NSF FEW Workshop on

A SUSTAINABLE RURAL FRAMEWORK FOR THE UPPER GREAT PLAINS

Rapid City, SD | Oct. 19-20, 2015

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Report of
The National Science Foundation Food, Energy, and Water (FEW) Workshop on

A SUSTAINABLE RURAL FRAMEWORK FOR THE UPPER GREAT PLAINS

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EXECUTIVE SUMMARY

This document reports on the workshop, A Sustainable Rural Framework for the Upper Great Plains, held in Rapid City, South Dakota on October 19-20, 2015. The goals of the workshop were: 1) to explore and identify fundamental problems and critical thresholds for regional food (agriculture), energy, and water nexus sustainability, and 2) to explore the sustainability of exporting food, energy, and water products from the upper Great Plains. Dr. James Stone and Heidi Sieverding from the host university, South Dakota School of Mines and Technology organized the workshop in cooperation with Drs. Eakalak Khan and Jayaraman Sivaguru, North Dakota State University; Dr. David Clay, South Dakota State University; Dr. Ranjit Koodali, University of South Dakota; Mafany Mongoh; Sitting Bull College; and Mahesh Pattabiraman, University of Nebraska-Kearney. The workshop was sponsored by the NSF Hydrologic Sciences Division (Award # 1541736). Additional support for participant meals and transport was provided by South Dakota School of Mines and Technology, South Dakota State University, North Central Sun Grant Center, University of Nebraska-Kearney, North Dakota State University and South Dakota EPSCoR offices, and RESPEC Engineering. The workshop was held in response to the NSF Dear Colleague Letter (NSF 15-040) dated February 2, 2015.

The workshop was attended by over 100 academic, government, and industry leaders from the region, and it was designed to encourage interdisciplinary discussions on regional food, energy, and water (FEW) nexus sustainability. Formal presentation by national and international experts on unconventional oil/gas development, fossil fuel and bioenergy energy production, agriculture, bio-product production, hydroelectric power generation, hydrology, and sustainability. Four panel discussions were held with speakers and regional experts on FEW and nexus integration. The formal talks were augmented by graduate student posters where local topics were considered. Participants provided their perspectives on nexus sustainability issues in small groups. Each group contained people with a diverse array of experience and expertise, ranging from biochemistry, earth sciences, engineering, agricultural production, hydrology, tribal government, remote sensing, ecology, manufacturing, to energy production. The small groups addressed a list of key questions around nexus sustainability:

- Why is rural FEW sustainability important?
- How would the country/world be impacted by the inability of the upper Great Plains region to achieve sustainability?
- What are important nexus intersections within our upper Great Plains region?
- What synergies should we explore?
- What are the stressors or controlling factors that impede regional sustainability?
- Who are the key stakeholders and how might they better cooperate to elicit beneficial change?
- What goals are needed to achieve sustainability in our region?
- What are the regional sustainability tipping points (critical vulnerabilities)?
- What are key considerations that should be included in future solicitations?
- What tools and data are needed to successfully model nexus systems?
- What technologies do we need to implement or develop to advance our understanding?
- What key human behavioral attributes do we need to change? And, how?

The small group discussions led to recommendations for action as detailed in this white paper. Key recommendations call for research into:

- Sustainability impacts of rural land-use change (trade-offs), management decisions, and associated loss of ecosystem services.
- Triage (need/use significance-based) systems for regional FEW resource export and allocation.
- Human sustainability paradigms and constructing socio-economic influences to support sustainable behavior.
- Development of effective sustainability-oriented economic incentives and/or penalties.
- Sacrifice zones (non-reversible land use/ecosystem change) and the long-term impacts of service loss.
- Soil and ecosystem health and regional adaptation to change.
- Regional ecological thresholds for agricultural production and natural environments due to climate and land use change.
- Interconnection of rural and urban sustainability demands (export/import dynamics) and model development.
- FEW-integrated resource recycling and reuse to reduce waste; specifically, addressing industrial and agricultural production advances to preserve and improve long-term water quantity and quality.
- Short- and long-term economic impacts of FEW sustainability.
- FEW optimization of infrastructure as well as development novel, sustainable (synergistic) infrastructure retro-fitting and replacement alternatives.
- Development and advancement of FEW production and products which have cross-cutting sustainability and efficiency benefits.
- Systems integration and cross-disciplinary relationship/systems modeling.
- Regionalization and increased accessibility of integrated FEW nexus modeling and climate change forecasting.

TABLE OF CONTENTS

Disclaimer i

Executive Summary ii

Introduction 1

NSF Few Workshop 1

Wicked Problems 1

Rural Sustainability 1

Workshop Structure 3

Workshop Chairs 3

Cognizant Nsf Program Officer And Observer 3

Participants 3

Critical Vulnerabilities 5

Trade-Offs And Sacrifice 5

Triage 7

Paradigms 7

Adaptation 8

Integration 9

Optimization 10

Accessibility 10

Regional Threshold Indicators 11

References Cited 12

INTRODUCTION

NSF FEW Workshop. This document reports on the NSF sponsored Food-Energy-Water (FEW) workshop 'A Sustainable Rural Framework for the Upper Great Plains' held at the South Dakota School of Mines and Technology in Rapid City, South Dakota on October 19-20, 2015. Workshop material is available at http:/sdsmt.edu/FEW-2015. The goals of the workshop were: 1) to explore and identify fundamental problems and critical thresholds for regional food, energy, and water nexus sustainability; 2) explore the sustainability on the export of food, energy, and water product from the upper Great Plains (UGP); and 3) to encourage interdisciplinary discussions on regional food, energy, and water nexus sustainability. The workshop was attended by greater than 100 academic, government, and industry leaders from the region. The formal talks by international leaders on nexus sustainability were augmented by graduate student posters that highlighted local issues. Participants provided their perspectives and addressed key questions regarding nexus sustainably that led to recommendations for action as detailed in this paper.

Wicked Problems. The population of the Earth is growing, and the world's natural resources are finite. Urban areas are expanding with population growth. Industrialization of food, resource extraction, and energy production and consumerism have increased the demand for fossil fuels and fresh water. To support urban areas, rural areas unsustainably export critical agricultural products, energy resources, and water.

The semi-arid upper Great Plains (UGP) is a net exporter of food and energy, and is essentially 'mining' valuable water and nutrient resources to do so. It is also the site of tremendous competing nexus interests: the Bakken shale-oil boom, corn grain ethanol production, in-situ uranium mining, coal mines, wind farms, and major hydroelectric dams contrast with public and private good in relation to land-use alternatives. Large and volatile changes in agricultural commodity and livestock prices, competing land-use for incoming bioenergy crops, increasing agriculture efficiencies through biotechnology and precision agriculture; and regional effects of long term climate trends and short term climate variability have impacted regional agriculture and water resources. Recent energy and commodity end-use developments have led to substantial regional economic growth; however it has strained infrastructure (e.g. lack of housing, power transmission, pipelines, roads/rail lines) contributed to grassland to cropland conversion, resulted in soil salinization and sodification, and reduced ground water supplies.

Rural Sustainability. Across the globe, resource mining and agriculture compete for human, land, transportation, and fresh water resources. This competition is exemplified in the UGP. An imbalanced system cause's harm to the environment, changing once renewable and recyclable resources such as water into waste. The food, and energy products produced by the rural community are the foundation of our supply chain. ***Sustainability must begin at the source of the supply chain - with the farm, ranch, mine, or well.***

Shale-oil has created a new wave of fossil fuel exploration. Many abandoned oil-fields now contain recoverable oil and gas through horizontal drilling and hydraulic fracturing techniques. In order to hydraulically fracture (frac) the Bakken shale, large volumes of fresh water are needed, on average 8.3 million liters (2.2 M gal.) per well (Freyman, 2014). A steady input of fresh water must be trucked in and saline water must be trucked out to maintain oil production resulting in an average per well lifetime production water consumption of over 30.2 million liters [8 M gal (Freyman, 2014)]. Waste water is typically hauled to deep well injection sites or specialized treatment facilities. Unfortunately, nation-wide the locations of these fossil fuel resources are often in agricultural production areas (e.g. PA, OH, MI, IN, LA, MS) and in water-sensitive regions (e.g. TX, OK, CO, CA, NM, ND, MT, UT). The UGP encompasses SD, ND, NE, WY, and MT is part of a large agricultural region which extends into south central Canada. These states produce the majority of the durum and over 30% of all wheat in the nation (NASS, 2014) plus many other specialty commodities (e.g. sunflowers, safflower, canola, flaxseed, lentils, dry beans). In addition, the abundant corn and soybean production in the eastern part of the region supports a fledgling bioenergy (corn-, cellulosic-ethanol and soybean-biodiesel) industry. The wheat-fallow growing system in western ND, NE, SD, and eastern MT and WY produce bread wheat. Unfortunately, bread wheat production in the region is threatened by wide scale disease problems. In the region, many bread wheat fields are sprayed with fungicides two or three times a year. This risk can be minimized by expanding the crop diversity by introducing drought-tolerant non-food oilseeds for biofuel production, such as *Brassica carinata* (carinata), into cropping rotations. The incorporation of next-generation biofuel crops in place of fallow provides the prospect to develop regional biofuel-related industries, similar to corn-ethanol facilities.

The semi-arid UGP region is a tremendous exporter of raw energy resources. Unconventional oil development has become an economic driver in recent years [total value-added economic activity in 2012 for ND, SD, and NE was reported at $7.6 billion (IHS, 2012)]. The Williston Basin contains the Bakken Formation, the site of one of the largest active shale-oil reservoirs and is the second largest oil producing region in the US (Coleman et al., 2014). In the US, coal is king and WY is the crown jewel. Coal is the foundation of the nation's baseload power (~40%). Low-sulfur coal from the region is used both nationally and internationally to curb emissions. The largest coal reserves in the nation are mined in eastern WY and MT (EIA, 2014) and the surface of the landscape is peppered with coalbed methane wells. Abandonment of these wells has become a chronic problem with the downturn in natural gas prices. This leaves state and federal officials and farmers/ranchers dealing with the danger, cost, and difficult water issues. In-situ uranium recovery wells are active in WY, NE, and proposed in SD. The region contains tremendous utility-scale wind energy potential capacity (NREL, 2014) with wind contributing an increasing portion of the regional power portfolio (EIA, 2015). The region overall typically produces and exports twice as much electricity as it consumes (EIA 2012 net electricity trade index ND:2.3, NE:1.1, MT:1.8, SD:1.0, WY:2.6).

The water resources of the region are used for industrial, urban, agricultural, and energy production and development. The region contains the Missouri River; where flow is controlled by mainstream dams producing hydroelectric power in ND and SD. Water releases from these dams are critical for barge traffic on the Missouri and Mississippi Rivers downstream but water consumption is now also critical for shale-oil extraction, manufacturing, and drinking water locally. These barges are used to transport the regions food products to the nation and world.

The region's industries that produce food and energy products co-inhabit the same land - competing for the same water, labor and infrastructure (e.g. transmission lines, transportation, housing) resources. ND, SD, and NE also face challenges as oil pipeline infrastructure expands and crosses these states, raising concerns about environmental consequences of pipeline infrastructure failures. The net result has been an imbalance of infrastructure and resources resulting in localized economic booms/busts coupled with social and environmental issues (e.g., oil spills, soil and water contamination, excessive water withdrawals).

Innovative new forms of rural transportation, energy transmission and production, agriculture, irrigation, water purification and recycling, and resource use are critical for sustainable development and growth. The UGP, like most rural agricultural areas, is generally socially and fiscally conservative. The primary driving forces for economics are external investors and product export. Therefore a balance between economics, technological innovation, and culture must be met to achieve long-term sustainable solutions.

WORKSHOP STRUCTURE

On October 19-20, 2015 – a transdisciplinary gathering of researchers and concerned citizens met in Rapid City, South Dakota to explore rural FEW sustainability issues. The focus of the discussion was the sustainability of product and resource export from rural areas. The workshop sought to identify regional synergies, stressors, and critical vulnerabilities.

In the two-day workshop, participants heard presentations from agricultural (food), energy, water, and systems integration perspectives. After each session, panel discussions were held. Interdisciplinary break-out discussions were held during the afternoons of the workshop. Break-out groups consisted of five to eight participants with different backgrounds. Break-out groups were not the same both days. A single member of the group was asked to record the discussions and submit responses to the workshop organizers. Over 100 people, predominantly from North and South Dakota, participated in the break-out group sessions. At the end of the break-out group sessions, the groups reported back their discussion results. The results yielded the key issues and research needs discussed in this white paper.

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Eakalak Khan, North Dakota State University
Ranjit Koodali, University of South Dakota
Mahesh Pattabiraman, University of Nebraska-Kearney
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WORKSHOP AT-A-GLANCE

Title:
A sustainable rural framework for the upper Great Plains

Purpose:
Define fundamental sustainability issues regarding rural commodity exports

Date: October 19-20, 2015

Location: Rapid City, SD

Sponsoring Organization:
National Science Foundation

Additional Sponsors:
SD Mines, SDSU, UNK, North Central Sun Grant Center, SD EPSCoR, NDSU EPSCoR, RESPEC Engineering

Disciplines Represented:
Agriculture, Forestry, Biology, Ecology, Chemistry, Geology, Hydrology, Environmental Science, Sociology, Engineering

Career Levels:
High School-Doctoral Students; University Faculty and Researchers; Tribal, Government, Defense, and Non-Profit Agency Personnel; Industry Representatives

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CRITICAL VULNERABILITIES

As we cope with resource constraints and anthropogenic change, the UGP will encounter 'tipping points' after which the ability to recover will be greatly diminished. FEW nexus sustainability is important because it aids in mitigating negative consequences such as war and famine. Addressing critical vulnerabilities in the FEW nexus will help maintain stability.

UGP Nexus sustainability is critical for the nation and world because the region is a net exporter of food and energy products and the production of these products forms the economic backbone of the region. Because these resources are finite, without sustainable practices and export the economy and lifestyle of the region will suffer. The region contains stark economic contrasts. Many parts of the region enjoy lowest long-term unemployment rates in the nation [ND:2.9%, NE:2.9%, SD:3.5%, WY:4.0%, MT:4.1% (USBLS, 2015)] whereas on the reservations in South Dakota, some of the highest rates of poverty exist in the nation (~45%) with a endemic unemployment rate of over 25% (DOI, 2014). Any shortcomings will impact the most vulnerable segments of our society the hardest. Highly efficient production and geographically isolated systems have been developed which will be difficult to improve. The significant gains in production and efficiency that were achieved in the past will be more difficult to accomplish in the future without substantial investment. A SWOT analysis on FEW nexus sustainability for the UGP based on workshop feedback is summarized in Figure 1.

Critical vulnerabilities create difficult questions which if unaddressed may tear the fabric of our economy and society. In order to achieve sustainability, critical vulnerabilities need to be addressed while maintaining existing strengths and expanding opportunities. The following sections represent the key vulnerabilities (weaknesses and threats) identified during the workshop for the upper Great Plains.

TRADE-OFFS AND SACRIFICE

Background: There is a cost to everything. As we continue to produce goods and services, we must make decisions. The repercussions of those decisions can be small or they can have long-term impacts. Decisions must be made as to the permitting of energy development and planting of crops. Brine, oil, and chemical contamination of agricultural land and water resources from unconventional oil development can irreversibly damage production and the ecosystem. Conversion of forest and grasslands to agricultural and/or energy production can permanently damage ecosystems and associated ecosystem services.

Vulnerability: The UGP is sacrificing vital natural systems to fulfill societal needs for food and energy products. In doing so, the sustainability tipping point may be approached.

For example, in the upper Great Plains, South Dakota agricultural producers between 2006 and 2012 converted 1.8 million acres of grassland to annual crops, whereas in Brazil, farmers are grazing the rainforest, followed by converting the degraded lands to soybean production. These natural environments are being sacrificed to support our burgeoning demand for food and biofuel feedstocks. Grasslands provide critical habitat to pollinators and wildlife and are used for livestock forage. North Dakota is the largest honey producer in the nation, followed by Montana and South Dakota. The five-state area (ND, MT, SD, WY, NE) produces nearly 50% of the honey in the nation. Beekeepers rotate their hives from California and Florida to grasslands of the upper Great Plains to meet their summer quotas and to allow bees to recuperate. New biofuel feedstocks, drought tolerant commodity crops, and federal insurance are allowing agricultural producers to increase risk and expand crop production

STRENGTHS	WEAKNESSES
• High current productivity • Production reserves • Experience • Capacity to grow • Established systems and infrastructure • Alternatives available • Agricultural connectivity • Ecosystem relationship • Self-reliant • Conservative • Adaptable	• Trade-offs and sacrifice • Lack of balance and prioritization • Cultural paradigms • Absence of adaptation strategies • Poor integration • Not optimized based on sustainability • Bias and counter-productive influences • Accessibility • Existing infrastructure condition • Low rural funding
OPPORTUNITIES	**THREATS**
• Management improvements • Sharing resources • Prioritization • Support system development • Incentives • Mitigation • Strengthen support and integration • Modeling • Forecasting • Innovation • Infrastructure development	• Soil health (salinity/sodification) • Aquifer and surface water decline • Pests • Destabilization • Ecological health and habitat • Erosion • Climate change • Inflation • Aging • Segmentation • Resource availability • Future conservation

Figure 1. SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis for FEW rural sustainability in the UGP based on workshop discussions.

into marginal land. Often, these marginal lands are grasslands. As demand increases, it is expected that grasslands will be diminished. This is expected to decrease wildlife and insect populations and increase erosion and water pollution. There is also the effect of 'indirect land use change', if we do not put more land into cultivated production - then other places will do so to meet the demand. Within those same grasslands, unconventional oil and natural gas development and coal mining are expanding. These energy developments are further fragmenting habitat and create a contamination risk.

This is merely one of a multitude of trade-offs occurring which have cascading ecological and economic effects. Other examples include: flooding of land for hydroelectric dams, urban and industrial development of open space, habitat fragmentation, loss of floodplains through development encroachment and stabilization efforts, water use (e.g. irrigation, drinking, electricity generation, fracking, or ecological habitat), etc.

What is the best use of land? What are the impacts of changing land-use or degrading them?

Recommendations:

- Research the sustainability impacts of rural land-use change (trade-offs), management decisions, and associated loss of ecosystem services.
- Increase understanding of sacrifice zones (non-reversible land use/ecosystem change) and the long-term impacts of loss.

TRIAGE

Background: Our FEW resources are limited and demand is out-pacing supply. At some point, demand will outstrip supply that can result in rapid commodity price increases. We have multiple demands on the same resources. In situations where resources are scarce, cut-backs must be made.

Vulnerability: Nexus interactions are not adequately understood to create comprehensive policies.

The impacts of resource limitations are complex and can have a cascading failure effect. FEW resource supply limitations need to have a well-planned response due to complexity of interactions.

In an on-going example, Missouri River water is stored behind a series of dams. This water has many uses including, for hydropower generation, irrigating cropland, human and livestock consumption, hydraulic fracking of unconventional oil and gas, cooling water for power production, recreational use, barge traffic and navigation, and fish and wildlife habitat. These interests and needs are often in conflict. If flows are increased in the spring and decreased in the summer for ecological habitat - shorelines may erode, there may not be enough water in reserve for barge traffic or irrigation, and the water may be too warm to be used as cooling water for power production. If barge traffic cannot occur, then grain must be shipped through less efficient alternative means such as rail or road. The flow of the Missouri is federally-regulated and managed. However, other resources such as ground water, smaller surface water bodies, and food and fuel allocation are not. In times of crisis, the needs and wants of an individual or a small group may have to be ceded to the overarching needs of society to maintain stability.

What is the best use of resources? Which uses are critical to stability and well-being of society? How does the loss of those resources affect others?

Recommendations:

- Develop equitable and understandable scaled triage (need/use significance-based) systems for FEW resource export and allocation systems.

PARADIGMS

Background: A century ago, the founders of the wilderness movement established our national parks and worked to preserve the natural environment. Their words and their warnings still hold true:

> "Civilization has so cluttered this elemental man-earth relation with gadgets and middlemen that awareness of it is growing dim. We fancy that industry supports us, forgetting what supports industry."
>
> Aldo Leopold*, A Sand County Almanac*, 1949

We live in a society generally disconnected from the natural environment. Through social and industrial evolutions, conveniences have been gained but the understanding core FEW systems and complexities by the general populace has been lost. The world looks toward the U.S. to set an example. But, we are primarily driven by economics, not by sustainability.

Vulnerability: In order to be sustainable, consumption patterns need to be changed and consumers must pay the real cost of resources and products. Society and culture are relatively slow to change.

It is difficult to de-couple economics and FEW sustainability. Therefore, in order for sustainable solutions the true costs of natural resources must be identified. For example, what is the value of an inch of top soil or 1000 gallons of water in an aquifer?

We need to better understand the price of our consumption. Ground and surface waters are not valued or regulated in the same manner across the nation. Where water is monetized, it is at a rate significantly lower than the actual cost to the renewability of the resource and ecosystem value. Devaluing water leads to waste and abuse of resources. As climate change progresses and as resource demand increases, allocation and conservation of water resources will become more critical.

Another pertinent issue is lack of public scientific understanding and apathy towards FEW nexus sustainability issues. We need to effectively change behaviors at all levels of society. The burden of the human 'rights' to food, water, and energy are not equitable and the full costs are not borne by individuals leading to abuse and waste. We need to make sustainable activities 'easier' and more profitable in order to succeed. Appealing to people's instinct for self-preservation and survival may result in inequitable distribution of resources.

How do we create a functional and accepted value system for ecosystem services, water, and other non-monetized resources? How do we get people to 'care'?

Recommendations:

- Calculate the carbon and water footprints of the energy and food products produced within the region.
- Change human sustainability paradigms and constructing socio-economic influences to support sustainable behavior. As well as development of effective sustainability-oriented economic incentives and/or penalties.
- Estimate short- and long-term economic impacts of FEW sustainability.
- Create a value system for all FEW resources, including ecosystem services and water.

ADAPTATION

Background: There is a need to maintain and/or increase regional FEW resource production to feed and power the nation and world. Climate change and ecosystem service losses are occurring and will likely increase in the future. It is not understood how natural and anthropogenic systems will be affected by these changes. Adaptation to these system changes is needed to maintain production.

Vulnerability: Soil systems, ecosystems, and impacts of climate change and increasing need to produce food are not well enough understood to develop comprehensive adaptation strategies.

In the region, climate change is altering equilibrium relationships between the physical, chemical, and biological constraints between the surface soils, rocks, and sediments underlying this region. In many areas, increasing temperatures and rainfall have changed the chemical composition of the surface soils, which in turn can impact human and soil heath. For example, high Se concentrations can be detrimental to livestock and human health.

Changes in soil chemical composition may also contribute to diminished soil stability and increased erosion. Soil organic matter can increase productivity and water retention. Healthy soil contains a complex system of interactions between plants, fungi, bacteria, micro-organisms, climate, chemistry, and geology. Five factors influence soil development: parent material, climate, living organisms, topography, and time. Soils take decades to millennias to develop. Soil is an ecological foundation for crop production, animal, and hydrologic systems. Different soils and ecosystems need differing management and will not all be equally affected by anthropogenic change.

Soils are fragile systems which do not develop or repair themselves quickly. We have disturbed soil systems through agricultural and energy production, construction and landscaping, urbanization, water management, and climate change - leading to potentially catastrophic changes in the natural development process.

Ecosystems are complex webs reliant on natural space (e.g. grasslands, forests, wetlands, water bodies). Fragmentation of ecosystems through agricultural, energy, and water resources development accompanied by climate change has led to range shifts, seasonality changes, 'dead zones', and increases in pests and diseases in the UGP.

Loss of soil and ecosystem health will negatively impact goods and services to an unknown extent.

How will natural systems adapt to climate change? Can we assist in adaptation? How can we preserve natural systems while maintaining or increasing production?

Recommendations:

- Better understand soil and ecosystem health and regional adaptation to change.
- Improve our understanding on how climate change will impact the quality of foods produced in the region, and the resulting impact on soil sustainability.
- Develop regional ecological thresholds for agricultural production and natural environments due to climate and land use change.

INTEGRATION

Background: Tackling FEW nexus solutions will take cross-disciplinary research at multiple scales (i.e. local, state, regional, national, global) which addresses the interconnection between resources and scales.

Vulnerability: The interconnections between localities, scales, actions, and impacts are complex and often simplified or modeled based on assumptions. This creates generalized results or narrow perspectives and disciplinary silos.

To solve these FEW issues - coupled soil, crop, water models are needed to assess the likely impacts of climate change on human and soil sustainability. Findings from these models need to be effectively shared with the general public.

Broad solutions with multiple benefits need to be developed. Solutions need to create net improvements and address issues from a FEW nexus perspective. Holistic efficiency improvements and waste reductions need to be incorporated into every segment of industry and society.

Demands and resource exchanges need to be changed to reduce waste and directed to the 'best use'. To do so, accurate, scaled FEW import and export models need to be developed.

How do we create simple, spatially explicit models the incorporate FEW complexities?

Recommendations:

- Research interconnection of rural and urban sustainability demands (export/import dynamics) and model development.
- Develop innovative FEW-integrated resource recycling and reuse techniques to reduce waste; specifically, addressing industrial and agricultural production advances to preserve and improve long-term water quantity and quality.

- Incorporate systems and cross-disciplinary relationship/systems in modeling.

OPTIMIZATION

Background: The foundation of current optimization systems is economic. Efficiency is not based on environmental impact, resource conservation, or social gains. Sustainable systems are based on overall efficient processes and products.

Vulnerability: Economic optimization is not equivalent to sustainable optimization.

Nexus sustainability gains may not be cheap. In rural regions, sustainability exports will be in large part reliant on infrastructure redevelopment. Infrastructure is costly from both resource and economic perspectives. The longevity and net impact of the infrastructure must be understood and weighted against sustainability gains. Economic balance is and always will be an important societal factor. Optimization processes need to be expanded to include more perspectives.

Process improvements, synergistic infrastructure development, and efficient transport will be key to rural export sustainability. Systems need to be multi-functional and flexible.

How do we re-invent rural transport systems? Are novel, sustainable transport options possible?

Recommendations:

- Optimize FEW infrastructure and develop novel, sustainable (synergistic) infrastructure retro-fitting and replacement alternatives.
- Develop and advance FEW production and products which have cross-cutting sustainability and efficiency benefits.

ACCESSIBILITY

Background: Scientific data is often buried in a complex quagmire of technical jargon and reports rendering it inaccessible and perplexing to non-technical users. To achieve sustainability, the populace must understand their interest in the outcome.

Vulnerability: Stakeholders, such as farmers and government officials, are not heavily involved or vested in integrated FEW scientific research. The public and stakeholders are biased by self-interest or existing beliefs, confused by the complexity of issues, and influenced by special interest groups and media.

There needs to be better non-technical communication and information accessibility. Unbiased, trusted information sources need to be comprehensively developed and openly available. Research projects need to engage stakeholders and build confidence in solutions developed. Relationships with stakeholders need to be adaptive and collaborative, not just instructive. Local stakeholders need ownership of knowledge so that it is eagerly shared. We need to make science accessible and actionable.

How do we convey complex FEW problems in an understandable manner without losing important details or oversimplifying issues?

Recommendations:

- Increase accessibility and regionalization of integrated food, energy, and water nexus modeling and climate change forecasting.
- Involve more people and key stakeholders in creating solutions.
- Remove barriers to accessing research.

REGIONAL THRESHOLD INDICATORS

The UGP is a critical part of the U.S. agricultural, energy, and water resource production system. The following regional systems were identified as measurable FEW nexus tipping points and thresholds:

- Aquifers represent a significant contribution to the water resources of the UGP. Aquifers vulnerability is critical to understand. Ground water level decline can be measured and used as an indication of resource loss.
- The destabilization of sensitive habitats, such as the Nebraska Sand Hills, will indicate wide-spread system collapse. Mobilization of the Sand Hills (currently a vegetated dune-field) will mean that the Ogallala Aquifer has been regionally dropped to non-recoverable levels and a prolonged drought has killed off all surface vegetation. Previously, it was a 100-year process to destabilize the Sand Hills, however, how climate change and aquifer withdrawals have accelerated this process is unknown.
- Loss and segmentation of natural landscapes (i.e. grasslands, forests) and climate change will reach an ecological threshold where ecosystems and food webs begin to collapse. Populations of keystone species, endangered, and species of special concern can be used as an indicator of change.
- When vulnerable segments of society (in UGP, they are mostly Native American tribal communities) no longer have the resources to obtains food, fuel, electricity and meet other basic needs.
- Continued decline of rural communities and infrastructure will reach a point of loss of efficiency and potential collapse of workforce.
- The ecological health of regional wetlands (i.e. Prairie Potholes) is critical for waterfowl migration and wildlife habitat. Loss of biodiversity, changes in wetland footprint, and pollution can be indicators of system collapse.
- Continued social and environmental disconnect between external owners and corporations and local operators and communities. High costs, external investments, and corporate consolidations have created absentee landowners, profit-first parent companies, and detached management of regional resources. This leads to unsustainable decisions, poor resource management, and local resentment/distrust.
- Changes in temperatures, seasonality, and precipitation lead to negative impacts on crops, livestock, and energy production.
- The landscape becomes a series of monocultures. Monocultures promote pest development, increased dependence on chemicals, and ecological 'dead-zones'.
- Cost of fossil fuel for production and/or transportation become prohibitive for export of regional products.
- Surface water quality and use classification changes impact ecosystems, energy production, and drinking water. Climate change models project that the UGP will lose the majority of cold-water fisheries and fish reproduction habitats in the next fifty to one hundred years (EPA, 2015). This will change ecosystems by increasing water temperature, parasites, and algal/fungal blooms and decreasing oxygen and water quality. The trophic state and classification of lakes and reservoirs will change. Nutrient pollution, contamination, excessive water withdrawal, and sedimentation will likely impact regional surface water more in the future.
- When our land stewards and elders are no longer able to understand the land and act in a manner to preserve land and resources for future generations.

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