MAPS

Microbiomes of Aquatic, Plant, and Soil Systems Across Kansas

Strategic Plan

Kansas NSF EPSCoR RII Track-1
OIA-1656006

Project Director/Principal Investigator
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Project Dates:
September 1, 2017 to August 31, 2022

Photo Credit: Larry Schwarm Photography “Fall in the Flint Hills, Chase County” 2009

Vision Statement

MAPS' vision is a world in which microbiomes and their interactions with the environment are used to manage ecosystem processes and mitigate environmental degradation in agricultural and native landscapes.

Mission Statement

MAPS' mission is to elucidate how microbiomes interact within native and agriculturally dominated aquatic, plant, and soil habitats, leveraging the steep precipitation gradient across Kansas as a means of projecting system response to environmental change. To this end, MAPS will provide a vehicle for education, training, and outreach that includes informing policymakers and managers.

EXECUTIVE SUMMARY

Microbiome science is an emergent discipline recognized as a critical pursuit for understanding ecosystem function. This NSF EPSCoR RII Track 1 project seeks to utilize the unique precipitation gradient extending across the Kansas landscape to establish an observational and experimental network on ***M***icrobiomes of ***A***quatic habitats, ***P***lants, and ***S***oils (***MAPS***). The challenge of simultaneously feeding a growing population, sustaining agriculture, maintaining soil quality, and minimizing greenhouse gases and water contaminants requires new data-driven solutions based in a fundamental understanding of the role and dynamics of MAPS. MAPS mediate the disease and productivity of plants, control the quality of water, and moderate edaphic characteristics and greenhouse gas production. This project transcends traditional microbiological and disciplinary boundaries by harnessing cutting-edge research tools and coupling technologies to rigorous field and experimental environmental approaches while working from genes to ecosystems and across habitats from terrestrial to aquatic. The resultant discoveries and enabling technologies will provide critical knowledge to enable scientists, engineers, and policy makers to develop approaches to sustain food production systems while preserving biodiversity and ecosystem services to address challenges relevant to Kansas, the nation, and the planet.

Research and Education

Thrust 1, Aquatic Microbiome, seeks to understand how connectivity between the terrestrial and aquatic environments influences and structures microbiomes. This thrust focuses on the aquatic microbiomes of rivers, streams (intermittent and permanent), and reservoirs. ***Thrust 2, Plant Microbiome,*** seeks to understand how the microbiomes of plants impact terrestrial ecosystem functions. This thrust focuses on plant microbiome structure and function, and the contribution of different types of microbiomes to plant productivity. ***Thrust 3, Soil Microbiome***, seeks to understand how soil microbiome identity and functioning influence key ecosystem-scale processes. These include site productivity, nutrient availability, soil organic C retention *versus* release, and characteristics of surrounding water bodies. ***Thrust 4, Integration of Aquatic, Plant, and Soil Microbiome Science***, represents the unifying goal of the project and seeks to integrate scientific outputs from Research Thrusts 1 to 3 dealing with the structure and function of the aquatic, plant and soil microbiomes.

Thrust 5, Workforce Development, Education, and Diversity, is closely integrated with the first four Thrusts. These initiatives include faculty professional development and mentoring, with First Awards for junior faculty members and Merit Awards to recognize research achievements. Diversity initiatives include collaboration with the Kansas State University Louis Stokes Alliances for Minority Participation (KSU LSAMP) program and a partnership with the Haskell Environmental Research Studies (HERS) Institute, the latter focusing on combining Indigenous ecological knowledge with scientific approaches. Other education initiatives focus on elementary school students and secondary school teachers and students at schools with large minority enrollments from rural and urban Title 1 schools. By collaborating with the Konza Environmental Education Program (KEEP) Program, the public will receive MAPS information to support awareness and understanding of the importance of ecosystems and the role of MAPS across Kansas.

Other Project Elements

Thrusts 6, ***7***, and ***8***, include ***Partnerships and Collaborations***, ***Communication and Dissemination***, and ***Sustainability***, respectively, and are associated with expanding and sustaining the MAPS science initiatives. Current partnerships include Tribal Colleges and Kansas High Schools. These collaborations, together with dissemination of MAPS science through venues ranging from museums to social media, will lead to sustaining the MAPS initiative with extended funding from a variety of sources.

In order to assist in accomplishing the goals of Thrusts 1 through 8, ***Thrust 9***, ***Project Management***, will provide oversight to both research and education initiatives as well as all other project activities. This oversight includes research guidance involving the hiring of personnel and purchasing equipment, as well as overall administration, including interactions with external evaluation groups and stakeholders such as the Kansas Board of Regents and the Science and Education Advisory Committee (SEAC). ***Thrust 10***, ***Evaluation and Assessment***, provides formative and summative external evaluation and assessment, and serves as a means of providing feedback on performance and progress in the project to guide for future directions.

The ***Risk Management Plan*** evaluates ***Risk Likelihood*** and ***Risk Impact*** as high, medium, or low, and ***Immediacy of Impact***, immediate (< one year), mid-term (two – three years), and distant (four years and beyond). Especially high risks impacting the entire project include issues of extreme weather and/or other natural occurrences and difficulty in faculty hires and/or loss of faculty due to raids. Risks impacting specific research aspects include issues with microbial drivers and microcosms, site selections, and data harvesting. Management strategies include providing novel alternative strategies and additional back-up scenarios.

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Introduction

Overview

Kansas is dominated by agricultural land uses overlaid by a precipitation gradient broadly representative of both current and future precipitation regimes (Fig. 1). Within these landscapes, society must grapple with food production while sustaining broader environmental health. Thus, Kansas provides an ideal living laboratory to build future research capacity in microbial ecology and environmental science by:

- Conducting observational studies and experiments across precipitation and land use gradients to reveal the driving forces governing water quality, soil organic matter and nutrient retention and release, and plant productivity;
- Creating a base data set on microbiomes of Kansas and their linkages to environmental data that will be used for this and future projects; and
- Recruiting a team of investigators at diverse career stages, plus new faculty hires, across multiple Kansas universities.

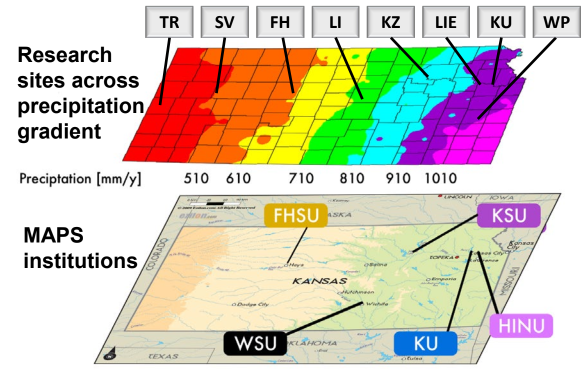

Figure 1: Kansas MAPS involves: University of Kansas (KU), Kansas State University (KSU), Wichita State University (WSU), Fort Hays State University (FHSU), and Haskell Indian Nations University (HINU). The precipitation gradient across the state covers from arid grassland [510 mm/y] to deciduous forest [1010 mm/y]. Potential research sites are Tribune (TR), Smoky Valley (SV), Fort Hays (FH), The Land Institute (LI), Konza (KZ), The Land Institute-East (LIE), KU Field station (KU), and Welda Prairie (WP).

MAPS science is well-aligned with Kansas interests and needs. The Regents Universities' State S&T Plan (*Kansas: **B**uilding an **E**nvironment of **S**cience and **T**echnology for Innovation*, **B.E.S.T.**, 2012). B.E.S.T. calls for a partnership among the research areas to leverage traditional research strengths with emerging opportunities and clearly identifies agriculture as a "primary driver of its technology economy." A follow-up 50-year vision report created with input from Kansas citizens focuses on Kansas' water needs (*A Long-term Vision for the Future of Water Supply in Kansas*, 2015) and serves to emphasize the need for research in areas such as MAPS. The plan preface states, "*Water and the Kansas economy are directly linked. Water is a finite resource and without further planning and action we will no longer be able to meet our state's current needs, let alone growth*." MAPS science underpins the function and supply of freshwater ecosystem services.

Research universities in Kansas face serious issues: rising start-up costs; multi-user equipment costs and maintenance; lack of research space and critical masses of researchers in high profile fields; and faculty raids. This multi-disciplinary, multi-institutional project will play an active role in addressing these barriers by creating a powerful and unique research network interweaving scientific findings that link aquatic, plant, and soil microbiome knowledge in MAPS. This funding will catalyze a thriving, sustained research effort built upon the foundation of core Kansas facilities including the Center for Metagenomic Microbial Community Analysis, the Genomics Center, and the Kansas Applied Remote Sensing Center at the University of Kansas (KU); and the Bioinformatics Center, the Integrated Genomics Facility, and the Soil Carbon Center at Kansas State University (KSU). The MAPS project invests in these facilities to meet the demand for technical expertise and training in microbial genomics and informatics. The strategies for meeting this demand include:

- Building a collaborative group of microbial ecologists;
- Attracting and mentoring new faculty members who will establish careers in Kansas;
- Creating an open access database on microbiome sequences linked to environmental patterns across Kansas habitats, which will serve as a foundation for MAPS research as well as future research initiatives;
- Purchasing shared research infrastructure instrumentation; and
- Linking STEM programs to our network of researchers to inform and excite the next generation of scientists and citizens, while, at the same time, increasing the diversity and skill set of future researchers.

This RII Track 1 EPSCoR project focusing on MAPS research transcends traditional microbiological and disciplinary boundaries by harnessing cutting-edge research tools and coupling technologies to rigorous field and experimental environmental approaches, while working from genes to ecosystems. The resultant discoveries and enabling technologies will provide critical knowledge that enables scientists, engineers, and policy makers to develop approaches to sustain food production systems while preserving biodiversity and ecosystem services. By initially utilizing the unique precipitation gradient across the Kansas landscape, MAPS researchers will provide much needed knowledge of the interrelationship among aquatic, plant, and soil microbiomes (Fig. 2) to address the challenges associated with MAPS that are relevant to Kansas, the nation, and the planet.

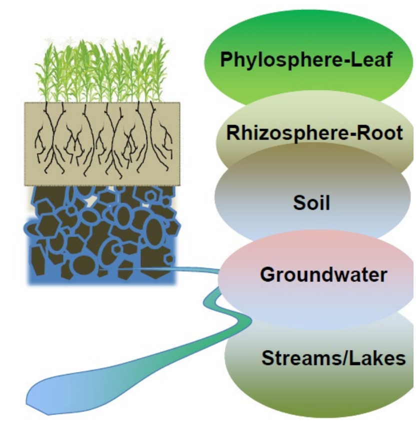

Figure 2. Overlapping and interacting habitats of microbiomes of aquatic, plant, and soil systems (MAPS).

Project Implementation

The Research and Education initiatives of this NSF EPSCoR RII Track 1 project will be implemented by the lead investigators at KSU and KU. Walter K. Dodds, University Distinguished Professor in Biology and Charles W. Rice, University Distinguished Professor in Soil Science at KSU; and James D. Bever, Foundation Distinguished Professor and Sharon A. Billings, Professors of Ecology and Evolutionary Biology at KU, will lead ***Thrusts 1*** - ***4***, ***Aquatic***, ***Plant***, ***Soil***, ***and Integrated Microbiome*** initiatives. Jay T. Johnson, Associate Professor of Geography and Peggy A. Schultz, Research Specialist, both at KU, will spearhead ***Thrust 5***, ***Workforce Development***, ***Education***, ***and Diversity*** initiatives. Oversight of the entire project will be provided by the Kansas NSF EPSCoR office staff, consisting of Kristin Bowman-James, Project Director and University Distinguished Professor of Chemistry, Doug Byers, Assistant Director, Rosemary Blum, Education and Outreach Coordinator, and Candi Wilbur, Business Manager. Together, this group of investigators and EPSCoR staff make up the Management Team. ***Thrust 10*** and Appendix A provide additional information about Project Management, and Appendix B provides a listing of all of the key researchers, their affiliations, and roles.

The overarching goal of ***Thrust 1, Aquatic Microbiome***, is to understand how connectivity between the terrestrial and aquatic environments influences and structures microbiomes. We predict that hydrologic connectivity, land use, and nutrient loading are important drivers in structuring variation in the aquatic microbiomes across the state of Kansas. This thrust focuses on the aquatic microbiomes of rivers, streams (intermittent and permanent), and reservoirs; streams are important for transforming and transporting nutrients and microbes across the state, whereas reservoirs are important sources of drinking water, irrigation, and recreation and are prone to harmful cyanobacterial blooms. A combination of statewide field and manipulative experiments provide understanding of the connection between aquatic drivers and the resultant aquatic microbiomes. Statewide surveys will also be used to study aquatic microbiomes in order to characterize the structure and biogeochemical processes of aquatic (stream and reservoir) microbiomes (Goal 1.1). Results will be integrated with manipulative experiments to test the contribution of different types of microbiomes to plant productivity, including those at sites with high N inputs and those susceptible to toxin production and nuisance species (Goal 1.2). Objectives include site selections, characterizations, and information integration for Goal 1.1 and assessment of rates of N processing and evaluation of toxin effects on microbiomes for Goal 1.2.

Together, with the soil group, the resilience of terrestrial communities to nutrient loss against precipitation variation and perturbation will be tested and individual micro-organisms will be isolated and tested for their roles in promoting plant productivity and conferring ecosystem benefits.

The overarching goal of ***Thrust 2, Plant Microbiome***, is to understand how the microbiomes of plants impact terrestrial ecosystem functions such as plant productivity, soil fertility, and resource retention and influence aquatic microbiome and water quality. Field surveys of plant microbiome structure and function to characterize the structure and biogeochemical processes (Goal 2.1) will be integrated with manipulative experiments to test the contribution of the phyto- and rhizo-biome and their interaction to plant productivity. Jointly with the soil group, the resilience of terrestrial communities to nutrient loss against precipitation variation and perturbation will be determined (Goal 2.2) by assessing coupled microbiome functions between plant-soil and shoot-root microbiomes. Individual micro-organisms will be isolated and tested for their roles in promoting plant productivity and conferring ecosystem benefits (Goal 2.3). Objectives include characterization of plant community structure and function for Goal 2.1; assessments of resilience and climate adaptations, and disentangling of different microbiome contributions and interactions for Goal 2.2; and developing and testing candidate microbes as drivers of plant productivity and ecosystem service functions for Goal 2.3.

The overarching goal of ***Thrust 3, Soil Microbiome***, is to understand how soil microbiome identity and functioning influence key ecosystem-scale processes like site productivity, nutrient availability, soil organic C retention *versus* release, and characteristics of surrounding water bodies. First, abiotic and biotic drivers of the stocks and fluxes of C and N across the precipitation and land use gradient will be determined (Goal 3.1). Objectives include quantifying soil depth distributions of C and N pools and transformation rates across Kansas. These observations will be linked to historic and contemporary climate and to microbiome composition. Jointly with researchers in Thrust 2, coupled functions between plant-soil and shoot-root microbiomes will be assessed to obtain a mechanistic understanding of the drivers of precipitation and land use-associated patterns of these stocks and fluxes in the field. Objectives include conducting similar assays as in Thrust 2 in manipulated, controlled monolith mesocosms to parse the role of the microbiome from abiotic drivers, and to assess the interactions among these parameters.

The overarching goal of ***Thrust 4, Integration of Aquatic, Plant, and Soil Microbiome Science***, is the integration of scientific outputs from Thrusts 1 to 3 on the structure and function of the aquatic, plant and soil microbiomes. This Thrust represents the culminating goal of the project: understanding how land use and precipitation alter the functions of MAPS and mediate ecosystem responses. Objectives include integrating results from field and mesocosm research through coupled regression and structural equation models, using the results of empirical studies to parameterize general models, and using these models to simulate dynamics under alternative climate scenarios.

Thrust 5, Workforce Development, Education, and Diversity initiatives are integral to this project and are interwoven throughout each of the Research Thrusts. Goals include 1) building a diverse and competitive workforce in MAPS fields, 2) introducing students, teachers, and Kansas residents to MAPS science through education and outreach initiatives, and 3) using MAPS science to increase the participation of underrepresented groups from diverse backgrounds to STEM fields. Workforce development objectives include faculty professional development and mentoring, with First Awards for junior faculty members and Merit Awards to recognize research achievements. Educational objectives focus on elementary school students and secondary school teachers and students in schools with large minority enrollments from rural and urban Title 1 schools. A partnership with the Konza Environmental Education Program (KEEP) Program will provide the general public with MAPS information to support awareness and understanding of the importance of the ecosystems and the role of MAPS across Kansas. Diversity objectives include a new collaboration with the Kansas State Louis Stokes Alliances for Minority Participation program and a partnership with the Haskell Environmental Research Studies Institute, the latter focusing on combining Indigenous ecological knowledge with scientific approaches.

Other ***Project Elements*** are provided in ***Thrusts 6***, ***7***, and ***8***, and are associated with expanding and sustaining the MAPS science initiatives. These include ***Partnerships and Collaborations***, ***Communication and Dissemination***, and ***Sustainability***, respectively. Current partnerships will be expanded and new partnerships will be formed, the latter involving Tribal communities and Kansas High Schools. Dissemination of MAPS science includes professional networking, including state and multi-jurisdictional meetings; exhibits at local and state museums; and social media, as well as a dedicated website for the MAPS project. Sustaining Kansas' expanded MAPS research network beyond EPSCoR funding will capitalize on the newly formed collaborations and partnerships, new faculty hires, and new research infrastructure-building instrumentation to obtain extended funding from federal and other sources.

Project Management details are provided in ***Thrust 9*** and are divided into two goals, management of the research activities and overall project oversight. Research management includes as objectives: hiring personnel, including three new faculty members, one each at KU and KSU in environmental metagenomics and one at Haskell associated with the HERS Institute; purchasing research infrastructure needs, including a mass spectrometer and computational resources; and organizing research project oversight and infrastructure. The overall project management objectives include creating an effective environment for management coordination and communications; engaging the Kansas Board of Regents-appointed EPSCoR Steering Committee and the Kansas NSF EPSCoR-appointed Science and Education Advisory Committee (SEAC) in research activities; and appointing a co-Project Director as part of the Project Director (PD) succession plan. A more detailed description of the Management Structure is provided in Appendix A.

Evaluation and Assessment details are provided in ***Thrust 10***. The overall goal involves integrating formative and summative evaluation and assessment components to form a feedback system that assists Kansas NSF EPSCoR to successfully attain the full range of proposed goals and objectives set out in the MAPS project. Objectives include developing and implementing a performance tracking process that mirrors NSF annual report metrics and external evaluation needs; obtaining technical reports from the SEAC; and implementing an evaluation methodology to provide performance and progress feedback to the researchers and the Kansas NSF EPSCoR office.

Research and Education Elements

Thrust 1: Aquatic Microbiome

Goal 1.1 Characterize the structure and biogeochemical processes of the aquatic (stream and reservoir) microbiome resulting from variation in hydrologic connectivity, nutrient loading, and land use across the Kansas precipitation gradient.

- Objective 1.1.1 Identify sites to capture range and variation in stream discharge and flux of nutrients and microbes above/below reservoirs
- Objective 1.1.2 Characterize stream hydrology in order to understand how it influences aquatic microbiomes
- Objective 1.1.3 Characterize aquatic microbiome in order to elucidate microbial variation across the precipitation gradient
- Objective 1.1.4 Characterize variation water chemistry to estimate nutrient transport across the precipitation gradient
- Objective 1.1.5 Integrate biogeochemical, hydrologic and genetic information to understand how precipitation and land use gradients drive aquatic microbiomes

Objective 1.1.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 1.1.1a: Establish sites	Workshop discussion on best site selection informed by spatial data	Refine site location as needed	Identify sites for in-depth metagenomics	Final site refinement as needed		Burgin, Dodds, Sturm, Sullivan, Zeglin
Activity 1.1.1b: Hire personnel with aquatic expertise	Hire graduate students and postdoc to explore/collect prelim data	Hire summer seasonals	Hire summer seasonals	Hire summer seasonals		Burgin, Zeglin, Sullivan
Activity 1.1.1c: Establish infrastructure	Purchase sensors, field vehicle, begin sensor installation	Maintain sensors; replace as needed	Maintain sensors; replace as needed	Maintain sensors; replace as needed	Maintain sensors; replace as needed	Burgin, Zeglin, Sullivan

Objective 1.1.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**

Activity 1.1.2a: Integration of sensor data	Define contributing catchments and land cover types	Establish protocols for data sharing and analysis	Data analysis	Data analysis/integrate with models	Data analysis/integrate with models	Sullivan

Objective 1.1.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 1.1.3a: Collect samples	Collect prelim samples	Full synoptic sample collection, microbial and water quality	Full synoptic microbial and water quality sample collection	Full synoptic microbial and water quality sample collection		Sturm, Zeglin
Activity 1.1.3b: Barcode amplicon library sequencing	Begin processing samples	Amplicon sequencing: finish year 1 samples	Amplicon sequencing: finish year 2 samples	Amplicon sequencing: finish year 3 samples	Finish amplicon sequencing	Sturm, Zeglin
Activity 1.1.3c: Metagenomic data collection			Metagenomic sequencing on select samples	Finish metagenomic sequencing		Sturm, Zeglin
Activity 1.1.3d: Data processing and analysis	Create and standardize bioinformatics pipeline to integrate with rest of MAPS	Data analysis: finish year 1 analysis	Data analysis: finish year 2 analysis	Data analysis: finish year 3 analysis including integrating amplicon and metagenome data	Finish data analysis	Sturm, Zeglin

Objective 1.1.4	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 1.1.4a: Analyze samples	Analyze prelim samples from 1.1.3	Analyze full synoptic samples	Analyze full synoptic samples	Analyze full synoptic samples		Burgin, Dodds

Activity 1.1.4b: Data analysis and processing		Finish year 1 analysis	Finish year 2 analysis	Finish year 3 analysis	Finish data analysis	Burgin, Dodds

Objective 1.1.5	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 1.1.5a: Preliminary evaluation		Integrate data from first year, identify gaps/ challenges				Burgin, Dodds, Sturm, Sullivan, Zeglin
Activity 1.1.5b: Spatial data integration			Integrate data from second year	Integrate data from third year, including metagenomic		Burgin, Dodds, Sturm, Sullivan, Zeglin
Activity 1.1.5c: Temporal data integration					Integrate all data to identify interannual trends	Burgin, Dodds, Sturm, Sullivan, Zeglin

Goal 1.2 Evaluate whether benthic microbiomes from sites with histories of high N inputs process N faster than those from sites with low N and assess the influence of increased N and P on downstream algal blooms.

- Objective 1.2.1 Use experiments & data collection (use samples from pilot field sites) and assess rates of N processing
- Objective 1.2.2 Evaluate whether microbiomes from lakes susceptible to toxin production are more likely to shift to bloom states as a result of climate change and land use alterations to nutrient loads

Objective 1.2.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 1.2.1a: N cycling experiments		Run lab experiments & data collection to establish N cycling rates	Analyze data, write and submit publication			Dodds, Zeglin

Objective 1.2.2	Specific Milestones					
	Year 1- 2018	Year 2	Year 3	Year 4	Year 5	Responsible party
Activity 1.2.2a: Mesocosm experiments		Plan experiments based on results of soil mesocosms	Setup mesocosms	Run experiments, initiate data analysis	Writing	Burgin, Sturm

Outputs:

- Presentation of findings at national meetings by students and researchers
- Student- and researcher-led journal articles on aquatic microbiome
- Dissemination of knowledge to state level regulators
- **Goal 1.1:**
    - Hydrologic characterization of core sites to be uploaded to online data repository such as CUASHI hydroDB
    - Aquatic microbiome characterization across Kansas (precipitation and land-use gradient)
    - Water chemical characterization for all sites
    - Definition of dynamic range and level of covariance in stream microbiomes and biogeochemistry across Kansas
    - Improved understanding of sensitivity of stream microbiome structure and function to climate and land-use change
- **Goal 1.2:**
    - Generation of amplicon libraries (16S rRNA and *nosZ* genes) with associated denitrification potentials
    - Identification of stream benthic microbiome genotypes with high N removal potential
    - Understand how changing precipitation regimes affect probability of toxic algal blooms
    - Dataset linking chemistry and toxic algal bloom genetics/microbiome

Outcomes:

- Increase network of basic and applied aquatic biogeochemistry researchers across the state of Kansas, including more interaction with local managers and landowners
- Greater collaborative interaction with USGS, particularly regarding harmful algal bloom mitigation
- State level regulators have a better understanding of influence of microbiomes on agricultural issues

Thrust 2: Plant Microbiome

Goal 2.1 Characterize the structure and function of the plant microbiome: shoot, root, and rhizosphere, in response to gradients of precipitation and anthropogenic impact.

- Objective 2.1.1 Characterize the plant community structure by quantifying plant abundance and composition
- Objective 2.1.2 Characterize the structure of the plant microbiome using amplicon sequencing
- Objective 2.1.3 Characterize microbiome function using plant phytometers in greenhouse assays
- Objective 2.1.4 Characterize microbiome function using analysis of functional genes
- Objective 2.1.5 Integrate data for plant microbiome structure and function

Objective 2.1.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.1.1a: Establish Sites	Identify core sites - prelim data	Identify supplementary sites				MAPS Faculty
Activity 2.1.1b: Survey plant community	Seasonal surveys of core sites begin	Seasonal surveys of core sites continue	Survey plant community across all sites	Targeted survey of plant communities		Houseman, Greer, Bever
Activity 2.1.1c: Data entry and analysis	Data entry of cores sites begins	Data entry of core sites; begin analysis of core sites	Data entry of year 2; begin analysis of all sites	Analysis across years	Analysis of spatial and temporal patterns of plant composition	Houseman, Greer, Bever

Objective 2.1.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.1.2a: Collect Samples	Seasonal sampling of core sites	Complete seasonal sampling	Sample all sites	Follow-up field sites		PMB/SMB Faculty
Activity 2.1.2b: Barcode amplicon library sequencing	Initiate processing of samples	Continue processing seasonal samples;	Complete amplicon sequencing of seasonal samples;	Amplicon sequencing; finish year 3 samples	Amplicon sequencing	Jumpponen, Sikes, Bever, Platt

		Begin amplicon sequencing;	continue year 2 sequencing			
Activity 2.1.2c: Barcode data analyses	Initiate bioinformatics pipeline across MAPS	Standardize and update pipeline; begin processing of year 1 sequences	Implement and update pipeline; begin processing of cross site dataset	Implement and update pipeline; continue processing of cross sites and cross year dataset	Implement and update pipeline; complete processing of dataset	Sikes, Jumpponen, Liu
Activity 2.1.2d: Integration of phytobiome and rhizobiome data			Begin synthesis of plant microbiome	Assess linked microbiome changes	Analysis of spatial and temporal patterns of plant microbiome	Sikes, Jumpponen, Liu

Objective 2.1.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.1.3a: Initiate phytometer assessment experiments of microbial function		Phytometer assessment of core sites	Phytometer assessment of sites sampled in year 2	Phytometer assessment of sites sampled in year 3		Bever, Nippert, Alexander
Activity 2.1.3b: Harvest experiment and analyze data		Harvest and analyze phytometer test year 1	Harvest and analyze phytometer test year 2	Harvest and analyze phytometer test year 3	Synthesize phytometer metrics across years	Bever, Nippert, Alexander

Objective 2.1.4	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.1.4a: Sequence functional loci			Metagenomic sequencing			Jumpponen, Sikes, Liu, Platt

Activity 2.1.4b: Functional locus analyses				Develop bioinformatics pipeline; preliminary data analysis	Analyze data	Jumpponen, Sikes, Liu, Platt

Objective 2.1.5	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.1.5a: Integrate microbiome composition with phytometer results				Construct and test possible causal paths	Construct and test possible causal paths	Bever, Sikes, Platt, Reuman
Activity 2.1.5b: Integrate microbiome composition with functional locus analyses				Initiate analysis of data	Analyze data	Liu, Jumpponen, Sikes, New Hire

Goal 2.2 Assess coupled microbiome functions between plant-soil and shoot-root microbiomes.

- Objective 2.2.1/3.2.1 Assess resilience and climate adaptation of terrestrial ecosystem functions for coupled plant-soil (terrestrial) microbiomes (in conjunction with Objective 3.2.1)
- Objective 2.2.2/3.2.2 Disentangle microbiome and plant contributions to resilience and climate adaptation of terrestrial ecosystem functions for coupled plant-soil (terrestrial) microbiomes (in conjunction with Objective 3.2.2)
- Objective 2.2.3 Disentangle consequences of shoot-root microbiome interactions on plant function

Objective 2.2.1/3.2.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.2.1a/3.2.1a: Establish mesocosm experiment	Establish mesocosm experiment					Loecke, Sikes, Bever, Billings
Activity 2.2.1b: Measure ecosystem functions		Monitor and measure effluent	Measure resilience to climate perturbation	Measure resilience to climate perturbation		Loecke, Sikes, Bever, Billings

Activity 2.2.1c: Measure microbiome resilience		Sample, sequence, and analyze	Sample, sequence, and analyze			Loecke, Sikes, Bever, Billings

Objective 2.2.2/3.2.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.2.2a/3.2.2a: Establish mesocosm experiment			Establish and inoculate mesocosm experiment			Sikes, Bever, Loecke, Billings
Activity 2.2.2b/3.2.2b: Measure ecosystem functions			Monitor and measure effluent	Measure resilience to climate perturbation		Sikes, Bever, Loecke, Billings
Activity 2.2.2c/3.2.2c: Measure microbiome resilience				Sample, sequence, and analyze	Sample, sequence, and analyze	Sikes, Bever, Loecke, Billings

Objective 2.2.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.2.3a: Establish shoot-root reciprocal inoculation experiment			Initiate experiment			Nippert, Platt, Jumpponen
Activity 2.2.3b: Assess plant functional responses and microbiome consequences			Monitor, harvest and evaluate			Nippert, Platt, Jumpponen
Activity 2.2.3c: Analyze results				Analyze results		Nippert, Platt, Jumpponen

Goal 2.3 Test potential for individual microbes to mediate effects on plant productivity and ecosystem services.

- Objective 2.3.1 Develop candidate list of microbes that could be drivers of plant productivity and ecosystem service functions
- Objective 2.3.2 Isolate and test functional benefits of candidate microbes for plant growth promotion and ecosystem effects

Objective 2.3.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.3.1a: Develop candidate list	Develop *a priori* candidate list		Test spatial patterns of microbial candidates to select targets for isolation			Bever, Sikes, Jumpponen

Objective 2.3.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 2.3.2a: Isolate candidate microbes		Begin isolation of AM fungal candidates	Begin isolation of culturable fungal and bacterial candidates			Bever, Sikes, Jumpponen, Platt
Activity 2.3.2b: Test candidate microbes			Design tests of functional benefits of candidate microbes	Test candidate microbes in phytometer assays	Analyze experiments	PMB Faculty

Outputs:

- Organization of International Mycological Conference Symposium around Plant Microbiomes
- **Goal 2.1**: Characterization of plant microbiome structure and function across Kansas
- **Goal 2.2**: Assessment of coupled plant-soil and rhizo-phyllosphere microbiomes
- **Goal 2.3**: Development of culture collections of microbes from across land use and environments; test functions
    - Identification of cultured microbes which improve plant performance
- Presentation of findings at national meetings by students and researchers

Outcomes:

- Increased visibility of Kansas research and understanding of plant-associated microbiomes in international community
- Increased general understanding of rainfall and land use effects on plant microbiomes
- Determination of how plant microbiomes interact both *in planta* (rhizo-phyllo) and with soil microbiome
- Production of living library with functional measures of microbes
- Exploitation and evaluation of potential use of plant-growth promoting microbial consortia

Thrust 3: Soil Microbiome

Goal 3.1 Determine the abiotic and biotic drivers of the C and N stocks and fluxes across the precipitation and land use gradient of Kansas.

- Objective 3.1.1 Characterize soil physical, chemical, biological, and hydrologic properties across the precipitation and land use gradients to identify abiotic factors
- Objective 3.1.2 Determine land use influence on rooting depth across sites to investigate C and N inputs to the soil profile
- Objective 3.1.3 Characterize the composition of the soil microbiome among soil layers to understand how microbial structure relates to function
- Objective 3.1.4 Quantify soil C and N transformation rates and model in situ hydrologic and geochemical fluxes to constrain flux magnitudes under different environmental change scenarios

Objective 3.1.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 3.1.1a: Site selection	Identify core sites	Identify supplementary sites				MAPS Faculty
Activity 3.1.1b: Characterize physical and chemical attributes of the profile	In-situ soil taxonomy and characteristics for core sites	Soil taxonomy and characteristics complete for all sites. Laboratory characterization in progress for core sites	Laboratory characterization complete for core sites; in progress for supplementary sites	Laboratory characterization complete for supplementary sites		SMB Faculty
Activity 3.1.1c: Install lysimeters, soil water	Initiate soil monitoring array	Array installation and maintenance	Array installation for supplementary	Array maintenance	Array maintenance	Sullivan, Loecke, Kirk, Billings,

and gas sensors, and power sources	installation and maintenance for core sites, ensuring appropriateness of sites given aquatic site selection	complete for core sites; in progress for supplementary sites	sites complete; maintenance in progress for all sites	continued for all sites	continued for all sites	Greer
Activity 3.1.1d: Acquire and analyze historical weather data	Establish contact and data exchange with state climatologist	Characterize historic precipitation amounts and variability				Loecke, Sullivan

Objective 3.1.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 3.1.2a: Soil sampling	Initiate sampling from core sites	Sampling at core sites completed; in progress for supplementary sites	Complete sampling at supplementary sites			Billings, Loecke, Kirk, Rice
Activity 3.1.2b: Root assays	Initiate root biomass and/or density for core sites	Root biomass and/or abundance complete for core sites; in progress for supplementary sites	Root biomass and/or abundance complete for supplementary sites			Billings, Loecke

Objective 3.1.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 3.1.3a: Amplicon sequencing,	Initiate DNA extraction and amplification and	Amplicon sequencing and gene-specific	Amplicon sequencing and gene-specific analysis complete	Amplicon sequencing and gene-specific analysis	Analyze data	Sikes, Bever, Billings, Sturm, Jumpponen

metagenome development	pipeline development	work in progress for core sites	for core sites; in progress for supplementary sites	complete for supplementary sites		

Objective 3.1.4	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 3.1.4.a: Parameterize hydrologic flux models to characterize differences in sites' hydrology	Begin parameterization of model (e.g. Hydrus-D)	Complete model parameterization and initiate model runs	Continue model runs	Complete model runs		Sullivan, Kirk
Activity 3.1.4b: Quantify C and N release rates from organic matter	Initiate extracellular enzyme assays for core sites	Extracellular enzyme assays complete for core sites; in progress for supplementary sites	Extracellular enzyme assays complete for all sites	Analyze data		Rice, Loecke, Billings
Activity 3.1.4c: Quantify *ex situ* CO_2 and net N_2O efflux rates from soils	Initiate soil incubations for core sites	Soil incubations complete for core sites and in progress for supplementary sites; initiate analysis of gas samples	Soil incubations complete for supplementary sites; analysis of gas samples in progress	Analysis of gas samples complete		Rice, Loecke, Billings
Activity 3.1.4d: Quantify dissolved inorganic nutrient concentrations	Initiate extraction of soil samples from core sites	Extraction of soils complete for core sites and in progress for supplementary sites; initiate chemical analysis of extracts	Extraction of soils complete for supplementary sites; chemical analysis of extracts in progress	Chemical analysis of extracts complete		Rice, Loecke, Billings, Kirk

Activity 3.1.4e: Model geochemical fluxes	Begin parameterization of geochemical model	Complete model parameterization and initiate model runs	Continue model runs	Continue model runs		Sullivan, Kirk

Goal 3.2 Assess coupled microbiome functions between plant-soil and shoot-root microbiomes (in conjunction with Goal 2.2.).

- Objective 3.2.1/2.2.1 Assess resilience and climate adaptation of terrestrial ecosystem functions for coupled plant-soil (terrestrial) microbiomes (in conjunction with Objective 2.2.1)
- Objective 3.2.2/2.2.2 Disentangle microbiome and plant contributions to resilience and climate adaptation of terrestrial ecosystem functions for coupled plant-soil (terrestrial) microbiomes (in conjunction with Objective 2.2.2)

Objective 3.2.1/2.2.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 3.2.1a/2.2.1a: Establish mesocosm experiment	Establish mesocosm experiment					Loecke, Sikes, Bever, Billings
Activity 3.2.1b/2.2.1b: Measure ecosystem functions		Monitor and measure effluent	Measure resilience to climate perturbation	Measure resilience to climate perturbation		Loecke, Sikes, Bever, Billings
Activity 3.2.1c/2.2.1c: Measure microbiome resilience		Sample, sequence, and analyze	Sample, sequence, and analyze			Loecke, Sikes, Bever, Billings

Objective 3.2.2/2.2.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 3.2.2a/2.2.2a: Establish mesocosm experiment			Establish and inoculate mesocosm experiment			Sikes, Bever, Loecke, Billings

Activity 3.2.2b/2.2.2b: Measure ecosystem functions			Monitor and measure effluent	Measure resilience to climate perturbation		Sikes, Bever, Loecke, Billings
Activity 3.2.2c/2.2.2c: Measure microbiome resilience				Sample, sequence, and analyze	Sample, sequence, and analyze	Sikes, Bever, Loecke, Billings

Outputs:

- A soil monitoring array capable of providing real-time soil conditions across the state
- Presentation of findings at national meetings by students and researchers
- Papers, many of which will be in open access journals, and local, regional, national and international presentations describing:
    - Kansas soil resources as representatives of the North American Midwest
    - The capacity of these soil systems to exhibit resistance and resilience to environmental change
    - Hydrologic and land use controls on soil C and N stabilization
    - Synthetic linkages across microbial and biogeochemical disciplines

Outcomes:

- Enhanced understanding of how agricultural and natural land management practices influence ecosystem function
- Personnel infrastructure at multiple institutions across the state appreciative of the importance of synthesizing biological, physical, hydrologic and chemical data to understand ecosystem function
- Greater probability of procuring external funding for MAPS-related disciplines in the state
- A strengthened collaborative network amongst faculty at five institutions in the state
- A greater ability to retain faculty because of these strengthened working relationships
- Enhanced population of workforce in the state trained in MAPS-related disciplines

Thrust 4: Integration of Aquatic, Plant and Soil Microbiome Science

Goal 4.1 Understand how land use and precipitation alter the functions of MAPS and mediate ecosystem responses.

- Objective 4.1.1: Perform integrative analysis of field survey
- Objective 4.1.2: Perform integrative analysis of mesocosms
- Objective 4.1.3: Develop models to examine precipitation and land use decision impact the functional consequences of linkages between MAPS

Objective 4.1.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 4.1.1a: Determine dataset structure	Initiate drafting of database structure	Create database structure	Refine database structure	Refine database structure	Refine database structure	MAPS Faculty
Activity 4.1.1b: Structural equation modeling and alternatives				Test causal paths; link multiple models	Test causal paths; link multiple models	MAPS Faculty

Objective 4.1.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 4.1.2a: Determine dataset structure	Initiate drafting of database structure	Create database structure	Refine database structure	Refine database structure	Refine database structure	MAPS Faculty
Activity 4.1.2b: Structural Equation modeling and alternatives				Test causal paths; link multiple models	Test causal paths; link multiple models	MAPS Faculty

Objective 4.1.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**

Activity 4.1.3a: Develop dynamic model (DM)	Initiate discussion of modeling goals	Develop modeling framework	Develop modeling framework			Agusto, Platt, Reuman, Bever, MAPS Faculty
Activity 4.1.3b: Parameterize DM models with experimental results			Parameterize models	Parameterize models	Parameterize models	Agusto, Reuman, Platt, MAPS Faculty
Activity 4.1.3c: Analyze DM simulations			Analyze models	Analyze models; Sensitivity Analysis, project dynamics	Analyze models; Test model predictions	Agusto, Platt, Reuman
Activity 4.1.3d: Develop reactive transport models (RTM)	Initiate discussion of modeling goals	Build model framework				Sullivan, Billings, Loecke, Dodds
Activity 4.1.3e: Parameterize RTM		Being Model Parameterization	Parameterize models	Parameterize models	Parameterize models	Sullivan
Activity 4.1.3f: Analyze RTM			Sensitivity Analysis	Sensitivity Analysis	Test predictive capabilities	Sullivan

Outputs:

- Database of integrated sampling of plant, soil, and aquatic microbiome composition and function at sites of varying land use history across the Kansas precipitation gradient
- Presentation of findings at national meetings by students and researchers
- Statistical assessment of associations between plant, soil, and aquatic microbiome composition and function and key ecosystem responses observed at field sites and within experimental mesocosms
- Dynamic process-based ecosystem model linking the impacts of plant, soil, and aquatic microbiomes on key ecosystem responses
- Process-based reactive transport model that incorporates spatial and hydrologic influences on the impacts of plant, soil, and aquatic microbiomes on key ecosystem responses

Outcomes:

- Increased understanding of how the composition and function of plant, soil, and aquatic microbiomes vary with land use history and precipitation
- Assessment of the extent to which direct and indirect linkages between plant, soil, and aquatic microbiomes are associated with and influence key ecosystem processes

- Identification of key factors determining the impact of plant, soil, and aquatic microbiomes on key ecosystem responses through sensitivity analysis of the developed process-based models
- Projections of the impact of future climate change on key ecosystem processes through simulation of the developed process-based models

Thrust 5: Workforce Development, Education, and Diversity

Goal 5.1 Build a diverse and competitive workforce in MAPS fields.

- Objective 5.1.1: Implement a program of faculty professional development
- Objective 5.1.2: Train the next generation of MAPS scientists by fostering an active MAPS research environment

Objective 5.1.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 5.1.1a: Early Career Mentoring of MAPS junior faculty	Mentor new hires and MAPS junior faculty	Mentor new hires and MAPS junior faculty	Mentor new hires and MAPS junior faculty	Mentor new hires and MAPS junior faculty	Mentor new hires and MAPS junior faculty	Management Team
Activity 5.1.1b: First Awards related to MAPS Research	Award 5 to 7 First Awards	Award 5 to 7 First Awards	Award 5 to 7 First Awards	Award 5 to 7 First Awards	Award 5 to 7 First Awards for a total of 25 – 35 over the five year period	Management Team
Activity 5.1.1c: Research Merit Awards				Award 5 meritorious research awards		Management Team

Objective 5.1.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 5.1.2a: Undergraduate and Graduate Student Travel Awards	Award 4 to 5 Travel Awards	Award 4 to 5 Travel Awards	Award 4 to 5 Travel Awards	Award 4 to 5 Travel Awards	Award 4 to 5 Travel Awards. By the end of year 5, 20 or more students will	Management Team

					receive Travel Awards	
Activity 5.1.2b: Award up to 6 MAPS Research Experiences for Undergraduates.	Provide REUs to up to 6 students (Recruit 1 to 2 HERS students)	Provide REUs to up to 6 students (Recruit 1 to 2 HERS students)	Provide REUs to up to 6 students (Recruit 1 to 2 HERS students)	Provide REUs to up to 6 students (Recruit 1 to 2 HERS students)	By the end of year 5, a total of up to 30 MAPS REU awards will be provided	MAPS Faculty

Goal 5.2 Introduce students, teachers, and Kansas residents to MAPS science through education and outreach initiatives.

- Objective 5.2.1: Create new educational programs for Kansas K-12 students and teachers from diverse backgrounds using MAPS research as a theme
- Objective 5.2.2: Educate Kansas residents by providing MAPS information through the Konza Environmental Education Program (KEEP)

Objective 5.2.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 5.2.1a: Elementary School Students MAPS Discovery	Develop 1-3 third grade MAPS lessons and present to selected third grade classes	Develop 1-3 third grade MAPS lessons and present to selected third grade classes	Develop 1-3 third grade MAPS lessons and present to selected third grade classes	Develop 1-3 third grade MAPS lessons and present to selected third grade classes	By the end of year 5, up to 15 third grade lessons will have been created and presented to third grade classes	Schultz
Activity 5.2.1b: Kansas Ecosystems Summer Institute for Secondary Teachers	Train 8-10 high school teachers in lesson development with MAPS focus	Train 8-10 high school teachers in lesson development with MAPS focus	Train 8-10 high school teachers in lesson development with MAPS focus	Train 8-10 high school teachers in lesson development with MAPS focus	By the end of year 5, up to 50 high school teachers will have received training	Schultz

Objective 5.2.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**

Activity 5.2.2a: Contribute to the KEEP docent and teacher trainings	Create 1 fact sheet and give 2 to 3 talks	Create 1 fact sheet and give 2 to 3 talks	Create 1 fact sheet and give 2 to 3 talks	Create 1 fact sheet and give 2 to 3 talks	By the end of year 5, 5 MAPS related facts sheets will be created and our researchers will have delivered at least 10 talks to KEEP programs.	MAPS Faculty,

Goal 5.3 Use MAPS science to increase the participation of underrepresented groups from diverse backgrounds to STEM fields.

- Objective 5.3.1: Continue to build momentum in a Native American internship held by the Haskell Environmental Research Studies Institute (HERS) program by reaching out to up to 15 Native American students each year
- Objective 5.3.2 Provide funds for undergraduate research through a partnership with Kansas State's Louis Stokes Alliances for Minority Participation Program (LSAMP)

Objective 5.3.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 5.3.1a: Use the HERS institute as a vehicle for holding a summer research program for Native American students	Provide 8 weeks of intensive summer research training to 13-15 tribal college students	Provide 8 weeks of intensive summer research training to 13-15 tribal college students	Provide 8 weeks of intensive summer research training to 13-15 tribal college students	Provide 8 weeks of intensive summer research training to 13-15 tribal college students	By the end of year 5, 50 or more tribal college students are estimated to have experienced a summer research program	Johnson, Marshall
Activity 5.3.1b: Use the HERS Institute to provide professional development to Native American students		Provide graduate application preparation and professional development to HERS alumni	Provide graduate application preparation and professional development to HERS alumni	Provide graduate application preparation and professional development to HERS alumni	Provide graduate application preparation and professional development to HERS alumni	Johnson, Marshall
Activity 5.3.1c: Use the HERS Institute to provide pathways to	Provide GRA funding to 4 Native American	Provide GRA funding to 4 Native American	Provide GRA funding to 4 Native American	Provide GRA funding to 4 Native American	By the end of year 5, up to 20 Native American	Johnson, Marshall

graduate study for Native American students	STEM students (preference to new students) with subsequent funding from home department	STEM students (preference to new students) with subsequent funding from home department	STEM students (preference to new students) with subsequent funding from home department	STEM students (preference to new students) with subsequent funding from home department	STEM graduate students will have received one or more years of GRA funding from MAPS	

Objective 5.3.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 5.3.2a: MAPS partnership with Kansas State Louis Stokes Alliances for Minority Participation Program (LSAMP) provides funds for undergraduates	Provide stipends for up to 3 students for summer research	Provide stipends for up to 3 students for summer research	Provide stipends for up to 3 students for summer research	Provide stipends for up to 3 students for summer research	By the end of year 5, the project will fund a total of up to 15 MAPS summer LSAMP students	Beth Montelone

Outputs:

- 2 new faculty members in MAPS, in needed computational areas
- 1 new faculty position at Haskell in environmental science related to MAPS
- Up to 35 First Awards to new faculty
- 5 faculty recognized for meritorious research in year 4
- 40 or more graduate students presenting posters or talks at scientific meetings
- Up to 15 MAPS elementary lessons aligned with MAPS with teachers appropriately trained for lesson delivery
- Up to 50 high school teachers trained in MAPS elementary school lesson development
- Up to 30 REU presentations and posters
- Up to 15 LSAMP presentations and posters
- Up to 55 HERS STEM presentations and posters
- A web based repository for MAPS lessons to share with teachers across the state

Outcomes:

- Enhanced research capabilities in MAPS as a result of new faculty hires
- Junior faculty achieve enabled to compete more effectively for federal funding as a result of mentoring and First Awards

- 60% of the undergraduates participating in the diversity programs will apply to graduate school
- Elementary and secondary teachers from across the state will increase their capacity to teach MAPS concepts
- Elementary and secondary students will build capacity in MAPS/STEM research and the ecosystems in Kansas
- Undergraduate students will build capacity in critical thinking, reading scientific journals, and conducting research

Project Elements

Thrust 6: Partnerships and Collaborations

Goal 6.1 MAPS will expand its current partnerships and begin new partnerships/collaborations to provide opportunities for commercialization of research and education products and to pave the way for economic development in Kansas.

- Objective 6.1.1: Develop and extend current partnerships with start-ups (e.g. with Mycobloom), governmental organizations (Lawrence and Topeka Elementary Schools) and non-profit organizations (e.g. The Nature Conservancy)
- Objective 6.1.2: Develop new partnerships based on results from research and outreach

Objective 6.1.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 6.1.1a: Review partnerships	Review current partnerships	Annual self-assessment of partnerships	Annual self-assessment of partnerships	Annual self-assessment of partnerships	Annual self-assessment of partnerships	MAPS Faculty
Activity 6.1.1b: Solidify and expand current partnerships with Kansas school districts	Initiate partnerships with Lawrence and Topeka Schools	Expand partnerships, particularly with Lawrence and Topeka Schools	Maintain, enhance and expand as needed	Maintain, enhance and expand as needed	Maintain, enhance and expand as needed	MAPS Faculty, Schultz, Blum

Objective 6.1.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 6.1.2a: Develop new partnerships from results of research	Establish guidelines for commercial applications	Assess opportunities	Assess opportunities and solicit cooperative agreements	Assess opportunities and solicit cooperative agreements	Assess opportunities and solicit cooperative agreements	MAPS Faculty

Activity 6.1.2b:: Develop new partnerships with environmental offices of the four federally funded-recognized tribes in Kansas*	Initiate partnerships	Maintain, enhance and expand partnerships as needed	Maintain, enhance and expand partnerships as needed	Maintain, enhance and expand partnerships as needed	Maintain, enhance and expand partnerships as needed	Johnson, Marshall
Activity 6.1.2c: Develop new partnerships with Kansas High School teachers from results of outreach	Initiate partnerships with high schools across Kansas	Expand partnerships, with state high schools	Maintain, enhance and expand partnerships as needed	Maintain, enhance and expand partnerships as needed	Maintain, enhance and expand partnerships as needed	MAPS Faculty, Schultz, Blum

* Kansas Kickapoo Tribe, Prairie Band Potawatomi Nation, Sac and Fox Tribe of Missouri in Kansas, Iowa Tribe of Kansas and Nebraska

Thrust 7: Communication and Dissemination Plan

Goal 7.1 Reach a broad audience of researchers, educators, students, stakeholders and the general public via various platforms to promote MAPS research and education activities.

- Objective 7.1.1: Disseminate scientific results of MAPS research to a diverse professional network
- Objective 7.1.2: Integrate MAPS research into K-12 education curricula
- Objective 7.1.3: Demonstrate MAPS research and impacts to the general public through museum exhibits
- Objective 7.1.4: Present results and impacts of project activities at annual Statewide Meeting
- Objective 7.1.5: Maintain broad public outreach and communication through social media

Objective 7.1.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 7.1.1a: Publications in scientific journals	Produce project review as part of graduate course	Publish preliminary work	Individual group publications produced	Group publications continue, synthesis publications begin	Group publications continue, synthesis publications begin	MAPS Faculty

Activity 7.1.1b: Research presentations including talks and posters at professional meetings and invited seminars	Research presentations at research universities, PUIs, and to Kansas stakeholders by each researcher	10% increase in number of presentations at the three venues each year	10% increase in number of presentations at the three venues each year	10% increase in number of presentations at the three venues each year	10% increase in number of presentations at the three venues each year	MAPS Faculty
Activity 7.1.1c: Make database available	Create database	Make available to project participants	Continue to build database	Continue to build database	By end of project make data publicly available, consider data publication	MAPS Faculty

Objective 7.1.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 7.1.2a: Consult with State of Kansas science consultant	Meet in Fall	Meet in Fall	Meet in Fall	Meet in Fall	Meet in Fall	Schultz, Blum
Activity 7.1.2b: Find or create a state wide repository for teachers to share MAPS lessons taught in the elementary and high school classrooms	Find/Create a site to share with KS teachers and post 3 to 5 lessons	Post 3 to 5 lessons	Post 3 to 5 lessons	Post 3 to 5 lessons	By the end of yr. 5, 20 lessons will be posted	Schultz, Blum

Objective 7.1.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 7.1.3a: Disseminate request for Museum Project Proposals	Release RFP Fall 2017	Release RFP Fall	Release RFP Fall	Release RFP Fall	Release RFP Fall	KNE office

Activity 7.1.3b: Review and Make Awards	Spring, Summer	Spring, Summer	Spring, Summer	Spring, Summer	Spring, Summer	Management Team

Objective 7.1.4	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 7.1.4a: Plan and hold annual Statewide Meetings		Plan meeting in the Fall. Hold meeting in the Spring.	Plan meeting in the Fall. Hold meeting in the Spring.	Plan meeting in the Fall. Hold meeting in the Spring.	Plan meeting in the Fall. Hold meeting in the Spring.	Management Team

Objective 7.1.5	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 7.1.5a: Utilize YouTube as a way of disseminating MAPS activities and impacts		Develop 1 video based on NSF highlight	Develop 2 videos based on NSF highlight	Develop 2 videos based on NSF highlight	Develop 2 videos based on NSF highlight	Blum, Management Team
Activity 7.1.5b: Utilize Twitter, Facebook and KNE blog to disseminate MAPS activities, impacts and opportunities	Announce RFPs for First Awards, Museum, Travel Awards; Disseminate MAPS news	Announce RFPs for First Awards, Museum, Travel Awards; Disseminate MAPS news	Announce RFPs for First Awards, Museum, Travel Awards; Disseminate MAPS news	Announce RFPs for First Awards, Museum, Travel Awards; Disseminate MAPS news	Announce RFPs for First Awards, Museum, Travel Awards; Disseminate MAPS news	Blum, KNE office

Thrust 8: Sustainability Plan

Goal 8.1 Use this new multi-institutional, multi-disciplinary project to leverage the research capacity in Kansas through strategic investments of personnel plus new research infrastructure and education initiatives.

- Objective 8.1.1: Hire three new faculty members in the area of MAPS
- Objective 8.1.2: Submit proposals for extramural funding
- Objective 8.1.3: Provide small grants that allow for networking/ planning pursuit of larger projects

Objective 8.1.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 8.1.1a: New hires at KU, KSU, WSU, and HINU	Searches in the Fall; make offer in the Spring	New faculty members hired and begin appointment				MAPS Faculty

Objective 8.1.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 8.1.2a: Submit research proposals based on EPSCoR-funded MAPS research	Preliminary data gathered for proposals	Submission of single investigator and collaborative proposals based on MAPS research	Continued proposal submission with increased numbers of collaborative proposals	Continued proposal submission with increased numbers of collaborative proposals	Continued proposal submission including major center-like collaborative proposal	MAPS Faculty

Objective 8.1.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 8.1.3a: Make Research and Education Innovation (REI) Awards	Release RFP for REI Awards in the Fall; Make up to 4 awards	Release RFP for REI Awards in the Fall; Make up to 4 awards	Release RFP for REI Awards in the Fall; Make up to 4 awards	Release RFP for REI Awards in the Fall; Make up to 4 awards	Release RFP for REI Awards in the Fall; Make up to 4 awards	KNE office, Management Team

Thrust 9: Project Management

Goal 9.1 Manage Research and Education Components of MAPS

- Objective 9.1.1: Hire project personnel
- Objective 9.1.2: Purchase infrastructure
- Objective 9.1.3: Organize overall project structure and agree on project expectations

Objective 9.1.1	Specific Milestones					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 9.1.1a: Hire administrative assistance	Hire completed					Dodds
Activity 9.1.1b: Hire Graduate Students/ technicians	Determine if graduate students or technicians are more effective for specific tasks, hire	Hires completed	Hires completed			MAPS Faculty
Activity 9.1.1c: Hire information assistant	Hire					Sikes
Activity 9.1.1d: Hire KU faculty member	Initiate search	Hire completed				Bever
Activity 9.1.1e: Hire KSU faculty member	Initiate search	Hire completed				Dodds, Jumpponen
Activity 9.1.1f: Hire undergraduate help	Determine how sampling requirements match hiring requirements	Hire as needed	Hire as needed	Hire as needed	Hire as needed	MAPS Faculty

Objective 9.1.2	Specific Milestones					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**

Activity 9.1.2a: Purchase mass spectrometer	Purchase completed					Nippert
Activity 9.1.2b: Purchase field vehicle	Purchase completed					Zeglin
Activity 9.1.2c: Purchase computational and data storage needs	Purchase completed					Sikes, Jumpponen

Objective 9.1.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 9.1.3a: Create publication agreement, data sharing agreement, project participation document	Whole project face-to-face meeting, follow up committee meetings, finalize agreements	Revisit agreements at annual science meeting	Revisit agreements at annual science meeting	Revisit agreements at annual science meeting	Revisit agreements at annual science meeting	MAPS Faculty
Activity 9.1.3b: Determine dataset structure	Create database structure, start metadata document	Refine database structure	Refine database structure	Refine database structure	Refine database structure, finalize public sharing of database	MAPS Faculty, Database Committee
Activity 9.1.3c: Assess re-alignment of project resources based on results and participant progress from participation document	Obtain agreement on document produced under activity 9.1.3a	Assess prior to end of current year's funding, realign as needed	Assess prior to end of current year's funding, realign as needed	Assess prior to end of current year's funding, realign as needed		Billings, Bever, Dodds, Rice
Activity 9.1.3d: Site selection	Workshop whole group, group leaders visit potential sites	Re-evaluate based on results from preliminary sampling	Adjust if prior results require	Adjust if prior results require		MAPS Faculty

Activity 9.1.3e: Develop coordinated sampling and sample storage strategy	Workshop whole group, group leaders communicate specific needs, create methods manual	Re-evaluate based on results from preliminary sampling	Adjust if prior results require	Adjust if prior results require		MAPS Faculty

Goal 9.2 Oversee and guide the project in a way that supports research and education, builds collaborative relationships, strengthens institutional research infrastructure, and develops the leadership skills.

- Objective 9.2.1: Create an efficient and effective environment for management coordination and communication
- Objective 9.2.2: Engage the EPSCoR Steering Committee
- Objective 9.2.3: Plan for PD succession

Objective 9.2.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 9.2.1a: Management Team meetings	Establish roles and charges at start of project; Meet monthly via video-conference	Meet monthly via video-conference	Meet monthly via video-conference	Meet monthly via video-conference	Meet monthly via video-conference	Management Team

Objective 9.2.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 9.2.2a: Steering Committee	Reorganize makeup of the committee	Convene at annual Statewide Meeting in the Fall	Convene at annual Statewide Meeting in the Fall	Convene at annual Statewide Meeting in the Fall	Convene at annual Statewide Meeting in the Fall	Bowman-James, KBOR

Objective 9.2.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**

Activity 9.2.3a: Identify qualified candidates		Co-Director appointed				Bowman-James, VC Research KU

Thrust 10: Evaluation and Assessment Plan

Goal 10. Integrate formative and summative evaluation and assessment components to form a feedback system that assists KNE to successfully attain the full range of proposed goals and objectives set out in the MAPS project.

- Objective 10.1.1: Develop and implement a performance tracking process designed around NSF annual report metrics and external evaluation needs
- Objective 10.1.2: Obtain technical review and guidance of the MAPS scientific and educational activities by the SEAC
- Objective 10.1.3: Implement a mixed-method evaluation methodology to provide feedback to KNE about performance and progress

Objective 10.1.1	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 10.1.1a: Evaluate needs and select product for database	Pre award evaluation, Set up by Spring					Byers
Activity 10.1.1b: Implement online database for online reporting	Implement new system by mid-year; prepare and submit annual report in the Spring	Prepare and submit annual report in the Spring	Prepare and submit annual report in the Spring	Prepare and submit annual report in the Spring	Prepare and submit annual report in the Spring	Byers; Management Team

Objective 10.1.2	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 10.1.2a: Project review by Science and Education Advisory Committee (SEAC)	Charge SEAC with review of research and education projects	Convene at annual Statewide Meeting in the Spring; Follow	Convene at annual Statewide Meeting in the Spring; Follow	Convene at annual Statewide Meeting in the Spring; Follow	Convene at annual Statewide Meeting in the Spring; Follow	Management Team

		with written response	with written response	with written response	with written response	

Objective 10.1.3	**Specific Milestones**					
	Year 1- 2018	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible party**
Activity 10.1.3a: Annual assessment of overall project performance	Initial planning & evaluation development; baseline survey; report	Year-round review; case analysis; surveys; 1-2 site visits; annual report	Year-round review; case analysis; surveys; 1-2 site visits; annual report	Year-round review; case analysis; surveys; 1-2 site visits; annual report	Year-round review; case analysis; surveys; 1-2 site visits; annual report	Welch, Maynard- Moody
Activity 10.1.3b: Communication and interaction with KNE Office; attendance of MT meetings	MT meeting attendance; regular/as-needed comm. with PI	MT meeting attendance; regular/as-needed comm. with PI	MT meeting attendance; regular/as-needed comm. with PI	MT meeting attendance; regular/as-needed comm. with PI	MT meeting attendance; regular/as-needed comm. with PI	Welch, Maynard- Moody
Activity 10.1.3c: Feedback loop	Management team report review/action	Management team report review/action	Management team report review/action	Management team report review/action	Management team report review/action	Welch, Maynard- Moody

Risk Management Plan

MAPS Risk Catalog					
	Risk Likelihood & Risk Impact	**High**	**Medium**	**Low**	
	Immediacy of Impact	**Immediate <1 yr**	**Mid-Term 2-3 yrs**	**Distant 4 yrs**	
No.	**Risk**	**Risk Likelihood**	**Risk Impact**	**Immediacy of Impact**	***Major Actions or Mitigation Activity for high likelihood risks***
Risk Category: Research Effectiveness or quality of science					
1	Difficulty of hiring bioinformatics faculty				*We have already started search process so could conduct a second search in following year if needed.*
2	Extreme weather				*Take advantage of novel conditions to gain insights into key times of largest impact on systems and continue to sample existing sites.*
3	Insufficient data to allow inclusion of aquatic system into integrative statistical and mathematical models				*Communication across all research thrusts focused on identification of field sites that allow for aquatic integration without sacrificing the statistical power for terrestrial objectives. In addition, if necessary we can employ a flexible sampling strategy shifting effort toward sites with aquatic systems and develop alternate hypotheses.*
4	Project failure due to inadequate planning and integration across microbiomes				*We need constant reflection on the adequacy of the planning procedures.*
5	Difficulty with cross-disciplinary communication				*Alleviate communication deficiencies with frequent meetings and communication.*

6	Loss of sites due to extreme events or vandalism				*Reallocate funds to replace equipment and find new sampling sites or resume sampling at the same place.*
7	Incorporation of inaccurate assumptions when structuring models				*Open and frequent communication with and involvement of researchers with a wide range of expertise.*
8	Available data may result in parameter estimates with a high degree of uncertainty				*Depend on computational tools (e.g. Monte Carlo sampling methods) to allow simulation and sensitivity analysis despite uncertain parameter estimates.*
9	Loss of research leaders to other institutions				*Use grant to argue for keeping strengths in faculty members, create productive collaboration that existing faculty members are invested. We have a degree of redundancy (we have 2 key leaders in each major group).*
Risk Category: Aquatic					
10	Site selection is inadequate for our needs and supports the statistical power needed for plant/soil experimental design				*Initiate frequent communication within and across thrust areas.*
11	Terrestrial sampling does not inform aquatic results				*Communication across all research thrusts focused on identification of field sites that allow for aquatic integration without sacrificing the statistical power for terrestrial objectives. In addition, if necessary we can employ a flexible sampling strategy shifting effort toward sites with aquatic systems and develop alternate hypotheses.*
12	Extreme weather events (e.g., droughts) may necessitate changing our sampling locations to find areas that contain water				*Develop flexible sampling strategies that allow us to cover a range of conditions and still test our hypotheses.*
13	Mescosm work may fail, need to be redone, or we may not have bloom states				*Pilot experiments to grow algae in case we can't collect from natural sources. Experiments will run*

	in target reservoirs during the years we need to do the experiments				*at smaller scales to test method feasibility before moving to the larger mesocosm experiment.*
Risk Category: Plants					
14	Microcosms fail to represent ecosystem function				*Repeat experiments after analyzing probable reasons the mesocosm experiments do not represent ecosystem function correctly. Also, such experiments can be informative even if they do not represent the exact ecosystem they are intended to mimic, so still can generally be published.*
15	Limited power to test hypotheses				*Power comes from sampling sites with independent land-use and rainfall combinations. Inclusion of additional sites beyond the core sites will increase power. High dimensionality of metagenomic data can be collapsed into major axes of variation prior to analysis.*
16	Many potential candidate microbial drivers will limit our ability to test causal mechanisms				*High redundancies of microbial mechanisms may allow us to draw conclusions on mechanisms without testing all candidates. Microbial mechanisms that we do isolate are candidates for future microbiome applications.*
Risk Category: Soil					
17	Inadequate resources for sampling design				*Need to carefully plan sampling design and prioritize for greatest impact.*
18	Lack of control for variation in soils				*Need to ensure adequate soil characterization and use that as variables.*
19	Deep soil sampling can present surprises that limit ability to sample in the least destructive way				*Adjusting sampling location to alleviate challenges. Use more invasive approaches (e.g. soil pits instead of auger). Adequate characterization of sampling locations can minimize impact. Unexpected variation can be leveraged for future research.*

20	Low precipitation rates limit soil moisture available for sampling				*Collect samples as soon after rain events as possible, leveraging local technical help. Rely on sensor arrays to develop an understanding of moisture dynamics prior to, during, and after rain events and use this information to refine sampling timing.*
Risk Category: Workforce Development					
21	Summer REU programs may not be renewed				*Explore leveraging other REU programs in related fields or funding undergraduates on an individual basis.*
22	Faculty fail to volunteer to participate in the proposed workforce, education, and diversity programs				*Make funding of faculty research contingent on participation in these activities.*
23	Federal funding issues at Haskell may cause faculty furloughs, the closing of facilities, or loss of faculty				*Have alternative plans for KU faculty and staff to take over Haskell MAPS tasks including HERS. Have alternative plans for holding the program at KU if Haskell facilities are not available.*
24	Difficulties in recruiting students in the microbiome area and specifically students from under-represented groups				*Proactively recruit students at AISES, SACNAS and by reaching out to tribal college science faculty.*
25	Difficulties finding schools willing to participate.				*Expand search for partners beyond local and major city school districts.*

Baseline Data:

OUTPUTS

Category	9/1/14-8/31/15		9/1/15-8/31/16		9/1/16-8/31/17		Cumulative Total for Prior 3 Years	
Patents								
Awarded	0		0		0		0	
Pending	0		0		1		1	
Licensed	0		0		0		0	
Proposals / Grants / Contracts	***Number***	***Funds***	***Number***	***Funds***	***Number***	***Funds***	***Number***	***Funds***
Submitted	23	$17,626,744	18	$ 5,895,643	22	$13,855,812	63	$ 37,378,199
Awarded	16	$12,262,337	7	$ 791,655	8	$ 2,470,767	31	$ 15,524,759
Pending	[redacted]				2	$ 3,045,266	2	$ 3,045,266
Published Publications	28		35		37		100	

Administration and Management Structure

The composition and duties of each of the committees and teams are provided in Table 1. The reporting network of the Administration and Management structure is provided in Scheme 1.

Scheme 1. Administration and Management Structure

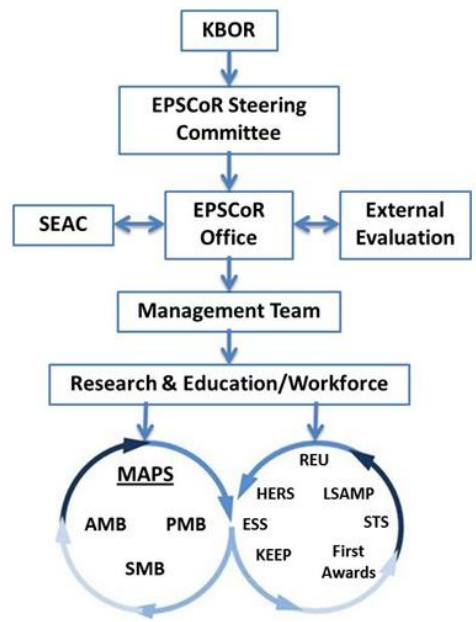

Table A. Committees and Assignments

Kansas Board of Regents (KBOR)

- Provide statewide S&T leadership
- Provide fiscal management of state EPSCoR funds
- Provide 50% of required matching funds
- Appoint members to the EPSCoR Steering Committee

EPSCoR Steering Committee

- Comprised of business managers, CEOs, academic administrators, Kansas government officials
- Provide oversight to research topics selected for Track-1 proposals
- Assess and manage state R&D and EPSCoR priorities

Kansas NSF EPSCoR Office: Bowman-James, Byers, Blum, and Wilbur

- Provide program management
- Oversee external relations
- Insure compliance and accountability
- Report to NSF and EPSCoR Steering Committee

Management Team: Bowman-James, Byers, Blum, Dodds (KSU), Rice (KSU), Billings (KU), Bever (KU), Johnson (KU), Maynard-Moody (KU)

- Coordinate major initiative (MAPS)
- Implement strategic plan research goals
- Monitor progress toward milestones
- Adjust strategies based on internal and external evaluation
- Provide input to annual and final reports

Science and Education Advisory Committees (SEAC)

- Comprised of noted educators and researchers in microbiome science
- Review 5-year strategic plan annually
- Review project annually
- Report yearly to KNE

External Evaluation: Welch (Arizona State University)

- Create comprehensive evaluation plan
- Assess the progress of Kansas NSF EPSCoR toward its overall goals
- Provide feedback to Management Team

Table B. Project Participants, Affiliations, and Roles (*recent hires)

Project Leaders	Title	Affiliation	Expertise	Roles
Kristin Bowman-James	University Dist. Prof.	KU	Project Director	PI
Walter Dodds	University Dist. Prof.	KSU	Water quality, aquatic ecology	Co-PI, AMB
James Bever*	Foundation Dist. Prof.	KU	Plant-microbe evolutionary ecology	Co-PI, PMB
Sharon Billings	Professor	KU	Ecosystem ecology, biogeochemistry	Co-PI, SMB
Charles Rice	University Dist. Prof.	KSU	Soil microbial ecology	Co-PI, SMB
Group Leaders	**Title**	**Affiliation**	**Expertise**	**Roles**
Terry Loecke*	Assistant Professor	KU	Plant soil microbe interactions	SMB
Ben Sikes*	Assistant Professor	KU	Microbial community ecology	PMB
Amy Burgin*	Associate Professor	KU	Aquatic biogeochemistry	AMB
Ari Jumpponen	Professor	KSU	Fungal ecology	PMB
Lydia Zeglin*	Assistant Professor	KSU	Soil and water microbial ecology	AMB
Matthew Kirk*	Assistant Professor	KSU	Subsurface biogeochemistry	SMB
Research Team	**Title**	**Affiliation**	**Expertise**	**Roles**
Belinda Sturm	Associate Professor	KU	Wastewater microbial ecology	AMB
Dan Reuman*	Associate Professor	KU	Theoretical ecology	PMB
Fola Agusto*	Assistant Professor	KU	Epidemiology	PMB
Greg Houseman	Associate Professor	WSU	Plant community ecology	PMB
Helen Alexander	Professor	KU	Plant Ecology	PMB
Jen Roberts	Associate Professor	KU	Microbial geochemistry	SMB
Jesse Nippert	Associate Professor	KSU	Plant physiology water relations	PMB
Mitch Greer*	Assistant Professor	FHSU	Grassland ecology	SMP
Pamela Sullivan*	Assistant Professor	KU	Ecohydrology, hydrogeochemistry	S/AMB
Sanzhen Liu*	Assistant Professor	KSU	Pathology and microbial genomics	PMB
Thomas Platt*	Assistant Professor	KSU	Microbial ecology/ disease ecology	PMB
New Faculty Hire	Assistant Professor	KSU	Environmental metagenomics	P/S/AMB
New Faculty Hire	Assistant Professor	KU	Environmental metagenomics	P/S/AMB
New Faculty Hire	Assistant Professor	KU	Aquatic ecolog	AMB
Education Team	**Title**	**Affiliation**	**Expertise**	**Roles**
Peggy Schultz*	Associate Specialist	KU	Soil microbial ecology, Edu. liaison	PMB
Jay Johnson	Associate Professor	KU	Environmental sci., HINU liaison	HERS
Joseph Brewer*	Assistant Professor	KU	Environmental sci., HINU liaison	HERS
Cody Marshall*	Interim Faculty	HINU	Indigenous/Amer. Indian, HINU liaison	HERS
New Faculty Hire	Professor	HINU	Environmental science	HERS

SWOT Analysis

Thrust 1. Aquatic Microbiomes

Strengths

- We have expertise across the scales of watershed modelling to biogeochemical processes to microbial genome sequencing. This will be critical in helping us interpret our findings at an integrated level.
- Our mesocosm experiment draws on existing infrastructure (tanks) at the KU Field Station. Drs. Burgin and Sturm both have experience working at this facility, including running mesocosm experiments with algae using wastewater effluent hauled from a municipal wastewater treatment plant, current preliminary protocol development to move water from reservoirs to the tanks, and culturing and growing cyanobacteria in the tanks.
- Our landscape microbiome movement/functional work draws on previous research conducted on lotic network level movement and processing of dissolved nitrogen (Dodds, Zeglin) and under dynamic hydrological conditions (Burgin) using synoptic sampling approaches. Zeglin has conducted synoptic sampling and linked microbiome/biogeochemistry research in arid watersheds (New Mexico/Arizona).
- A subgroup of us, including the team leads at KSU and KU, have collaborated in the past and co-authored publications in the area of research proposed here.

Weaknesses

- Our group has the smallest number of people of the three domains (plant, soil, water), but will generate similar numbers of samples as the plant and soil domains. Thus, we will have a higher workload per person in our section. As funding is finite, we will have to balance personnel costs with our objectives and statistical power.
- While decoupling land use history from the east west gradient is relatively straightforward on the terrestrially focused work, it is more challenging for aquatic systems as streams and reservoirs often integrate multiple terrestrial land-uses.
- We do not have an aquatic ecologist on the project who is currently working in western field sites.
- Many of the plant and soil domain investigators have never worked at the watershed scale before, so we will also need to learn the approaches typical of all domains in order to fully integrate our project.

Opportunities

- While we don't have an aquatic investigator on the project who currently works in the western part of the state, we do have contacts at the drier side of the aridity gradient, and this work will provide the impetus to establish active relationships with these colleagues. We anticipate recruiting aquatic ecologists into our project via the EPSCOR first awards.
- We are working Kansas Applied Remote Sensing personnel at the Kansas Biological Survey to estimate the land-use coverage for all candidate reservoirs along the east west gradient.
- Both KU and KSU have active sequencing facilities, including the Genome Sequencing Core and Center for Metagenomics Microbial Community Analysis at KU, and the Integrated Genomics Facility at KSU, with which we have already established high throughput sequencing protocols on soil and water samples, spanning archaea, fungi, and bacteria. These reliable data sources will anchor the growth of technical expertise at KU.

- The USGS office in Lawrence, Kansas has an extensive network of water quality sensors that they've used to build statistical models of concurrent transport of nutrients and potentially harmful bacteria and algae. We can work with their staff to ensure that our work can add value and extend this infrastructure, particularly by evaluating whether parameters they've documented promote blooms in lotic environments (our mesocosm experiments). There are many potential collaborative projects that could arise from better coordination with USGS.
- Because intensive soil sampling will be conducted at defined locations in our study landscape, we will have ample data for definition of endmember "terrestrial" microbiome characteristics.

Threats

- We need to coordinate sampling site selection and timing of sampling carefully with terrestrial arm of the MAPS team to maximize scientific value of the project.
- We need to balance statistical power with the budget and time constraints of the investigators doing the work. Likewise, high-throughput sequencing work and data analysis for the team will need to be supported outside of the graduate student model.
- We cannot control the weather, and sampling must be selective, so planned sampling excursions may not capture the full range of hydrological conditions characteristic of our study area.
- Troubleshooting of protocols and maintenance of sensors will be necessary but unpredictable, with some impact on project cost and efficiency.

Thrust 2. Plant Microbiomes

Strengths

- Proposed research takes advantage of sites with native and agricultural land cover across the steep precipitation gradient, a prominent natural feature of Kansas. The bioinformatics hires will greatly strengthen the metagenomic components of the research plan.
- Integration of agricultural, old-field, and native prairie sites is likely to ground the proposed work in application. We anticipate that research findings could be leveraged to improve crop yields and restoration efforts by integrating microbial contributions to the management and conservation of one of the most threatened ecosystems.
- The proposed plant microbiome experiments provide an ideal platform to dissect the impact of microbial communities on ecosystem function. The combination of the observational data and manipulative experiments permits analyses of the environmental drivers shaping microbial communities and their functional consequences.
- Faculty focused on the plant component of microbiomes span researchers at all participating institutions (e.g. KU, KSU, WSU, FHSU, & HINU) thus providing a strong foundation for inter-institutional collaboration.

Weaknesses

- The scattershot approach to use of metagenomics and metatransciptomics is relatively narrow and likely to be undersampled. Metatranscriptomics provides perhaps the best direct link between microbiome changes and ecosystem functions (e.g. pathogenicity). Because of the lack of expertise, cost, and sheer number of samples, it is currently narrowly focused and could be more broadly integrated in the proposed work.
- Our plant virologist has been poached which will limit our ability to explicitly analyze the effects of viruses on plant productivity.

- A major challenge in our research is the integration of the many dimensions represented within the microbiome sequence analysis into the structural equation models. The inoculation approach to assaying the effect of microbiome on plant productivity and ecosystem functions may not be effective in introducing all relevant microbes. These are both real constraints imposed by methodological limitations.
- In our mesocosm approach to assaying terrestrial ecosystem function, the plant species included within these studies may not be representative of all the plants in the community. While unplowed prairie will include long-lived plants and there may not be a lot of turnover. But in the successional communities and the agricultural system, there may be changes over time. Any changes in plant community will be measured so that we can statistically parse the plant composition contribution to ecosystem function metrics.

Opportunities

- The proposed research effort provides means to establish new collaborations among junior and senior faculty across multiple institutions within the state. The proposed links across disparate research programs and sites is likely to spur novel research, capitalizing on the collaborations among faculty established in the course of the proposed plan. Junior faculty in particular can take advantage of built in EPSCoR First Awards to rapidly get these inter-institutional ideas off the ground. The research platforms and the field survey provide a confirmed and guaranteed access to the best research facilities in the state with distinct edaphic and climatic attributes.
- The EPSCOR first awards may be used to integrate other instate plant virologists and attract new microbiologists into the project.
- Collaboration and access to this critical mass of personal and sites within the state is likely to increase competitiveness for any available state funding or research needs (i.e. getting on the radar). This may be particularly important for junior faculty.
- Establishing regional strength in metagenomics that is focused on precipitation, disease, and system resilience can make Kansas institutions go-to responders as climate increases precipitation variability within the entire region. Apart from the Kansas rainfall gradient applicability to the region, shifting precipitation predictions through 2050 (NOAA) show a deepening gradient with some regions getting wetter (NE KS) while other areas get drier (SW KS) potentially allowing for predictive capacity across the region.
- Proposed human infrastructure additions substantially contribute to the research capacity across the participating institutions. Reviewers correctly point out that information management and data manipulation are an ever-growing challenge. Additional hires proposed here permit better tackling of those challenges.

Threats

- Stagnant and/or declining state investments to research present a substantial challenge, particularly to the junior faculty working towards establishing successful research programs.
- Deviations from normal by extreme weather conditions can disconnect plants and their associated microbiomes that may have specifically adapted to the prevailing conditions thus disrupting productivity in natural and agricultural systems. We integrate across disciplines and research programs to make use of a novel and ambitious research platform that permits dissection and decoupling these connections.
- Rapid shifts in the use of specific agricultural genotypes and common agricultural practices (e.g. widespread glyphosate, no till) may have significant impacts on microbiomes that are distinct and belie clear predictability based on precipitation alone.

- Limited availability of publicly available prairie sites may inhibit inferences and application of prairie microbiome knowledge to other land uses, and clear linkages with soil and aquatic microbiomes (e.g. finding entire prairie watersheds that are available for research).

Thrust 3. Soil Microbiomes

Strengths

- The Kansas aridity gradient, coupled with control on land use based on careful site selection, will allow this project to develop an unprecedented understanding of the response of the soil microbiome to changes in precipitation and land management and feedbacks on that response for water quality, carbon emissions, and food production.
- We will significantly advance our understanding of interactions of the soil microbiome with associated plant and aquatic microbiomes.

Weaknesses

- Low rates of precipitation may limit opportunities to collect water samples from soil monitoring arrays. Greater reliance on sensor data can help us accommodate this possibility.
- Differences in soil thickness may make it difficult to define uniform sampling depths between sites.
- Variation in the composition of underlying bedrock at each site can contribute to variation in soil mineralogy.

Opportunities

- The network of soil monitoring arrays created by this project will stimulate growth new research directions and collaborations.
- New collaborations among researchers interested in soil will strengthen soil research and our ability to develop best-practices for soil management in a state that depends heavily on agricultural productivity.

Threats

- Our sampling plan may be overly ambitious relative to the scope of research funding. In refining our sampling plan, we need to balance the need for statistical power with the resources and time we have available to ensure successful completion of project goals.

Thrust 4. Integration of Aquatic, Plant and Soil Microbiome Science

Strengths

- We have strong faculty with complementary research on terrestrial and aquatic ecology and microbiology, which makes this project possible.
- Our proposed research capitalizes on the Kansas precipitation gradient, a prominent natural feature of our state.
- This precipitation gradient provides a focus that unites our cross-habitat sampling into functional questions on terrestrial productivity and linkages to water quality.

Weaknesses

- While KSU and KU have individuals with expertise in informatics, this area remains a major challenge to the analysis of environmental sequence data, particularly in light of how rapidly sequencing and data analysis methods are changing.
- We are counting on “standard” weather patterns in the first several years of sampling.

- While we have built positive relationships during the proposal writing, we don't have many long-standing collaborations bridging the institutions conducting this research.
- Availability of locations where terrestrial and aquatic microbiomes can be linked within a watershed may be limited across our precipitation and disturbance gradient.
- Our sampling regime is ambitious, creating a tremendous workload.

Opportunities

- We have plans to hire additional faculty in informatics at both KU and KSU, which should alleviate our informatics need.
- New directions can be integrated into our research as additional faculty members are brought into our project through the EPSCOR junior faculty First Awards program.
- Environmental extremes could generate new perspectives on resilience of plant, soil and aquatic microbiome functions.
- Funding incentives encourage interinstitutional and interdisciplinary collaborations. This can generate new initiatives and novel research directions.

Threats

- Low research investment within our state makes our faculty vulnerable for poaching. We lost our KSU virologist to a competing offer from North Carolina.
- Extreme weather could disrupt normal linkages among plant, soil and aquatic microbiomes.
- We have to overcome our sub-disciplinary and institutional silos to maximize value of project integration.

Thrust 5. Workforce Development, Education, and Diversity

Strengths

- There are First Award funding opportunities for Early Career Faculty and professional development assistance through mentoring by established faculty.
- REU's and LSAMP are established, successful programs.
- Many of the MAPS faculty members have already been involved with the summer REU programs at KU and KSU.
- Similar K-12 programs run by Dr. Schultz in Indiana have been tested and have been successful.
- The HERS program has a six year track record of success. Over 55% of alumni are currently in graduate programs or have already completed graduate degrees.

Opportunities

- The First Awards provide assistance to Early Career Faculty in getting equipment and setting up labs.
- The travel awards provide support for students travel so they can present their research and/or attend professional meetings.
- Kansas students have the opportunity to perform research within their own environment.
- K-12 programs can benefit from faculty expertise and acquire science materials to assist with the development of exciting educational activities and research at elementary and high schools across Kansas.
- The HERS program can be replicated by other tribal college-research university collaborations to increase the number of Native Americans successfully completing STEM graduate degrees.

Weaknesses

- There are no summer REU programs at WSU or FHSU.

- The Summer REU and LSAMP programs are driven by student choice of project, so maybe some REU/LSAMP projects offered by our researchers may not be selected by the student applicants.

Threats

- Summer REU programs may not be renewed. The renewal proposal for the REU program at KSU is pending. The KU program is in its last year and will need to write a renewal to continue the program.
- Faculty members may fail to participate in the proposed programs (Mentoring, Summer REUs, LSAMP, Teacher Workshops, Docent trainings and Fact Sheet creation).
- Federal funding issues at Haskell may cause faculty furloughs, the closing of facilities, or loss of faculty.
- Experiencing difficulties with recruitment may be a threat.
- Local school districts might be hesitant to be included in our elementary school outreach effort.

Glossary of Abbreviations and Acronyms

Ag	Agricultural
AISES	American Indian Science and Engineering Society
AM	Aquatic Mesocosm
AMB	Aquatic Microbiome
C	Carbon
CO_2	Carbon dioxide
CUAHSI	Consortium of Universities for the Advancement of Hydrologic Science, Inc.
DM	Dynamic model
DNA	Deoxyribonucleic acid
DV	Diversity
e.g.	exempli gratia - “for example”
EOD	Education, Outreach and Diversity
EPSCoR	Established Program to Stimulate Competitive Research
ESS	Elementary School Students
FHSU	Fort Hays State University
GHG	Greenhouse gas
GIS	Geographic Information System
GRA	Graduate research assistant
HERS	Haskell Environmental Research Studies
HINU	Haskell Indian Nations University
HS	High school
Hydrus-D	A solute model for water flow in soil
INCLUDES	Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science
K-12	Kindergarten through 12^{th} grade
KARS	Kansas Applied Remote Sensing
KBOR	Kansas Board of Regents
KBS	Kansas Biological Survey
KEEP	Konza Environmental Education Program
KNE	Kansas NSF EPSCoR
KS	Kansas
KSU	Kansas State University
KU	University of Kansas
LSAMP	Louis Stokes Alliance for Minority Participation
MAPS	Microbiomes of Aquatic, Plant, and Soil (Systems)
N	Nitrogen
N_2O	Nitrous oxide
nosZ	Nitrous oxide reductase
NRT	NSF Research Traineeship
NSF	National Science Foundation
OIA	Office of Integrative Activities
P	Phosphorus

PD	Project Director
PI	Principal Investigator
PMB	Plant Microbiome
R&D	Research and Development
REI	Research and Education Innovation (Awards)
REU	Research Experiences for Undergraduates
RFP	Request for Proposals
rhizo-phyllo	Rhizosphere-phyllosphere
RII	Research Infrastructure Improvement
rRNA	Ribosomal ribonucleic acid
RTM	Reactive transport model
S&T	Science and Technology
SACNAS	Society for Advancement of Chicanos/Hispanics and Native Americans in Science
SEAC	Science and Education Advisory Committee
SMB	Soil Microbiome
SOC	Soil organic carbon
STEM	Science, Technology, Engineering, and Mathematics
STS	Secondary Teachers and Students
SWOT	Strengths, Weaknesses, Opportunities, Threats
TCUP	Tribal Colleges and Universities Program
USGS	United States Geological Survey
WFD	Workforce development
WSU	Wichita State University