricultural production and other challenges, there has been greater attention to the need to produce more of the food supply on less land, or with fewer emissions, for example. Unfortunately, existing metrics of productivity have failed to capture critical environmental and societal impacts, often leading to an incomplete understanding of productivity and related tradeoffs. Analyses that more comprehensively consider the impacts on energy, water, or other resources from producing food are generally lacking. Even more problematically, existing metrics have not included how nourishing, healthy, accessible, or affordable food is. Today, despite impressive agricultural yields, food insecurity persists for approximately 14% of population (USDA ERS 2014) and leads to problems such as poor mental and physical health outcomes for children (Cook et al. 2004) and higher incidences of cardiovascular risks in adults, including hypertension and hyperlipidemia (Seligman et al. 2010). **To achieve sustainable human and related environmental well-being, agricultural systems and landscape design must develop novel ways to account for public health outcomes.**

Select Research Questions

- FOOD: What are the smartest metrics and systems for understanding the nutritional benefits and long-term health implications of food produced in any given system? How can we understand and improve the impacts of a diverse local food system on health and nutrition?
- ENERGY: What are the energy tradeoffs between producing more diverse, healthier foods as compared to less-complex farming systems that produce less-healthful foods? How can energy costs and savings be accounted for and valued appropriately in food system productivity assessments?
- WATER: What are the tradeoffs between healthier farming systems and water use? How can improvements in water quality or water conservation be accounted for in food system productivity assessments?

CROSS CUTTING PRINCIPLES FOR INFEWS RESEARCH

- **Tools and technologies at the scale of agroecological systems:** Achieving new knowledge in the areas listed above will hinge on the development of tools and technologies targeted at agroecological systems. For example, small to medium sized farms with complex landscapes need to be adequately resolved in numerical models that can evaluate impacts of management on productivity, water resources, and climate change. Remote sensing tools at the appropriate scale need to be developed to aid in management decisions (for example, to learn where conservation efforts would be most effective). Finally, data management systems that can make “big data” on complex systems most useful, and that can facilitate knowledge sharing, will be essential. Such tools and technologies can be used to organize baseline data and track the growth of agroecological and conservation practices.
- **Education and training for interdisciplinary, systems-based sciences:** Underpinning all research priorities is a need for continued rethinking the training and preparation of students at all education levels to understand complex challenges through a systems-thinking framework, work collaboratively across disciplines, and communicate results for broader impact (Graybill et al. 2006, Romolini et al. 2013, Basche et al. 2014). Prior NSF initiatives such as the GK-12 program provide models for how students might increase impacts of research while inspiring a next generation of elementary, middle and high school aged students to the challenges of the 21st century.

- **Understanding and confronting cultural obstacles for change:** Frequently, the successful adoption of new solutions in the agricultural sciences depends in part on social and cultural obstacles (Prokopy et al. 2012). For this reason, behavioral science, sociology, economics, and other social science disciplines are needed to facilitate landscape level change and should be integrated into INFEWS research priorities with intentional programmatic design that fully recognizes the need for and merits of social science research.

OPPORTUNITY FOR A NOVEL APPROACH TO THE "GRAND CHALLENGES"

Agricultural systems are at the center of FEWS issues, pointing to a clear need to bring agronomists, crop and soil scientists together with biological, earth, and social scientists to develop sustainable solutions. The Agronomy, Crop Science, and Soil Science Societies recognize food security, ecosystem service enhancement and a socially responsible agricultural sector, among others, as key components of their science's "Grand Challenges" (Adweppo et al. 2013, ASA-SSSA-CSSA Science Frontiers). While traditional funding streams have enabled significant advances in these sciences, there has been inadequate funding to address many fundamental, multi-disciplinary, and high-risk questions that could serve as the foundation for transformative change. Thus, there is enormous potential for NSF to support valuable and insightful progress in this interdisciplinary FEWS research area. It is possible that the most impactful opportunities may be identified through an interagency partnership, particularly with the USDA's National Institute of Food and Agriculture. In conclusion, the INFEWS program represents a rare chance to encourage and invest in agroecological research as the basis for high-impact, publicly beneficial outcomes related to the food-energy-water nexus.

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