COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
NSF 17-593 **03/02/18**

☐ Special Exception to Deadline Date Policy

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NSF PROPOSAL NUMBER

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)
DEB - Long-Term Ecological Research

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				555917996	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
416007513

SHOW PREVIOUS AWARD NO. IF THIS IS
☒ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL
1234162

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
University of Minnesota-Twin Cities

AWARDEE ORGANIZATION CODE (IF KNOWN)
0023879000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
200 OAK ST SE
Minneapolis, MN 55455-2070

NAME OF PRIMARY PLACE OF PERF
Cedar Creek Ecosystem Science Reserve

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
Cedar Creek Ecosystem Science Reserve
2660 Fawn Lake Drive
East Bethel ,MN ,550059718 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply)
☐ SMALL BUSINESS
☐ FOR-PROFIT ORGANIZATION
☐ MINORITY BUSINESS
☐ WOMAN-OWNED BUSINESS
☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **LTER: Multi-decadal responses of prairie, savanna, and forest ecosystems to interacting environmental changes: insights from experiments, observations, and models**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **6,762,000**	**72** months	**01/01/19**	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date ________
PHS Animal Welfare Assurance Number ________
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number ________
Exemption Subsection ________ or IRB App. Date ________
☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED
☒ COLLABORATIVE STATUS
A collaborative proposal from one organization (PAPPG II.D.3.a)

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PROJECT SUMMARY

Overview:

The research goal of the Cedar Creek Long Term Ecological Research program (CDR) is to use long-term observations and experiments, theory, and models to achieve a mechanistic and predictive understanding of how ecological systems respond to interacting human-driven environmental changes and how those responses feed back to alter environmental processes and ecosystem services. By comparing and contrasting long-term data from grassland, savanna, and forested ecosystems, the CDR research group seeks generality as it generates and tests hypotheses about processes and feedbacks across scales of space, time, and biological organization.

Intellectual Merit:

CDR research leverages ongoing long-term empirical studies and modeling approaches to seek general principles and novel insights about how ecological systems respond to interacting human-driven environmental changes at multiple biological, spatial, and temporal scales, and how these responses feed back to further influence the earth system and alter the ability of ecosystems to provide the services that support human well-being. Research proposed for this renewal builds on the CDR hallmark of developing and testing theory by combining data from long-term experiments and observations to explore the interactive effects of changes in resources (nutrients, atmospheric carbon dioxide), climate (temperature, precipitation), biodiversity (species richness, phylogenetic and functional diversity, trophic structure), and disturbance (fire, land use change) on linked ecological attributes and processes across multiple scales.

CDR research proposed for the next six years will continue core long-term studies of the ecological impacts of multiple environmental change drivers, including the longest-running biodiversity and elevated CO2 experiments in the world, and some of the longest-running studies of nutrient enrichment and fire. New CDR research initiatives will build from past insights and seek generality. First, a new forest biodiversity experiment will build on past CDR grassland biodiversity research to disentangle the roles of multiple facets of biodiversity (functional, phylogenetic, and species) and use trees to test the generality of theory developed for other taxonomic groups. Second, new experiments replicated in the long-term biodiversity experiment and savanna will determine the interactive effects of drought, nutrients, warming, and biodiversity on ecosystem processes and stability. Third, new initiatives will develop and test theoretical predictions about ecosystem recovery from chronic nitrogen enrichment. Fourth, new experiments will test hypotheses about the how consumers and fire disturbance interact to restructure and alter the functioning of grassland, savanna, and forest ecosystems.

Broader Impacts:

CDR is committed to integrating research with K-12 and undergraduate education and engaging local community members (4,477 students and teachers participated in 2017 alone). New initiatives in education will focus on developing formal assessments of the impacts of K-12 education programs in partnership with the Science Museum of Minnesota and enhancing integration of research and education activities, by incorporating long-term data collection and analysis into student activities. CDR will broaden participation by members of underrepresented groups through continuing and new education partnerships that bring students from inner-city schools to CDR, incorporate local indigenous knowledge into education programs, and empower girls in STEM. CDR will continue to develop a diverse, globally competitive STEM workforce by mentoring summer research interns and providing them with independent research and professional development opportunities. CDR will continue to increase public scientific literacy and public engagement with STEM through its renewed citizen science activities, newsletter, membership and volunteer programs, public tours, adult education, and arts/humanities partnerships, reaching thousands of visitors and participants each year, including teachers, neighbors, public officials, and other members of the public. CDR will enhance infrastructure for research and education by continuing to welcome researchers to use its long-term experiments as research platforms for value-added research activities. CDR investigators will engage with regional resource managers and with the Bell Museum of Natural History to inform environmental decision making and benefit society.

TABLE OF CONTENTS

For font size and page formatting specifications, see PAPPG section II.B.2.

	Total No. of Pages	**Page No.* (Optional)***
Cover Sheet for Proposal to the National Science Foundation		
Project Summary (not to exceed 1 page)	1	
Table of Contents	1	
Project Description (Including Results from Prior NSF Support) (not to exceed 15 pages) **(Exceed only if allowed by a specific program announcement/solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**	32	
References Cited	25	
Biographical Sketches (Not to exceed 2 pages each)	12	
Budget (Plus up to 3 pages of budget justification)	17	
Current and Pending Support	13	
Facilities, Equipment and Other Resources	2	
Special Information/Supplementary Documents (Data Management Plan, Mentoring Plan and Other Supplementary Documents)	2	
Appendix (List below.) **(Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**		

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

I. RESULTS FROM PRIOR NSF SUPPORT

DEB-1234162 (Tilman, PI, 2013-2015; Seabloom, PI, 2016-2018; Hobbie, Isbell, Reich, co-PIs) $5,879,701. UMN. 2013-2018. "LTER: Biodiversity, Multiple Drivers of Environmental Change and Ecosystem Functioning at the Prairie Forest Border." The goal of the 2013-2018 Cedar Creek LTER (CDR) Award was to use the interplay of long-term experiments, long-term observations, and theory to gain a mechanistic and predictive understanding of the dynamics and functioning of grassland, savanna, and forest communities and ecosystems. As outlined below, we have contributed to major advances in biodiversity and ecosystem function science, global change ecology, trophic and community ecology, and trait-based ecology. Major new activities included (1) establishing and initiating data collection in a new Forest and Biodiversity Experiment (FAB 1) to examine the importance of functional and phylogenetic diversity for forest ecosystem functioning; (2) overlaying new warming and precipitation manipulations on existing long-term experiments to further understanding of interactions among global change factors; (3) coordinating a long-term manipulation of nutrients and consumers replicated at CDR, seven other LTER sites, and > 100 sites worldwide towards achieving general understanding of resource and consumer control of grassland ecosystems; and (4) expanding research on the ecology and evolution of cities to uncover generalities in the ecosystem impacts of residential development. From 2013-2018, CDR produced 234 peer-reviewed publications, indicated by an asterisk in the **References Cited**. 29 of these appeared in *Nature*, *Science*, or *PNAS*. 112 appeared in *Ecology*, *Ecology Letters*, *Ecological Monographs*, *AREES*, *TREE*, *Nature*, *Science*, *PNAS*, other *Nature* family journals, *Global Change Biology*, *New Phytologist*, or *Journal of Ecology*. CDR papers were cited 5817 times and 12 publications had ≥100 citations. Of these, we highlight 10 papers, selected because of their significance and representation of the breadth of studies conducted as part of CDR, and briefly describe their key findings.

I.A. 10 Most Significant Publications (in chronological order)

1. *Isbell et al. 2013. Nutrient enrichment, biodiversity loss, and consequent declines in ecosystem productivity. Proceedings of the National Academy of Sciences.* Synthesis of results from three long-term CDR grassland experiments showed that chronic N enrichment initially increased NPP and reduced plant species richness. Loss of plant diversity subsequently caused the impact of N fertilization on productivity to decrease because of the biased loss of high nitrogen-use efficient plant species (Fig. 1).

2. *Borer et al. 2014. Herbivores and nutrients control grassland plant diversity via light limitation. Nature.* The Nutrient Network, an experiment replicated at CDR and other sites around the world, tested the generality and biotic contingencies of ecological theory of resource limitation. This work demonstrated that increased nutrient supply reduces plant species richness under a wide variety of conditions (Fig. 2), but herbivores can rescue diversity at sites where herbivory alleviates light limitation.

3. *Reich et al. 2014. Plant growth enhancement by elevated CO_2 eliminated by joint water and nitrogen limitation. Nature Geoscience.* This study provided key evidence of multiple resource constraints on biomass in elevated CO_2 environments, using the BioCON experiment. When both water and N were at low supply, plant biomass was unchanged by elevated CO_2, but when limitation by either resource was alleviated, plant biomass increased with elevated CO_2 (Fig. 3).

4. *Hautier et al. 2015. Anthropogenic environmental changes impact ecosystem stability via biodiversity. Science.* This study synthesized data from 12 multi-year experiments at CDR that manipulate global change drivers, including biodiversity, N, CO_2, fire, herbivory, and water. Only those factors that altered plant species richness also altered the stability of NPP across years (Fig. 4).

5. *Hobbie 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology and Evolution*. This review reexamines the assumption that litter traits and decomposition rates reinforce patterns of NPP and nutrient constraints across soil fertility gradients. The review expands on ideas that grew out of early CDR research examining species effects on N cycling.

6. *Cowles et al. 2016. Shifting grassland plant community structure drives positive interactive effects of warming and diversity on aboveground net primary productivity. Global Change Biology.* Positive effects of species richness on aboveground NPP were amplified by warming, because of greater positive effects of warming on C_4 grasses and legumes at higher levels of species richness, and because species-rich plots ameliorated effects of warming, exhibiting cooler temperatures and greater surface soil moisture than monoculture plots (Fig. 5).

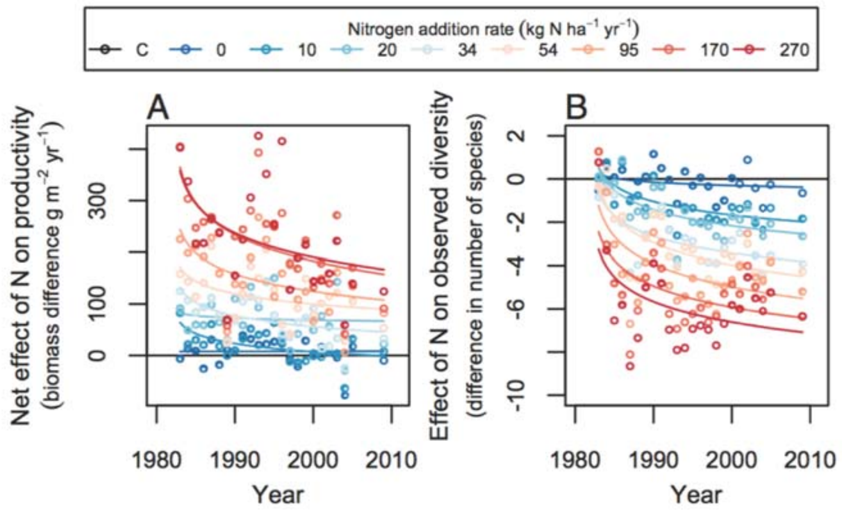


Figure 1. Effects of 26 years of N addition on productivity and plant diversity in successional grasslands at CDR. Figure modified from Isbell et al. (2013a).

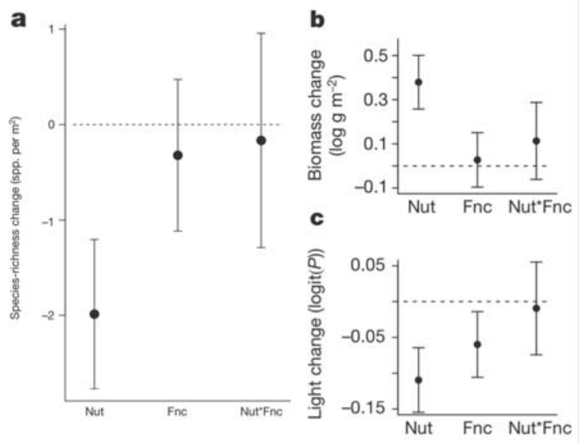


Figure 2. Effects of nutrient addition and herbivore exclusion on plant richness, total biomass, light at ground level in Nutrient Network, headquartered at CDR. Nutrient addition (Nut) and herbivore exclusion by fencing (Fnc) represent the difference from control plots; Nut*Fnc is the additional effect of combining nutrients and fences (the interaction). Error bars represent the 95% confidence interval. Figure modified from Borer et al. (2014).

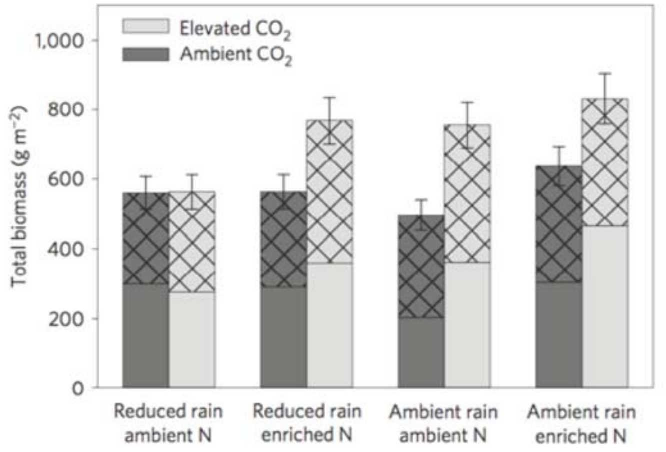


Figure 3. Total biomass in BioCON experiment in relation to all combinations of rainfall, N and CO_2 treatments. Error bars represent ± one SE. Root biomass shown in open, and aboveground biomass in cross-hatched, part of each bar. Figure modified from Reich et al. 2014.

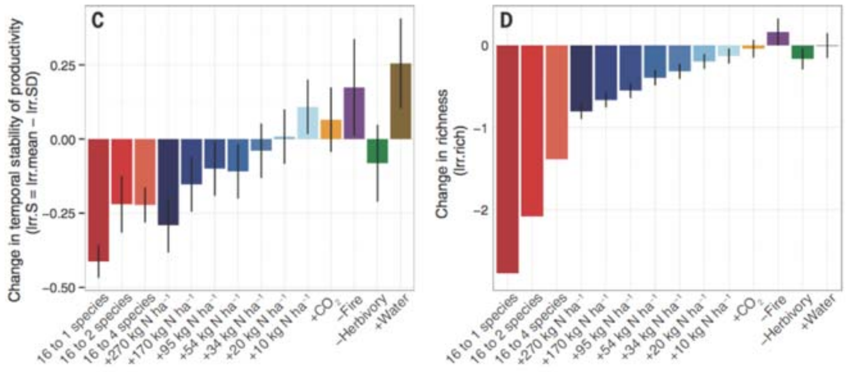


Figure 4. Effect of human-driven environmental changes on stability and species richness across different experiments at CDR. Error bars represent 95% CI. Figure modified from Hautier et al. (2015).

7. *Cavender-Bares et al. 2017. Harnessing plant spectra to integrate biodiversity sciences across biological and spatial scales. American Journal of Botany*. This essay develops an approach to integrating across different aspects of biodiversity, from genetic and phylogenetic diversity to functional diversity, using plant reflectrance spectra. Spectra from the CDR BioDiv experiment is used to illustrate how remotely derived alpha and beta spectral diversity can enhance ground-based measures of biodiveristy such as species richness.
8. *Grossman et al. 2017. Species richness and traits predict overyielding in stem growth in an early-successional tree diversity experiment. Ecology.* This paper demonstrated that mechanisms underlying diversity-productivity relationships in grasslands generalize to forest stands. In young, densely planted forest stands, higher diversity increased total tree growth because of complementarity among species rather than selection of a few high performing species (Fig. 6). The best predictors of productivity were tree species richness and key plant functional traits (leaf N and Ca, mycorrhizal type).
9. *Seabloom et al. 2017. Food webs obscure the strength of plant diversity effects on primary productivity. 2017. Ecology Letters.* A food web manipulation superimposed onto one of the first and longest-running plant species richness experiments in the world revealed that removal of arthropods and foliar fungi increased plant biomass more in higher diversity communities, resulting in a stronger effect of biodiversity on NPP in the absence of consumer impacts (Fig. 7).

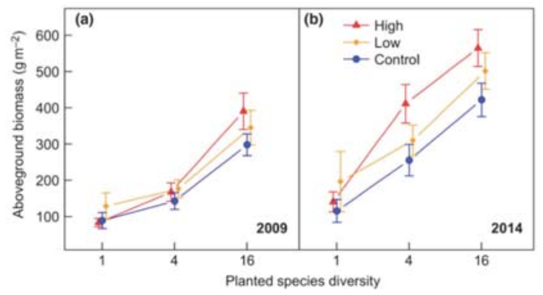


Figure 5. The effect of warming and biodiversity on aboveground biomass in the first (2009) and final year (2014) of data collection in the BAC experiment. Figure modified from Cowles et al. (2016).

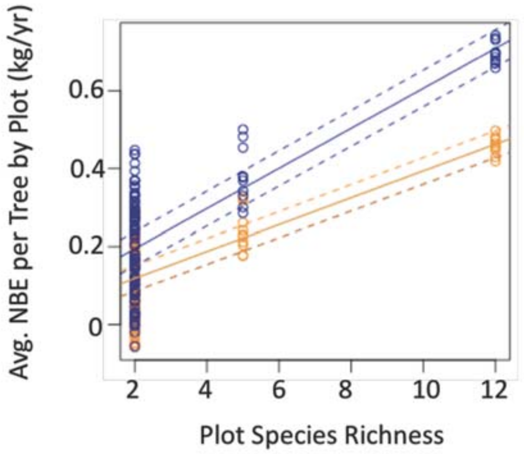


Figure 6. Net Biodiversity Effects (NBE) on tree height as a function of plot level species richness in 2013-2014 (orange) and 2014-2015 (blue) in FAB I. Figure modified from Grossman et al. (2017).

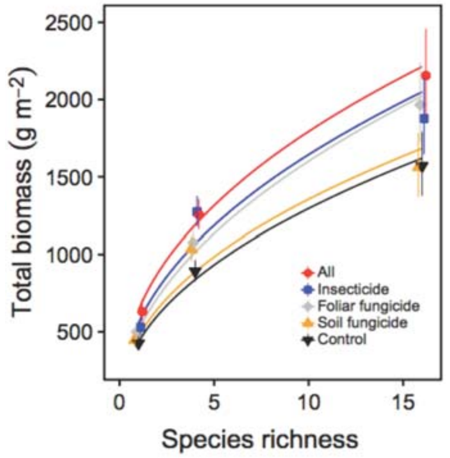


Figure 7. Effects of heterotroph removal on the total, aboveground, and belowground biomass along an experimental species richness gradient in BioDiv-EnRem. Figure modified from Seabloom et al. (2017).

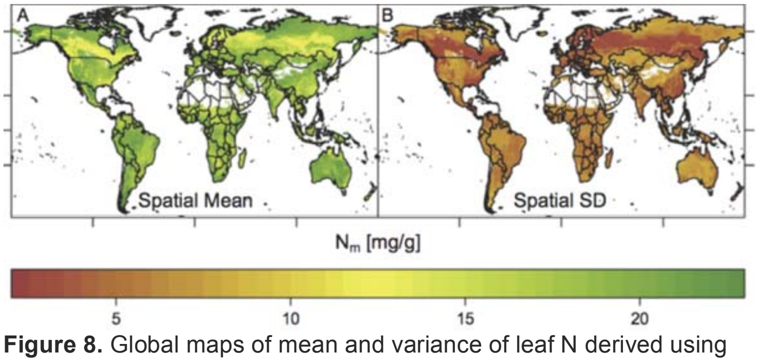


Figure 8. Global maps of mean and variance of leaf N derived using Bayesian spatial modeling of plant trait data including data from CDR and the TRY database. Figure modified from Butler et al. (2017).

10. *Butler et al. 2018. Mapping local and global variability in plant trait distributions.* Proceedings of National Academy of Sciences. Currently, Earth System Models (ESMs) represent variation in plant life as plant functional types (PFTs), each of which accounts for hundreds to thousands of species across thousands of grid cells on land. This paper presented gridded maps of plant traits, expanding plant traits from a single mean value per PFT to a full distribution per PFT that varies among grid cells (Fig. 8), allowing for a more accurate representation of the land surface and its biodiversity in ESMs.

I.B. Report on Data Availability

As requested, we include a table that lists our available datasets as a supplementary document. This table includes 492 datasets and for each we have indicated the LTER core areas relevant to the dataset and have highlighted datasets used in the top 10 publications, above.

I.C. Results of Broader Impacts

Full participation of women, persons with disabilities, and underrepresented minorities in STEM. CDR has encouraged full participation in STEM at multiple levels. 28 graduate students conducted research at CDR during the grant period, and of those, 45% were women, 34% were international, and 21% were students of color. Of the 21 postdoctoral researchers working at CDR, 38% were women, 17% were international, and 10% were persons of color. CDR partnered with a NASA-funded ESTEEM program to provide STEM opportunities for Native American students focused on the intersection of climate change and traditional ways of life. Native American middle school students participated in summer camps where they gained hands-on field ecology experiences and Native American REU students conducted independent research projects. CDR graduate students served as camp leaders and as REU mentors. They prepared for these roles by attending Gidakiimanaaniwigamig ("Gidaa") STEM camps for Ojibwe children in Cloquet, MN over the winter, listening to Ojibwe stories about the natural world, and gaining a better understanding of the contemporary cultural context for those stories, including climate change.

Improved STEM education and educator development. From 2013-2018, CDR and Cedar Creek Ecosystem Science Reserve (Cedar Creek, hereafter) partnered to greatly expanded STEM education and educator development activities. Our popular K-12 programs have grown immensely over the last decade: in 2017, Cedar Creek provided programming to 4477 K-12 students and teachers (18,205 contact hours), a doubling relative to 2012, and a more than 7-fold increase from 2007. Many of these are minority students coming from inner-city schools, with trips funded by external grants. We also began offering an undergraduate *Ecology* course on-site during May Term. This 3-credit course offers the same rigorous introduction to ecology as the on-campus academic year course for biology majors, but immerses students in field experiences including work in iconic long-term experiments highlighted in their textbook.

Development of a diverse, globally competitive STEM workforce. Cedar Creek supports undergraduates through courses, field trips, and a vibrant summer intern program that reached more than 203 students and post-baccalaureates since 2013. Interns assist with research in LTER experiments and engage with site scientists. In a new University of Minnesota (UMN) program, six graduate students are hired each summer to mentor two dozen undergraduate interns in independent research and to organize: (1) a June symposium in which CDR researchers present results from ongoing studies; (2) a weekly summer seminar and workshops that provide training on writing proposals, reading journal articles, analyzing data, and delivering scientific presentations; and (3) an August symposium for interns to present independent projects. REU and RET programs engage undergraduates from indigenous communities and local teachers.

Increased public scientific literacy and public engagement with science and technology. In addition to formal education programs, we have expanded and strengthened our public engagement programs. In 2017, we reached more than 4400 members of the public through open houses, scientist-led tours of LTER experiments, adult classes, and participation at community events like the Minnesota State Fair and environmental festivals. A highlight was the 75th anniversary celebration for Cedar Creek; 450 people visited, including the public, UMN leadership, and local politicians. We expanded our citizen science opportunities from our long-running (10 yr) Red-headed Woodpecker Recovery Project to include projects on wildlife tracking, phenology, and pollinator monitoring. Nearly 100 community members contributed to long-term research in 2017 alone. CDR research has inspired science education videos, through the MinuteEarth YouTube channel (PI Reich is a founding producer). Since 2013, MinuteEarth has released >140 videos (>150 million views), many touching on subjects relevant to LTER science, including ones released in 2016-17 on biodiversity and ecosystem function ("*Why biodiversity is good for the economy*"), biodiversity and bees (“*This is not a bee*”), plant diversity as a source of global food staples (“*Why apple pie isn’t American*”), and ecohydrology (“*Why most rain never reaches the ground*”). Cavender-Bares and Isbell are supporting international policy efforts by participating in the United Nations Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (§ III.B.5).

Enhanced infrastructure for research and education. CDR’s numerous long-term experiments, such as BioCON/TeRaCON, BioDiv, Savanna Fire Experiment, Old Field Chronosequence, and nutrient enrichment studies, have served as research platforms for numerous students, postdocs, and visiting researchers, and as field trip sites for K-12 students and teachers and the public. Cedar Creek has leveraged CDR’s scientific reputation to obtain resources to upgrade boardwalks to Cedar Bog Lake, Beckman Bog, and Fish Lake towards enhancing accessibility for education and outreach activities.

I.D. Results of Supplemental Support

In 2015 we received an **equipment supplement** for $49,998 that was used to upgrade equipment for prescribed burning (all terrain vehicle equipped with 50-gallon tank and fire pump + hose and second pumps for two pickup trucks). We used this equipment to impose prescribed burning treatments on 535 hectares from 2015-2017, including LTER Experiments in old-field and savanna ecosystems. Twelve peer-review publications resulted from these experiments during 2015-2018. This supplement was additionally used to purchase a Dual Spectral Scanner (UniSpec-DC Dual Channel Spectral Analysis System) for frequent, non-destructive biomass measurements. We have used this scanner for annual vegetative measurements in BioCON since 2016 and for spectral work in FAB. In 2016 we received a **carbon dioxide supplement** for $196,000 to offset costs of purchasing CO_2 for the BioCON and TeRaCON experiments. This experiment resulted in 27 peer-reviewed publications and one PhD dissertation in 2016-2017.

II. RESPONSE TO PREVIOUS REVIEWS

CDR hosted its mid-term site review team in July 2015. We appreciated the positive remarks of the site review team: “*The review team noticed a high level of collegiality, collaboration, and mutual respect among all of the personnel engaged in field research at CDR. This collaborative spirit clearly has a strong positive influence in fostering creativity and productivity of the CDR LTER research program. The site review team was impressed with the project’s performance over the past three years and amazed by the incredible quality and quantity of research being conducted by the highly talented CDR research community.*” We also appreciated the thoughtful and constructive recommendations of the team, which we address in detail below.

II.A. Research Recommendations

“The PIs continue to work toward producing a conceptual framework that is compelling enough to capture the depth and complexity of their research program.” Response: we developed a Conceptual Framework based on discussions among the CDR PIs, graduate students, and postdocs (Box 1).

“The CDR research team should organize an annual meeting to integrate graduate student researchers and also provide an opportunity to revisit and reflect on the goals expressed in the current proposal.” Response: we now hold two meetings per year with PIs, graduate students, postdoctoral researchers, and staff: a spring symposium of short talks followed by socializing at a local brewpub, and a summer “field day” of short field talks given onsite at the long-term experiments of Cedar Creek.

“The PIs spend more time explicitly discussing options [for funding BioCON] and making realistic alternative plans.” Response: we have taken three steps to secure more funding for BioCON: (1) we received support from the Office of the Vice President for Research to help defray CO_2 costs (prior to site review); (2) we obtained an NSF MRI award to upgrade the BioCON infrastructure and purchase previously rented equipment; (3) we submitted an LTREB proposal that has now been recommended for funding.

“The site team follows through on providing additional support for graduate student collaborative synthetic research.” Response: we are promoting synthesis among graduate students in two ways. First, we provide funding for graduate students who propose workshops to attend the All Scientists Meetings and to host follow-up workshops, resulting in collaborative publications (Ladwig et al. 2016). Second, students in the Ecology, Evolution and Behavior graduate program take a Foundations core course that requires independent group projects and provides instruction on information management and data synthesis. Students used CDR datasets to learn modeling, statistical methods, and R, including from BioCON, Old Field Chronosequence, N Addition, and Nutrient Network studies. Going forward, we will partner with the Insti-

tute on the Environment's Boreas Leadership Program and the new CREATE graduate training program (Hobbie, co-PI) to develop workshops on working in collaborative teams.

"We…recommend using the traits information developed with TRY and through spectral traits research as a means to integrate across long-term experiments while testing the utility of trait-based approaches." Response: PI Cavender-Bares is deeply engaged in research linking trait databases, spectral data, and ecosystem functional information from biodiversity experiments. Former postdoc Kevin Mueller (faculty at Cleveland State University), current postdoc Habacuc Flores-Moreno, and PhD candidate Kaitlin Kimmel are integrating trait datasets with species data from CDR experiments. PI Reich is mapping traits and using them to improve ecosystem and land surface models, using CDR and other LTER sites as test beds.

II.B. Education and Outreach Recommendations

"Facilitate the development of assessment tools." Response: Since the mid-term review, we have implemented assessments of teacher and student training experiences. 88% of teachers rated their field trip experience as "good" or "excellent" for enhancing their science curriculum. 96% of students reported increased knowledge of ecology and geography. 100% of teachers and 87% of students expressed interest in returning to Cedar Creek. Assessment activities will be further developed going forward (§ V. Education and Outreach Activities).

"Collect data on number of visitors reached and short and long-term impact of a visit to CDR." Response: CDR education staff record daily participant numbers and contact hours for all education and outreach groups, and has reconstructed historical data, where possible. Isbell and the Cedar Creek Graduate Fellows collect data on the impact of our summer research internship each year. Potter collects similar data on the impact of a field trip on educators. These data will be incorporated into the CDR database.

II.C. Information and Project Management Recommendations

"Integrate PASTA DOIs into site databases." "Consult with PASTA team so that tables in PASTA metadata render properly." Response: DOIs are now collected via automated local scripts and uploaded into our local databases. The most recent PASTA DOI is presented for each dataset. Metadata encoding for methods has been adjusted so that tables are human-readable within the PASTA system.

"The PIs articulate a set of guiding principles that will be used when it becomes necessary to make strategic decisions regarding resource allocation." Response: see Project Management Plan.

III. PROPOSED RESEARCH

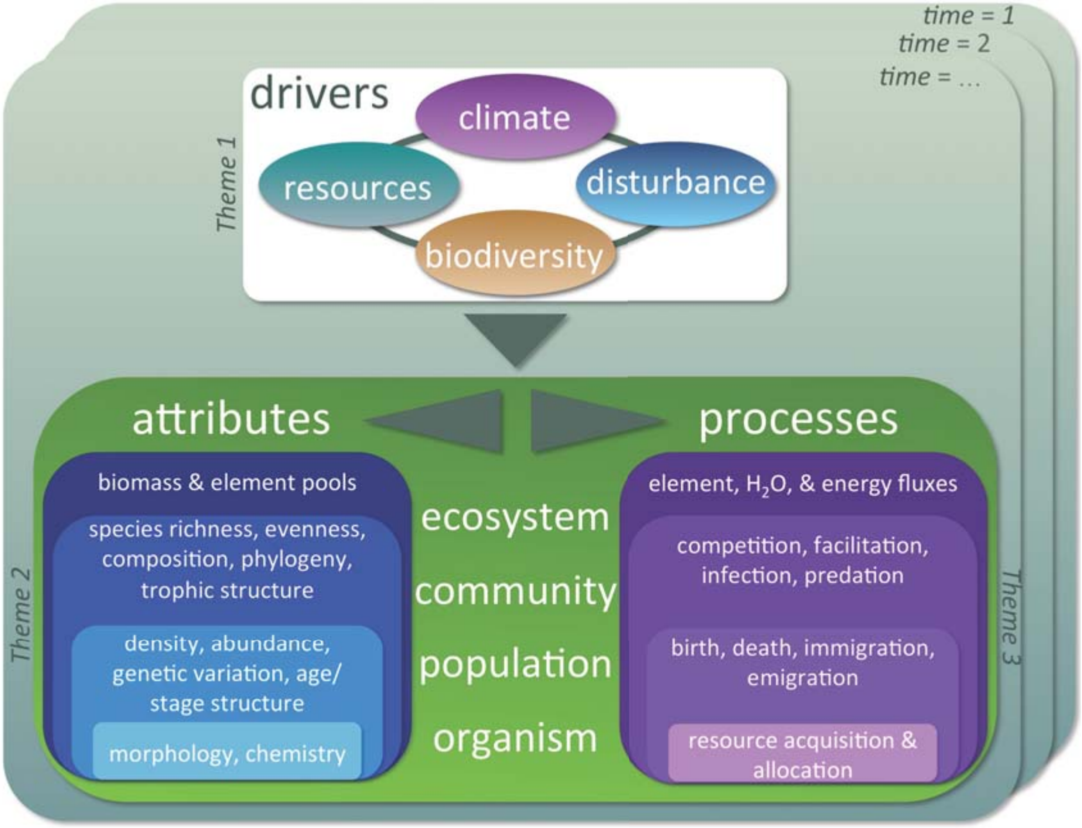
III.A. *Conceptual Framework and Research Questions*

III.A.1. Overall Research Goal

We will advance our research agenda by combining long-term data, new experiments, theory, and models to explore the **interactive effects of multiple environmental change drivers on responses across ecological scales**. Ecological systems are impacted by a myriad of human-driven environmental changes occurring at local to global scales, including alterations in resources, climate, biodiversity, and disturbance (Box 1). Climate and atmospheric chemistry, such as CO_2 concentration and N deposition, are changing in ways that are pushing Earth into physical domains unprecedented on millennial timescales (Vitousek 1994). Biotic changes, such as loss of species diversity and introduction of novel species, including pests and pathogens, are causing wholesale changes in the structure and functioning of ecological communities and ecosystems (Hector and Bagchi 2007, Weidenhamer and Callaway 2010, Preston et al. 2016). Land use/cover change represents a complex mix of abiotic and biotic changes whose interactions are altering Earth's surface (Ellis and Ramankutty 2008). Together, these environmental changes represent fundamental shifts in the availability of resources, abiotic conditions, and biological interactions occurring within ecological systems. In some cases, human actions already may have moved Earth beyond a safe operating space (Steffen et al. 2015). The overall goal of CDR is therefore:

To use long-term observations and experiments, theory, and models to achieve a mechanistic and predictive understanding of (1) how ecological systems will respond to interacting human-driven environmental changes at multiple biological, spatial, and temporal scales and (2) how ecological responses feed back to moderate or amplify environmental changes and alter the ecosystem services that support human well-being.

Box 1. Cedar Creek LTER Conceptual Framework. In our Conceptual Framework, human activities are changing multiple ***interacting environmental drivers*** (Theme 1) that alter ecological systems. Because of their long-term importance for altering CDR ecosystems, the drivers we focus on at this site include plant **resources**, (atmospheric CO_2, reactive N, soil moisture), **climate** (temperature and precipitation), **biodiversity** (species, phylogenetic, and functional richness and composition at multiple trophic levels), and **disturbance** (fire and changes in land use and cover). Environmental drivers interact to affect the linked attributes and processes of ***interacting ecological systems*** at **organism**, **population**, **community**, and **ecosystem** scales. For instance, increased N deposition, fire suppression, climate variability, as well as declining biodiversity influence processes at CDR such as resource acquisition at organism scales, demographic processes in populations, species interactions in communities, and fluxes of elements and energy in ecosystems, with implications for attributes including traits, population structure, community composition, and biomass and element pools across site-level environmental gradients (Theme 2). Such changes in structure further influence how systems respond to changing conditions over long time scales (Theme 3). Our conceptual framework is at once generic in that we use it to frame theory and experiments comprising constructed communities, and specific when we apply it to the grasslands, savannas, and forests of Cedar Creek and consider the particular biodiversity actors, disturbances (fire, land use change), and resources (N, light, CO_2) relevant to those systems.



III.A.2. Core Research Questions and Themes for the Cedar Creek LTER

At CDR, we closely integrate long-term observational and experimental data with a range of analytical, simulation, and data-driven modeling approaches to address the following overarching research question:

How do multiple environmental change drivers (climate, resources, disturbance, and biodiversity) interact to affect the attributes and processes of ecological systems across hierarchical scales (organism, population, community, and ecosystem) over spatial scales that encompass ecological heterogeneity and temporal scales that encompass biotic interactions and feedbacks (Box 1)?

Four interrelated themes tie together the research at CDR:

1. **How do multiple interacting environmental change factors impact ecological systems?**
2. **How do inter-related components of biodiversity (species, phylogenetic, trophic, and functional) determine ecological responses to environmental change?**
3. **How do biotic interactions and feedbacks in ecosystems influence long-term ecological responses to environmental change?**

4. **What general insights can be achieved by integrating CDR findings through synthesis, cross-site studies, theory, and modeling?**

In the following sections, we provide background and conceptual framing for each of these inter-related themes. How each Theme fits within our overall Conceptual Framework is also shown in Box 1.

III.A.3. Background

Theme 1. Discovering how multiple interacting environmental change factors impact ecological systems. Concurrent global changes to climate, resources (e.g., CO_2, N, or P), disturbance (e.g., fire and changes in land use), and biodiversity (e.g., invasions and extirpations) are impacting ecosystems. Because these multiple drivers of ecological transformation interact in complex ways that may dampen or exacerbate their individual effects (Leuzinger et al. 2011, Goll et al. 2012), developing a mechanistic understanding of how these changes affect organisms, populations, communities, and ecosystems requires long-term experiments that simultaneously manipulate multiple factors. ***A hallmark of CDR research will continue to be long-term experiments (both decades-old ones and new ones proposed here) that manipulate multiple global change factors concurrently, including resources (CO_2, nutrients), climate (temperature, precipitation), biodiversity (species richness, species identity, trophic structure, phylogenetic diversity, functional diversity), and disturbance (land use, fire), to build deeper mechanistic understanding of the impacts, interactions, and feedbacks caused by concurrent anthropogenic changes to the earth system (Box 1).***

In our Conceptual Framework (Box 1), global change drivers both interact with and affect one another. For example, future effects of increased atmospheric CO_2 concentration and temperature will occur in eutrophied ecosystems with diminished biodiversity, and theory predicts that productivity response to elevated CO_2 will depend upon the supply of other resources (Rastetter et al. 1997, Luo et al. 2004). Consistent with that theory, CDR's BioCON (Biodiversity, CO_2, and N) and TeRaCON (Temperature, Rainfall, CO_2, and N) experiments have revealed that CO_2 enrichment increases plant growth in grassland communities only with sufficient water or N (Fig. 3) (Reich and Hobbie 2013, Reich et al. 2014). Further, CO_2 enrichment can reduce local extinctions caused by N addition (Reich 2009). These strong interactions demonstrate the importance of global change experiments that manipulate multiple concurrent factors to inform understanding of terrestrial CO_2 fertilization (Ciais et al. 2013) and improve ESMs (Goll et al. 2012, Harper et al. 2016).

Theoretical and empirical work at CDR and elsewhere also predicts strong interactive effects of multiple soil resources and light on NPP and plant biomass (Tilman 1982, Dybzinski and Tilman 2007, Hautier et al. 2009, Burkepile et al. 2017). The generality of this prediction has been demonstrated by the Nutrient Network, a globally distributed experiment supported by CDR that manipulates herbivores and multiple nutrients at more than 100 grasslands spanning six continents (Borer et al. 2017). Across dozens of grasslands worldwide, addition of multiple nutrients was more likely to increase plant biomass and led to greater declines in plant species richness than addition of single nutrients (Fig. 9) (Fay et al. 2015, Harpole et al. 2016, Borer et al. 2017), This loss of species was alleviated by herbivores when they increased the availability of ground-level light (Borer et al. 2014).

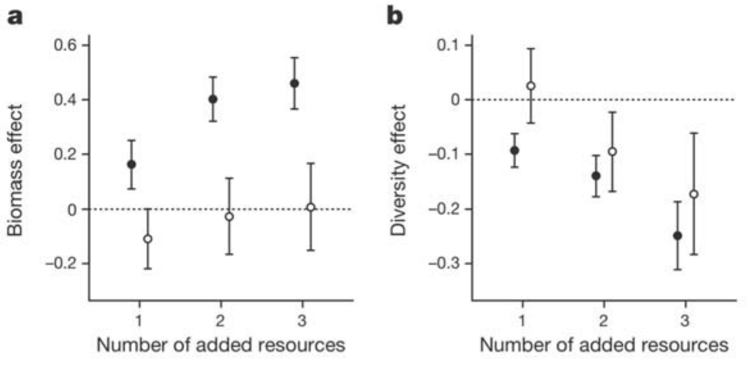


Figure 9. Increased number of added resources resulted in positive and increasing biomass (a) and negative and decreasing species richness (b) at Nutrient Network sites showing multiple resource limitation (filled points) and not limited by multiple resources (open circles). Figure modified from Harpole et al. (2016).

Disturbances associated with land-use change (Sala et al. 2000, Newbold et al. 2015), fire (Collins 1992, Briggs et al. 2005), and disease interact with and affect resources and biodiversity, with potential feedbacks to disturbance regimes. The longest-running experiment at CDR has demonstrated that disturbance by fire changes biotic structure and functioning by altering N cycling and light availability (Fig. 10) (Wilson and Tilman 1993,Peterson and Reich 2001, Reich et al. 2001b, Dijkstra et al. 2006, Pellegrini et al. 2018). Fire disturbance also changes biodiversity, altering invasion by introduced species (Moles et al. 2012) and eliminating fire-intolerant species (Cavender-Bares and Reich 2012, Li et al. 2013). In addition to resources and disturbance, CDR research considers biodiversity as an environmental change driver that can directly influence ecosystem processes and mediate ecosystem response to perturbations (Reich et al. 2001a, Isbell et al. 2015a, Craven et al. 2016). Ongoing CDR experiments manipulating diversity of both herbaceous and woody species has been seminal in demonstrating positive effects of species richness on NPP (Fig. 11) (Reich et al. 2012, Grossman et al. 2017) because of more complete resource capture (Mueller et al. 2013, Tilman et al. 2014, Kothari et al. 2018), with cascading effects on belowground communities. (Cline et al. 2018) and ecosystem processes and attributes (Fornara and Tilman 2012, Seabloom et al. 2017). Work at CDR and elsewhere also has demonstrated that more diverse communities are more buffered against environmental fluctuations and show greater stability (i.e., less year-to-year variation in biomass and NPP) (Proulx et al. 2010, Cadotte and Dinnage 2012, Hautier et al. 2014, Hautier et al. 2015, Isbell et al. 2015a).

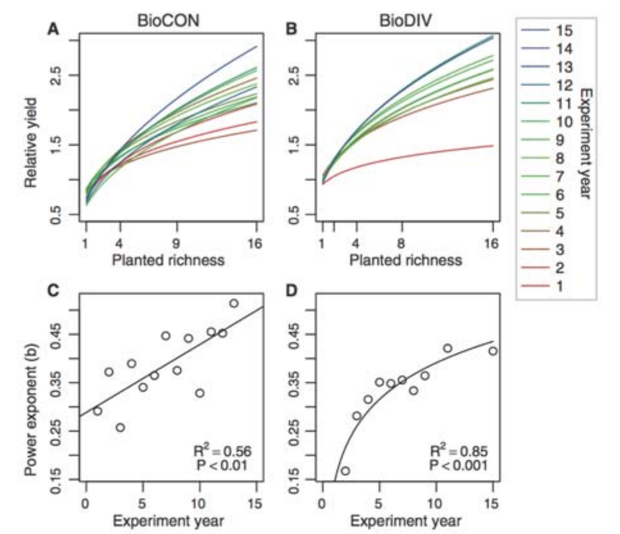


Figure 11. Effects of plant richness on relative yield of total biomass in the BioCON and BioDiv experiments (A, B) and the exponent of the power function in relation to experimental years (C, D). Figure modified from Reich et al. (2012).

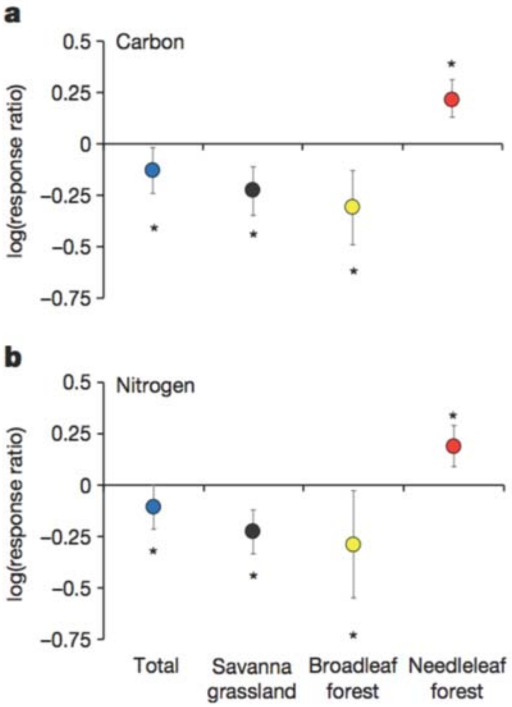


Figure 10. Effects of fire on soil C and N across ecosystems (including CDR savannas) and over time. Log response ratios of the concentrations of C (a) and N (b) is the concentration of C or N in burned plots divided by the concentration in protected plots. Figure modified from Pellegrini et al. (2018).

Plant composition and diversity also have important effects on the productivity, stability, composition, and phylogenetic diversity of consumer communities (Scherber et al. 2010, Borer et al. 2012, Lind et al. 2015). In turn, consumers (e.g., herbivores, predators, diseases, endophytes) play key roles in structuring communities and ecosystems, with consequences for ecosystem processes (Duffy et al. 2003, Proulx et al. 2010, Borer et al. 2015, Hobbie and Villéger 2015, Seabloom et al. 2017). For instance, plant diversity-productivity relationships can be modified by interactions with other trophic levels such as foliar fungi and herbivores, if consumers impact more species-rich communities differently than species-poor ones (Seabloom et al. 2017). Shifts in above- versus belowground plant allocation induced by herbivores or diseases can alter plant productivity, plant chemistry, and C inputs to soils (Milchunas and Lauenroth 1993, Knapp et al. 1999, Mitchell 2003, Borer et al. 2015, Seabloom et al. 2017), with consequences for nutrient cycling (Hobbie and Villéger 2015). Consumers can ameliorate local plant extinctions caused by nutrient addition by reducing the abundance of fast-growing species that reduce light availability (Lind et al. 2013, Borer et al. 2014). Consumers also can have consequences for rates of ecosystem processes if they result in functional shifts among plants (Ritchie et al. 1998).

Theme 2. Discovering how inter-related components of biodiversity (species, phylogenetic, trophic, and functional groups and traits) determine ecological responses to environmental change. Interacting environmental global change drivers act across a range of scales of biological organization, including organisms, populations, communities, and ecosystems (Box 1). At CDR, in addition to explicitly considering diversity as one of the *drivers* of ecosystem change (Theme 1), we consider diversity as a key component of most if not all of the attributes of ecosystems that *respond* to, and interact with, drivers of change (Box 1, attributes) to collectively determine processes across scales (Box 1, processes). Among ecological attributes, we consider composition across scales (e.g., trait values at the organism scale, genotype at the population scale, species identities and trophic position at community and ecosystem scales) as an explicit component of “diversity”. Clearly many facets of biodiversity modulate responses to environmental change across diverse ecosystems (Stachowicz et al. 2007, Smith et al. 2009); identifying the causal characteristics of these responses, particularly under multiple concurrent global changes, poses an ongoing challenge (Devictor et al. 2010). ***CDR research will continue to advance mechanistic understanding of long-term responses of ecological systems to multiple global change drivers (Theme 1) by integrating responses across interrelated components of biodiversity (Theme 2) from traits to ecosystems (Box 1).***

In our CDR studies, aspects of biodiversity play roles both in experimental treatment design (as drivers) and via responses to other treatments and interactions (as attributes and processes). For instance, at the organism scale, plants vary in correlated functional traits (e.g, foliar N, root mass to shoot mass, rooting depth, photosynthetic rates, leaf lifespan, specific leaf area, hydraulic architecture, growth rate, etc., Meinzer 2003, Reich et al. 2003, Wright et al. 2004, Tjoelker et al. 2005) and such traits often predict responses of individual species to environmental change and effects on ecosystem processes (Reich et al. 2012, Reich 2014, Hobbie 2015, Wei 2015). For example, adding N favors fast-growing species that share a set of physiological traits (e.g. high leaf N) over slower growing more N-use-efficient species (Dybzinski and Tilman 2007). Over multiple decades, loss of more N-efficient species dampens the positive effects of N on NPP due to the strong, positive coupling of species diversity and NPP (Fig. 1) (Isbell et al. 2013a). Trait differences also explain species responses to hydrological gradients at CDR. Tree species with hydraulic, morphological, and growth traits associated with stress tolerance persist in wetland environments and in drought-prone uplands while less stressful environments are dominated by fast growing species with high metabolic rates and hydraulic conductance (Savage et al. 2009, Savage and Cavender-Bares 2012, Wei et al. 2017b).

Differences in photosynthetic pathways also can determine plant responses to environmental change. For example, theory and short-term experiments have shown that C_3 species derive a greater benefit from rising CO_2 than C_4 species (Wand et al. 1999, Ainsworth and Long 2005), and this difference is incorporated into many ecosystem and Earth System Models (ESMs). However, a long-term experiment at CDR (BioCON) suggests that these short-term responses do not apply over more ecologically realistic time frames or in field settings with more realistic levels of complexity. While C_3 grasses initially derived a greater benefit, over the course of 20 years, plots composed of C_4 grasses have become increasingly productive under enriched CO_2 whereas the benefit of CO_2 has disappeared for C_3 grass plots (Fig. 12). Identifying the underlying causes of these divergent responses is critical to assessing long-held paradigms that predict ecosystem function in an increasingly CO_2-enriched world.

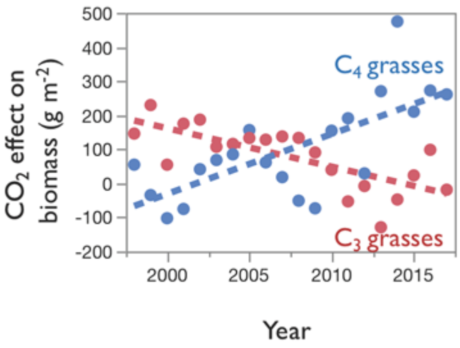


Figure 12. Biomass enhancement due to CO_2 for C_3 and C_4 grasses in the BioCON experiment from 1998-2016. Figure modified from Reich et al. (in review).

Theme 3. Discovering how biotic interactions and feedbacks in ecosystems influence long-term ecological responses to environmental change. At the core of the LTER mission is the recognition that short-term ecological responses to environmental drivers may represent transient dynamics that differ in strength or even direction from long-term responses. Long-term multi-factor experiments often reveal interactions among global change drivers not apparent until well beyond a normal three-year funding cycle (Fig. 13) (Knapp et al. 2012, Reich et al. 2012). Following perturbation, ecological systems may be slow to equilibrate (e.g., because of slow individual or population growth rates, Fig. 13A), exhibit delayed response (e.g., because of dispersal limitation or storage of excess nutrients, Fig. 13B), experience feedbacks that dampen or accelerate change (e.g., because of species-induced changes in availability of limiting resources, Fig. 13C), or show variable response over time (e.g., caused by stochastic environmental variation, Fig. 13D) (Carpenter et al. 1999, Melillo et al. 2017, Ratajczak et al. 2017). For all of these reasons, ecological responses are best elucidated with long-term experiments (Smith et al. 2009, Knapp et al. 2012) and observations that manipulate interacting environmental change drivers that occur at varying timescales and with varying dynamics. ***CDR research will elucidate how ecological responses to multiple interacting global change drivers (Theme 1) across scales from organs to ecosystems (Theme 2) in turn determine the long-term interacting dynamics of processes ranging from physiology of individual organs to species interactions to ecosystem fluxes of elements and energy (Theme 3).***

Work at CDR has shown that many of the mechanisms in Fig. 13 operate, causing short- and long-term responses to diverge. For instance, projections following short-term stimulation of NPP by N enrichment overestimated long-term NPP response because of long-term diversity loss with N enrichment (as in Fig. 13A) (Isbell et al. 2013a). Similarly, two different biodiversity experiments revealed that short-term results would have underestimated long-term results: relationships between manipulated species richness and productivity grew steeper over time (Fig. 11) (Reich et al. 2012), likely because of accumulation of N and soil C that increased soil water-holding and cation exchange capacity, and thus soil fertility. Buffered responses also can exhibit time lags (Fig. 13B). For instance, while N addition increased the rates of early-stage decomposition, N inhibited late-stage decomposition, likely because changing litter chemistry altered decomposer composition and decomposition capabilities (Hobbie et al. 2012). Similarly, herbivore exclosures increased N fixer abundance and accumulation of N stocks, but these effects were not immediately apparent, because more than a decade was required for arrival and establishment of N fixers and feedbacks to soil N stocks (Ritchie et al. 1998). In BioCON, the N constraint on the response of plant biomass to elevated CO_2 (Reich et al. 2006, Reich and Hobbie 2013) was not apparent for the first three years of the experiment, perhaps because the disturbance associated with establishing the experiment caused a transient increase in soil N levels (Fig. 13C). Similarly, CO_2 effects on soil net N mineralization in BioCON became more positive in C_4 grass plots and less so in C_3 grass plots, likely contributing to the shift from CO_2 stimulation of C_3 biomass to that of C_4 biomass (Fig. 12) (Reich et al. submitted).

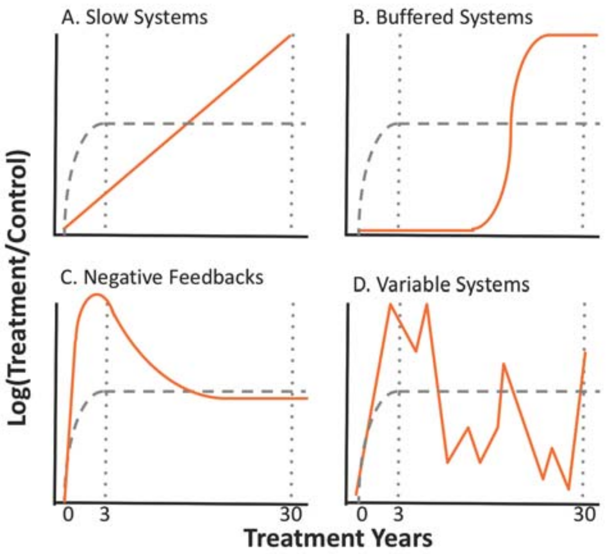


Figure 13. Short-term responses (e.g., 3 years) predict long-term responses (e.g., 30 years) when systems equilibrate quickly in response to experimental treatments (dashed gray line). Short-term responses will provide biased estimates of long-term responses (orange lines) when systems are slow to equilibrate (A), system response is buffered (B), negative feedbacks cause treatment effects to decline (C) or amplify (not shown), or responses vary over time (D).

In many CDR experiments, biotic interactions and feedbacks are shaping the long-term impacts of global change. While many CDR experiments (e.g., BioDIV, BioCON, Old Field Chronosequence, Old Field N

Addition) are >20 years old, and the Savanna Fire Experiment is >50 years old (Table 1), measurements of plant composition and NPP coupled with measures of soil properties and processes have continued to provide new insights into feedbacks and time lags that are still influencing long-term dynamics.

Theme 4. Discovering general insights through synthesis, cross-site studies, theory, and modeling. Empirical research is most powerful in advancing understanding when it (1) is informed by and used to develop and test theory (e.g., Scheffer 2009); (2) informs predictive modeling; and (3) is included in synthetic analyses (e.g., Balvanera et al. 2006) and cross-site studies (e.g., Hector et al. 1999, Finn et al. 2013) to reveal general principles. Research at CDR has a rich history of such close coupling between theory and experiments (e.g., Tilman 1982, Tilman 1985, 1988, Tilman 1990, Lehman and Tilman 2000, Clark 2017). ***Research at CDR combines theory, models, and empirical syntheses with place-based data to test the generality of relationships and processes revealed at our site (Themes 1, 2, and 3) and others to allow CDR findings to contribute more fully to understanding our changing world Theme 4).***

Over the past six years, LTER scientists have continued to make progress developing and testing ecological theory. For example, Clark (Clark 2017, Clark et al. 2018), used theory to explore the role of tradeoffs in structuring metapopulation and successional dynamics in CDR old-field communities and competitive outcomes in experimentally assembled plant communities. Lohier (2014) showed that data on transient dynamics enabled theoretical predictions to be reconciled with empirically measured ontogenetic root-shoot allometry. CDR researchers have contributed to advancing theory about trait-based ecology (Reich 2014, Shipley et al. 2016), plant diversity effects on ecosystem stability and productivity, and loss of species richness due to increased nutrient supply (Hautier et al. 2014, Isbell et al. 2015a, Grace et al. 2016, Harpole et al. 2016, Borer et al. 2017, Harpole et al. 2017).

In addition to advancing theory, CDR research has informed the development of predictive simulation models, including ecosystem process models and ESMs, integral to predicting biotic feedbacks to environmental changes, especially in climate and the global C cycle (IPCC 2013). For example, BioCON data have been used to test predictions from an ecosystem model comparing the responsiveness (and resulting competitive outcomes) of different plant functional types to elevated CO_2 (Ali et al. 2013, Ali et al. 2015, Terrer et al. 2016, Terrer et al. 2017). CDR researchers also have contributed to developing the TRY database (Kattge et al. 2011) and related efforts to represent both continuous trait surfaces and advance global change functional response in ESMs, improving upon the use of plant functional types and average trait values (Schrodt et al. 2015, Harper et al. 2016, Butler et al. 2017, Lu et al. 2017), to achieve biological realism and better functional logic (Verheijen et al. 2015, Huntingford et al. 2017).

While many of CDR's contributions to advancing ecological understanding have come from unique, long-term experiments (e.g. manipulations of fire frequency, herbivory, elemental nutrients, atmospheric CO_2, climate, biodiversity), achieving general understanding requires synthesis across sites and studies. CDR research has contributed to syntheses of the effects of fire (Moles et al. 2012, Pellegrini et al. 2018), elevated CO_2 (Feng et al. 2015, Andresen et al. 2016, Deng et al. 2016, Terrer et al. 2016, Piñeiro et al. 2017, Terrer et al. 2017, Terrer et al. 2018), climate change (Andresen et al. 2016, Carey et al. 2016, Crowther et al. 2016), N inputs (Suding et al. 2005, Clark et al. 2007), biodiversity (Isbell et al. 2015a, Liang et al. 2015, Venail et al. 2015, Craven et al. 2016, Guerrero-Ramírez et al. 2017, Hungate et al. 2017, Grossman et al. 2018), and the role of functional traits in community and ecosystem processes (Reich 2014, Shipley et al. 2016, Funk et al. 2017). Each of these syntheses has expanded from place-based work to generate a more general understanding of basic ecological principles and relationships.

CDR also leads or participates in multiple cross-site, *coordinated* networks of experiments, including the Nutrient Network (Borer et al. 2017), DroughtNet, and IDENT (Grossman et al. 2017), that are yielding novel ecological insights that could not have been gained from single-site research (Borer et al. 2014). For instance, the generality of experimental and theoretical work at CDR showing that adding nutrients can cause local species extinctions (Clark and Tilman 2008) was demonstrated using the distributed Nutrient Network (NutNet) experiment (Fig. 2, 9) (Borer et al. 2014, Harpole et al. 2016, Borer et al. 2017). Similarly, the NutNet experiment has shown that the positive effects of diversity on the productivity and stability of experimental grass communities at CDR are characteristic of naturally assembled herbaceous ecosystems worldwide (Hautier et al. 2014, Grace et al. 2016).

III.B. *Major Activities*

We propose research for the coming six years that builds on the CDR hallmark of combining long-term experiments and observations with development and testing of theory to explore **the interactive effects of multiple environmental change drivers on linked responses of attributes and processes across multiple ecological scales.** Consequently, our activities are deeply interrelated. We have chosen to first present the CDR experiments (§ III.B.1-4, Table 1), organized around the major drivers emphasized in our Conceptual Framework (Box 1). We start with new experiments that manipulate aspects of biodiversity (species, phylogenetic, functional) followed by long-term nutrient enrichment studies, followed by long-term and newer studies that manipulate combinations of drivers. All address aspects of Themes 1-3. Second, we describe synthesis activities aimed at generalizing the results of CDR studies in space and time via on-site and cross-site data syntheses (§ III.B.5) and theory and modeling (§ III.B.6) (Theme 4).

Table 1. Environmental change drivers studied in the activities described in sections III.B.1-4 (manipulated intentionally by experimentation or unintentionally by invasion in the case of Oak Wilt, indicated by "X").

				Environmental Change Driver			
Section	***Experiment or Initiative***	***Ongoing or New****	***Year Started (duration in 2018, y)***	***Resources*** (CO$_2$, H$_2$O, nutrients)	***Climate*** (temperature, precipitation)	***Disturbance*** (land use, fire)	***Biodiversity*** (SR, PD, composition, trophic structure)
III.B.1	FAB I	Ongoing	2013 (5)				X
	FAB II	New	2016-17 (1)				X
III.B.2	Old Field N Addition	Ongoing	1982 (36)	X			
	Old N Cessation	Ongoing	1982/1992 (36/26)	X			
	New N Cessation (x Fire)	New	1982/2014 (36/4)	X		X	
	N Addition across Forests & Grasslands	Ongoing	1999 (19)	X			X
III.B.3	BioDiv	Ongoing	1994-95 (23)				X
	Enemy Removal	Ongoing	2008 (10)				X
	BioDiv-BAC	Ongoing	2009 (9)		X		X
	BioCON	Ongoing	1997-98 (20)	X			X
	BioCON-TeRaCON	Ongoing	2007/2012 (11/6)	X	X		
	BioDiv-BAC-Drought	New	2017 (1)		X		X
	Droughtnet x Nutrients	New	2017 (1)	X	X		
III.B.4	Old Field Chronosequence	Ongoing	1982 (36)			X	
	Savanna Fire Experiment	Ongoing	1964 (54)			X	
	GLADES	Ongoing	1989-1995 (23)			X	
	Bison x Fire	New	2018 (0)			X	X
	Oak Wilt	New	2017 (1)			X	X
	N x Fire x Deer	Ongoing	2000 (18)	X		X	X
III.B.5	CDR Nutrient Network[†]	Ongoing	2007 (11)	X			X

*Most new studies were initiated near the end of the 2012-2018 funding period, but are "new" in that sampling largely will begin with the new grant; SR, species richness; PD, phylogenetic diversity. [†]International Drought Experiment (Droughtnet) datasets are included under III.B.3.

In each section, we discuss ongoing long-term studies and new initiatives that in many cases are layered onto existing long-term experiments (Table 1). First, a new forest biodiversity experiment will build on past CDR grassland and forest biodiversity research to disentangle the roles of multiple facets of biodiversity (functional, phylogenetic, genetic, and species) and use trees to test the generality of theory developed for other taxonomic groups. Second, new experiments replicated in the long-term biodiversity experiment and savanna will determine the interactive effects of drought, nutrients, warming, and biodiversity on ecosystem processes and stability. Third, new initiatives will develop and test theoretical predictions about ecosystem recovery from chronic nitrogen enrichment. Fourth, new studies will elucidate how introduction (either intentional or accidental) of novel trophic actors (bison, oak wilt and other diseases) are influencing the structure and functioning of grassland, savanna and forest ecosystems.

Environmental Change at Cedar Creek: Most of our research takes place within the 2094 ha Cedar Creek Ecosystem Science Reserve (see *Facilities, Equipment and Other Resources*). Cedar Creek is experiencing dramatic changes in the environmental drivers that are the focus of our long-term research: climate, resources, disturbance, and biodiversity (Box 1). Global climate change is altering the means, extremes, and seasonal pattern of temperature and precipitation. Since 1964, mean annual temperature has increased 0.4°C/decade and mean annual precipitation 0.9 cm/decade (NOAA Earth System Research Laboratory, Minnesota Climate Division 6). Despite increased precipitation, Cedar Creek summers will likely become drier, as growing season evapotranspiration is projected to exceed precipitation (Seager et al. 2014, Sherwood and Fu 2014). Changes in climate have direct and indirect effects on resources. Soil moisture is likely to become more limiting (Mueller and Zhang 2016, Douville and Plazzotta 2017) and warming and soil drying will alter soil processes. Soil N supply also is influenced by atmospheric N deposition (~10 kg N ha^{-1} y^{-1} in 2015 wet+dry deposition), which declined slightly over the past 1.5 decades at CDR (National Atmospheric Deposition Program 2016). Disturbances such as fire also influence biodiversity and the availability of resources such as light and N (Pellegrini et al. 2018). Much of the CDR landscape is undergoing successional change because of reduced fire frequency, widespread oak mortality due to disease, and abandonment of agricultural fields. Old-fields at Cedar Creek range in age from 2 to 90 years, and continue to be an important palette on which CDR researchers are developing an understanding of how ecosystems recover from disturbance (Knops and Tilman 2000, Clark 2017). Changes in climate, resources, and disturbance alter the composition and diversity of the plant, animal, and microbial communities (Knops and Bradley 2009, Cavender-Bares and Reich 2012, Isbell et al. 2013a). Finally, humans have introduced exotic species and extirpated keystone animals such as bison and wolves. *Here, we propose ongoing and new manipulations of climate, resource supply rates, disturbance frequency, and the presence of key consumer groups (pathogens, herbivores, and predators) to address our core research goals.* Here and below, the research questions and hypotheses are specific and focused to the named research initiative(s); we also point out how they map onto our Themes and overarching Conceptual Framework (Figs. 14-17, Box 1) and which drivers are manipulated (Table 1).

III.B.1. Effects of Biodiversity on Ecosystem Attributes and Processes: Species, Phylogenetic, Genotypic, and Functional Diversity

Background and Key Results: A defining characteristic of CDR is its emphasis on exploring the effects of biodiversity as a *driver* of ecological processes (Box 1). We established the world's longest-running biodiversity experiments, which manipulate grassland plant species richness (*Biodiversity Experiment*, BioDiv) and species and functional group composition and richness (*Biodiversity, CO_2, and N* experiment, BioCON) (§ II.B.2, below) (Reich et al. 2012) and found that species richness is an important driver of productivity, stability, foliar chemistry, disease incidence, soil fungal and bacterial diversity and function, soil fertility, insect communities, rooting patterns, and multiple ecosystem services (Tilman et al. 1997a, Tilman et al. 2001, Mitchell et al. 2002, Tilman et al. 2006, Waldrop et al. 2006, Dybzinski et al. 2008, Fornara and Tilman 2008, Cadotte et al. 2009, Fornara et al. 2009, Haddad et al. 2009, Zavaleta

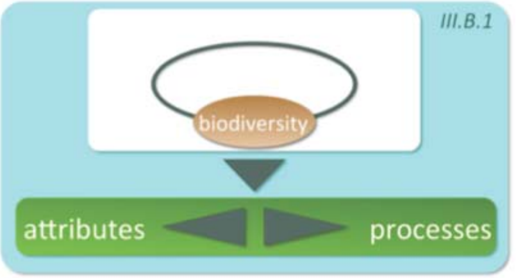


Figure 14. Modified Conceptual Framework showing that studies described in § III.B.1 largely focus on manipulations of biodiversity (species, phylogenetic, functional) as a driver. These studies are also shown in the corresponding blue section of Table 1.

et al. 2010, Haddad et al. 2011, Borer et al. 2012, Cadotte and Dinnage 2012, Reich et al. 2012, Tilman et al. 2012, Mueller et al. 2013, Borer et al. 2015, Seabloom et al. 2017). Similar effects of primary producer diversity on NPP have now been found in hundreds of other biodiversity experiments that have been conducted in grasslands, forests, and aquatic ecosystems worldwide (O'Connor et al. 2017).

While experiments at CDR and elsewhere continue to generate new insights into the role of species and functional group richness and identity, these and most other diversity experiments are unable to partition the potentially distinct effects of species richness, functional diversity (FD), and phylogenetic diversity (PD), as these components of biodiversity are highly correlated in most experimental and naturally assembled communities. Although short-term microbial experiments have begun to disentangle these (Steudel et al. 2016), demonstrating diversity effects on longer-lived organisms can require decades. In microbial communities, grasslands, and forests, plant functional diversity is key to promoting productivity and coexistence (Cadotte et al. 2009, Fornara and Tilman 2009, Cowles 2015, Grossman et al. 2017) and limiting the success of invading plant species (Fargione et al. 2003), whereas microbial phylogenetic diversity can inhibit overyielding (Steudel et al. 2016). Thus, across trophic levels, phylogenetic and functional diversity may induce different, and sometimes opposing, effects from species richness (Cadotte et al. 2009, Roscher et al. 2012, Grossman et al. 2017). Clearly, studies disentangling the influence of phylogenetic and functional diversity are sorely needed. ***We are determining the importance of species richness, phylogenetic diversity, and functional diversity in influencing species interactions (plant-plant, plant-symbiont, plant-consumer) and ecosystem processes, and how the relative importance of different aspects of diversity change over temporal and spatial scales (Fig. 14).***

To distinguish FD and PD effects in long-lived organisms, we initiated two new biodiversity experiments: *Forest and Biodiversity I* and *II* (FAB I and II) (Table 1). FAB I is a several-year-old high-density planting and FAB II is a newer lower-density planting in larger plots, suitable for measuring multi-decadal responses, where we have not yet begun measurements. Both have a gradient of species richness (1-12 species), and include plots that independently vary PD and FD. FAB II also has replicated, large monocultures of each species, and a set of known maternal lineages for five species. Although these experiments are new relative to the age and size of trees, in FAB I, functional traits and species richness already predict tree growth and damage by generalist herbivores (Fig. 6) (Grossman et al. 2017, Grossman et al. submitted). FAB I and II will continue to deepen understanding of the influence of different aspects of diversity on species interactions and ecosystem functioning.

Research Questions (Q) and Hypotheses (H):

Q1) *Which components of biodiversity (species, phylogenetic, or functional diversity) have the strongest effects on forest ecosystems at the organism, population, community, and ecosystem scales?*

> H1.1) Phylogenetic diversity will have stronger effects on herbivore diversity, leaf damage, soil microbial diversity, and fungal endophyte and ectomycorrhizal (ECM) diversity than species richness, functional trait means, or functional trait diversity, because PD is a proxy for latent variation in key traits (Webb et al. 2006, Gilbert and Webb 2007, Purschke et al. 2013, Nguyen et al. 2016). Higher phylogenetic diversity will decrease the effects of specialist herbivores but may increase the effects of generalist herbivores (Wein et al. 2016, Brezzi et al. 2017, Zhang et al. 2017).
>
> H1.2) Over multiple decades, tree maturation, self-thinning, and successional dynamics will favor less acquisitive and more stress-tolerant traits (Chapin 1980, Reich 2014). These changes in the tree community will drive successional changes in fungal endophyte, mycorrhizal, herbivore, and soil microbial community composition (Clemmensen et al. 2015, Kyaschenko et al. 2017).

Q2) *What mechanisms (e.g., complementarity or facilitation) mediate the effects of biodiversity (species, phylogenetic, or functional diversity) on community and ecosystem attributes and processes?*

> H2) Complementarity and facilitation will increasingly contribute to overyielding as forest stands develop as is found in grassland ecosystems (Fargione et al. 2007). Complementarity will increase, because morphological plasticity in response to neighbors (e.g., canopy shape) will allow increased light absorption, differences in rooting depth enable access to different soil resources, and different mycorrhizal types enable access to different nutrient pools. Facilitation will increase, because trees provide neighbors with photoprotection through shading and increased accessibility and uptake of nutrients through shared mycorrhizal networks (Bennett et al. 2017).

Study Design:

FAB I (Forest and Biodiversity I). FAB I, established in 2013 (Table 1), manipulates various aspects of diversity of 12 native angiosperm and gymnosperm tree species and includes species richness levels of 1 (n=36 plots; 3 replicates per species), 2 (n=10), 5 (n=10), and 12 (n=10) species, where 2- and 5-species mixtures are random draws. At the 2-species level, 18 additional combinations were included that followed a stratified random design to maximize differences in PD and FD. In total, 28 communities (replicated 3 times) represent 2-species mixtures with (1) low PD and high FD, (2) high PD and low FD, (3) high FD and PD, and (4) low FD and PD. PD was determined by calculating the branch length distances between species pairs. Functional diversity was determined by summing the normalized variation in specific leaf area, leaf life span, rooting depth, shade tolerance, drought tolerance, mycorrhizal type (none, ECM, AM, both), and wood density for each species and using both Scheiner et al.'s (2017) functional trait dispersion (*FTD*; correlated with species richness) or Laliberté and Legendre's (2010) functional dispersion (*FDis*; independent of species richness). Each 4.5m x 4.5m plot includes 64 trees randomly located within a 64-point grid (0.5 m spacing). Seeds were wild-collected in Minnesota.

FAB II (Forest and Biodiversity II). FAB II was established in 2016-2017. This experiment extends the work in FAB I and many other tree diversity experiment by having larger plots with 1 m spacing between individual trees to allow for long-term study; independent variation in species richness, PD, and FD; and multiple maternal lines within some species to examine genotype effects. FAB II includes several overlapping experiments. In 148 of the 10m x 10m plots (each with 100 trees), there is (1) a gradient of species richness from 1-12 species (1, 2, 4, 6 and 12 species), (2) independent variation of PD and FD in the 2, 4, and 6 species plots, and (3) multiple maternal lines (seedlings from a single mother) for five species, with about 15 maternal lineages each in each of the treatments containing those species. In 41 plots, 20m x 20m, there are (1) 36 monocultures (n=3 for each of 12 species) and (2) 5 12-species plots.

Future Research: The dynamics of long-lived organisms like trees unfold over decades as individuals mature and root systems and canopies develop, altering the aboveground resource environment and influencing soil properties and processes in ways that change belowground resource availability. Over time, as stands develop, species interactions (e.g., the consequences of neighbors for each other and for other trophic levels) will change. Thus, the effects of components of tree diversity for individual, community, and ecosystem processes can only be studied using long-term experiments. Efforts in FAB I and II will focus on annual or biannual measures of tree growth and reproduction, herbivore damage, above and belowground resources (light, soil N mineralization). To assess species effects on soil biogeochemistry and microbial communities, plots will be sampled every five years for foliar and leaf litter nutrient and carbon chemistry, root biomass and nutrient and carbon chemistry, and endophyte and soil microbial communities (Rodriguez et al. 2009). As trees mature, we will use ground-based LIDAR to measure height (Olofsson et al. 2014, Maan et al. 2015) and assess how individual canopies respond to neighbors (Williams et al. 2017). The composition of endophyte and soil microbial communities will be analyzed by culturing fungi and extracting DNA from surface sterilized leaf tissue (David et al. 2016) and from soils, and sequencing the ITS rDNA region using Illumina MiSeq sequencing (Leff et al. 2015).

III.B.2. Effects of Resources: Nutrient Enrichment and Cessation

Background and Key Results: Nutrient enrichment has long been known to increase plant productivity and decrease plant diversity in grasslands (Lawes and Gilbert 1880, Lawes et al. 1882). From its inception, CDR research has addressed the role of nutrients and nutrient enrichment in structuring populations, communities, and ecosystems (Tilman 1984, Tilman 1987), in successional grasslands, native savanna, and forests. These studies revealed strong N limitation of productivity and showed that N enrichment reduced plant species diversity, shifting the community from domination by native C_4 grasses, to domination by exotic C_3 grasses. Similarly, N addition causes strong declines in ectomycorrhizal fungal richness and dominance by nitrophilic taxa (Avis et al. 2003). More recently, we found that loss of plant species diversity reduced the stimulation of

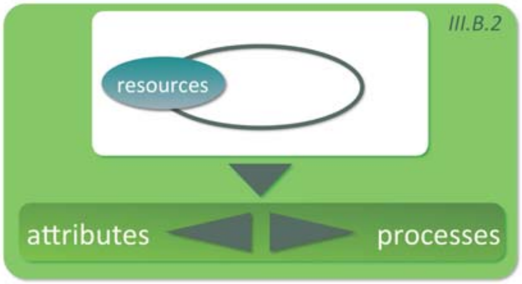


Figure 15. Modified Conceptual Framework showing that studies described in § III.B.2 largely focus on manipulations of resources (nutrients) as drivers. These studies are also shown in the corresponding green section of Table 1.

productivity by N due to negative feedbacks mediated by diversity loss (Figs. 1, 11C) (Isbell et al. 2013a). Furthermore, 20 years after N addition ceased, plots that had received 10 years of high rates of N addition (95–270 kg N ha^{-1} y^{-1}) remained dominated by two exotic C_3 grass species (*Elymus repens* and *Poa pratensis*) and still had not recovered to pretreatment diversity levels (Fig. 18) (Isbell et al. 2013b). This contrasts with results from the Park Grass Experiment, where reductions of nutrient enrichment have led to the recovery of plant diversity (Storkey et al. 2015). CDR research also showed that N limits decomposition rates, but only in the early stages of leaf litter decay when the mismatch between C:N stoichiometry of detritus and microbial biomass is greatest; in the later stages of litter decay, N inhibited decomposition, resulting in a larger slowly-decomposing litter fraction (Hobbie et al. 2012), possibly because of reduced oxidative enzyme activity. N effects on soil OM decomposition rates were less consistent when compared across sites: N either increased decomposition of fast-cycling C and reduced decomposition of slow-cycling C and microbial biomass or had little effect on SOM decomposition (Riggs et al. 2015, Riggs and Hobbie 2016, Kazanski et al. In Prep.).

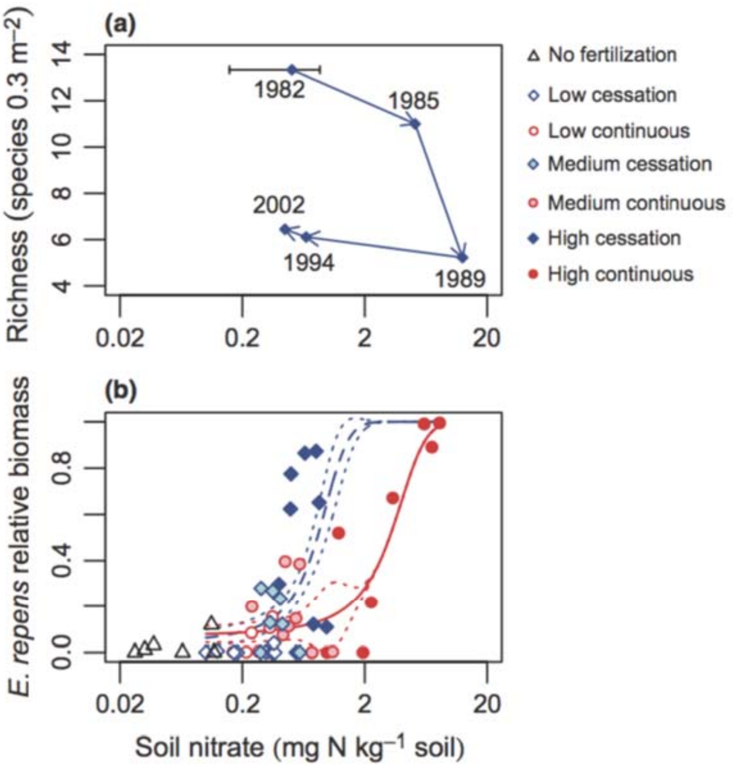


Figure 18. Effects of N addition on soil nitrate, species richness, and cover of an invasive C3 grass, *E. repens*, in long-term CDR N addition and cessation experiments. Figure modified from Isbell et al. (2013b).

Although nutrient enrichment at CDR and elsewhere increases NPP, decreases plant diversity, and alters decomposition processes, it remains unclear whether nutrient-induced plant biodiversity loss is reversible (Storkey et al. 2015), and if not, what mechanisms maintain alternative states (Carpenter et al. 1999, Schmitz 2004, Ratajczak et al. 2017), and how changes in consumer and microbial communities influence plant biodiversity, productivity, and decomposition responses to added N. CDR research suggests that regime shifts between alternative stable states reported for some eutrophic shallow lakes also may occur in grasslands. Preliminary theoretical work (§ II.B.6 and Fig. 19) suggests that C_3 grasses persist because their litter accumulates, reducing light availability and promoting rapid N cycling, even when N inputs are reduced. These effects should be offset by fire-induced N losses and reductions in litter accumulation. However, these mechanisms predicted by theory have yet to be tested experimentally. Also unknown is how consumers and soil biota mediate ecosystem responses to added N. Fungal taxa can alter decomposition rates and their response to N because of variation in traits such as N preference, exploration type, and deposition of melanin (Koide et al. 2014) and because of shifts in the fungal community among taxa that vary in their ability to degrade different C compounds (e.g., lignin vs. cellulose) (Fog 1988, van Diepen et al. 2017). N addition should reduce investment in mycorrhizae, which could lead to a competitive release of saprotrophic fungi (Fernandez and Kennedy 2016, Morrison et al. 2016), increasing decomposition rates, although N also favors ECM taxa with reduced saprotrophic capabilities (Lilleskov et al. 2002). In addition, N also might increase fungal cell wall melanin concentrations, slowing fungal necromass decomposition rates (Fernandez and Koide 2014), because fertilizer increases osmotic stress in litter due to increased solute concentrations (Kogej et al.

2006). ***We aim to determine how long-term nutrient enrichment alters plant and microbial communities and how such changes impact ecosystem processes and determine the dynamics of recovery following cessation of nutrient addition (Fig. 15).***

To achieve our aim, we are maintaining long-term N enrichment studies in grassland, savanna, and forest (Table 1). We are also continuing and planning major sampling campaigns and value-added experiments in manipulations that explore interactions between nutrient addition and consumers and decomposers. New experiments are aimed at elucidating the role of fire in reversing effects of chronic N enrichment.

Research Questions and Hypotheses:

Q3) *How are ecosystem responses to long-term nutrient enrichment mediated by changes in plant and soil-microbial community composition?*

H3) Nutrient enrichment will alter abundances of microbial guilds through both direct effects on the microbes (i.e., by alleviating nutrient limitation) as well as through effects on plant physiology and productivity, which will in turn modify both soil C and N cycling.

Q4) *Are the compositional or functional changes caused by N addition readily reversible?*

H4) Without disturbance, dominance by non-native C_3 grasses will persist, even following cessation of N addition. However, fire and consumers will counter effects of N addition on plant communities by promoting N losses, reducing litter accumulation, and increasing light availability, promoting the recovery of C_4 grasses following cessation of N enrichment.

Study Design:

N Addition and Cessation in Old-Fields. A long-term N addition experiment was established in three successional grasslands (Fields A, B, C) and a never-plowed oak savanna (Field D) at Cedar Creek in 1982 (Tilman 1987). 369 total plots (4m x 4m in Fields A, B, and C; 2m x 4m in Field D) receive non-N nutrients and N at eight rates ranging from 0 to 270 kg N ha^{-1} y^{-1} or no nutrients (unamended control) (Clark and Tilman 2008, Isbell et al. 2013a, Isbell et al. 2013b) (n=6 true replicates in old fields, n=5 true replicates in savanna). In one field (Field C), nutrient additions ceased in half of the replicate plots in 1992 (after 10 years, *Old N Cessation, Table 1*). In Fields B and C, after the first three decades (in 2014), nutrient additions were stopped in half of each replicate plot that was still receiving nutrients (*Recent N Cessation, Table 1*). In Field B, after the first decade (in 1992), fire treatments were fully crossed with N cessation.

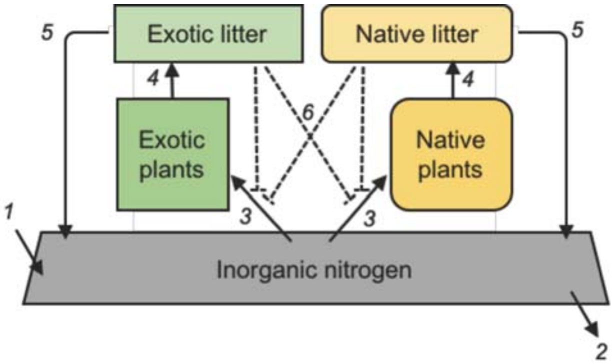


Figure 19. Ecosystem model of N cycling and interspecies interactions involves inorganic N, native and exotic plants, and their respective litter pools. Arrows represent N fluxes due to deposition (1), leaching (2), plant growth (3), death (4), and decay (5). Flat-end line segments (6) indicate inhibition of plant growth by litter pools. Differing sensitivities of native and exotic plant growth to litter can result in two stable states in the model, each dominated by one species group. Meyer et al. (In Prep.)

N addition across forests and grasslands. In 1999, we established an experiment to examine effects of N on litter decomposition across 8 sites that vary in litter chemistry (2 old-fields, 2 oak stands, 1 maple-basswood stand, 1 big-tooth aspen stand, and 2 white pine stands). In each site, 1.5m x 1.5m plots receive a water control or a fertilization treatment (10 g N m^{-2} y^{-1}). A second experiment, established in three sites (2 oak stands, 1 pine stand), manipulates different forms of N (organic vs. inorganic). These experiments continue to serve as a platform for litter and soil organic matter decomposition experiments (Hobbie 2005, 2008, Keeler et al. 2009, Hobbie et al. 2012) and have contributed to multiple syntheses (Cornwell et al. 2008, Sinsabaugh et al. 2008, Berg et al. 2010, Sinsabaugh 2010). Current research focuses on elucidating interactive effects of mycorrhizal type and N addition on soil organic matter decomposition, taking advantage of the gradient in mycorrhizal community composition from EM-dominated (oak and pine stands) to AM-dominated (maple stands, old-fields) sites, and on determining whether accumulation of greater microbial necromass during decomposition in N-fertilized plots can explain the accumulation of more slow cycling carbon during long-term decomposition of oak litter, in two oak-dominated stands.

Future Research:

N Addition and Cessation in Old-fields and *N Cessation x Fire.* The results, to date, of our N cessation experiment are paradoxical. Plots that received 10 years of low rates of N recovered diversity and composition rapidly (Clark and Tilman 2008), but plots that received high rates may have entered into a new stable state (Fig. 18) (Isbell et al. 2013b). Research on N cessation will focus on the hypothesis that fire can reverse the effects of N addition by reducing nutrient availability or increasing light availability**.** To test this, we will annually measure N pools (above and belowground live plant biomass, litter, and soil), light interception, and plant species abundance (via cover estimates and sorting clipped biomass to species).

N addition across Forests and Grasslands. We will establish new leaf litter and fungal necromass decomposition experiments to determine the relative importance of N-induced shifts in fungal traits vs. community composition (among ECM, white rot, and brown rot fungi) in determining N effects on long-term litter dynamics. There is growing recognition that dead fungal mycelium (necromass), particularly from mycorrhizal fungi, is a dominant part of soil organic matter in higher latitude forests (Clemmensen et al. 2013). Across stands that vary in their mycorrhizal type (ECM oak and pine; AM maple and grassland), we will establish long-term (4-year) decomposition experiments in control and N-fertilized plots using high-lignin (*Q. ellipsoidalis*, *Pinus strobus*) and low-lignin (*Acer saccharum*, *Schizachyrium scoparium*) leaf litter. Similarly, we will incubate fungal necromass of ECM fungal taxa that vary in melanin concentration (which controls rates of mass loss, Fernandez and Kennedy 2018). Mass loss and fungal community composition on decomposing substrates will be determined after 0.5, 1, 2, 3, and 4 years for leaf litter, and after 1, 3, 12, and 24 months for fungal necromass, which decomposes more quickly than leaf litter. Microbial community composition (high throughput sequencing) and hydrolytic (cellulases) and oxidative (phenol oxidases and peroxidases) enzyme activity for both substrates will be determined (Pritsch et al. 2011). New PI Kennedy has developed techniques for culturing large masses of fungal necromass for individual species and has deep experience with microbial community sequencing and enzymatic analyses, making this work feasible.

III.B.3. Effects of Biodiversity, Climate, and Resources on Ecosystems: Interactions between Plant Species Richness, Trophic Structure, Nutrients, Warming, and Precipitation

Background and Key Results: In addition to experiments designed to elucidate the independent effects of biodiversity (§ III.B.1), CDR experiments explore interactions between changes in biodiversity and other global change factors (Box 1), and interactions among changes in climate and resources like atmospheric CO_2 and N deposition. Some other studies have found additive effects of multiple global change factors on some response variables (e.g., Zavaleta et al. 2003). In contrast, early CDR results revealed interactions between biodiversity and climate, and between biodiversity and CO_2 or N. For instance, in an N enrichment experiment, productivity of diverse grassland plant communities was more resistant to drought, and had more fully recovered shortly after drought, than were more species-poor communities (Tilman and Downing 1994). A synthesis of data from 46 experiments, including BioCON and BioDiv, showed that biodiversity increased ecosystem resistance for a broad range of climate events. Wet or dry climate events had twice the effect on productivity in low-diversity communities than high diversity communities (Isbell et al. 2015a). Higher biodiversity also ameliorated the drying effects of warming treatment in the Biodiversity and Climate (BAC) experiment (Fig. 5) (Cowles et al. 2016), which imposes warming on a subset of BioDiv plots. In BioCON, biodiversity interacted with global changes that augment the supply of plant resources, namely elevated CO_2 and added N, such that species-rich communities responded more to resource enrichment than did species-poor

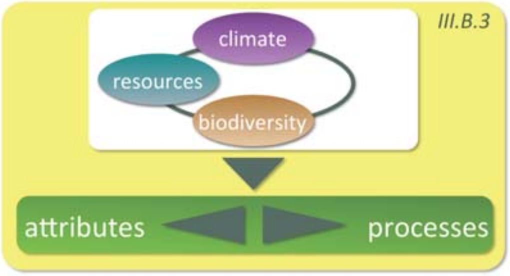


Figure 16. Modified Conceptual Framework showing that studies described in § III.B.3 largely focus on manipulations of biodiversity, resources, and climate as drivers. These studies are also shown in the corresponding yellow section of Table 1.

ones (Reich et al. 2001a) and elevated CO_2 offset the declines in biodiversity losses caused by N (Reich 2009). In BioCON, low availability of both water and N constrained productivity responses to elevated CO_2 (Reich and Hobbie 2013, Reich et al. 2014), suggesting that CO_2 fertilization effects in resource-poor environments may be modest at most (Fig. 3). In the Nutrient Network, fertilization weakened the positive effect of diversity on ecosystem stability (Hautier et al. 2014). In 12 CDR experiments, global changes decreased ecosystem stability only when they also decreased plant diversity (Fig. 4) (Hautier et al. 2015).

Variation in species and functional group composition and trophic position is also an important component of the response to global change drivers, sometimes in unexpected ways. For instance, species with C_3 and C_4 photosynthetic pathways initially showed predictable differences in biomass response to elevated CO_2 in BioCON, with C_3 species benefiting from CO_2 fertilization more than C_4 species (Fig. 12) (Reich et al. submitted). Recently, that pattern reversed. Functional group composition also drove ecosystem response to biodiversity in BioDiv: plots that contained both legumes and C_4 grasses exhibited the greatest increases in soil C (Fornara and Tilman 2008). Legumes and C_4 grass abundance also influenced fungal β-diversity (Cline et al. 2018), and the abundances of a substantial fraction of total fungal OTUs (15 and 19%, respectively). While most biodiversity experiments manipulate plants, trophic structure can have strong effects on ecosystems and interact with plant diversity (Duffy et al. 2007, Seabloom et al. 2017). In an experiment nested within BioDiv since 2008, we have manipulated presence of several broad groups of consumers (arthropods, foliar fungi, and soil fungi) to explore interactions between the diversity of primary producers and trophic structure. Effects of consumers on foliar tissue chemistry decreased with diversity (Borer et al. 2015). In contrast, the positive effect of plant diversity on productivity was much greater in the absence of consumers (Seabloom et al. 2017). Finally, the composition and functional characteristics of soil fungal and bacterial communities was significantly altered by foliar fungal exclusion, especially in low-diversity plant communities (Kinkel, unpublished).

While much has been learned about multiple resource limitation and biodiversity-stability relationships, the mechanisms underlying these relationships remain unknown. For instance, it is unclear whether biodiversity promotes ecosystem stability simply because diverse communities are more likely to include species that are highly resistant or resilient to variation in precipitation (Yachi and Loreau 1999, Loreau and de Mazancourt 2013), or because interactions between species are stabilizing (Lehman and Tilman 2000). Also unknown is how both directional and stochastic variation in external drivers, particularly climate, and the internal dynamics of the ecological system arising from responses by species and functional groups and related feedbacks drive long-term ecological responses to environmental change. Experimental comparisons of species dynamics between species in monocultures and mixtures, crossed with warming and drought treatments, and maintained for long time scales that encompass significant variation in temperature and precipitation and allow species interactions and feedbacks to play out are needed to rigorously test contrasting theoretical predictions and help determine the role of species interactions and feedbacks in diversity-stability relationships. Furthermore, while most work on the ecosystem effects of biodiversity at CDR has focused on plant diversity, diversity of vertebrate herbivores, insects, fungal pathogens can have dramatic effects on ecosystem productivity, tissue chemistry, and community composition (Ritchie et al. 1998, Knops et al. 2000, Coupe and Cahill 2003, Mitchell 2003, Gruner et al. 2008, Borer et al. 2015, Seabloom et al. 2017, 2018). ***We aim to determine how year-to-year variation in climate interacts with supply of other resources to influence community and ecosystem processes, and the mechanisms by which biodiversity at multiple trophic levels influences processes and mediates ecosystem stability in the face of environmental change (Fig. 16).***

To achieve our aim, we are maintaining multi-decadal experiments that manipulate plant species richness, temperature, and consumer identity (BioDIV, BAC, EnRem); plant species and functional group richness and composition, N inputs, atmospheric CO_2, temperature, and rainfall (BioCON, TeRaCON); and nutrient inputs and drought (IDE), towards understanding how these different treatments modulate responses to long-term fluctuations and directional changes in climate (ambient temperature and precipitation) (Table 1). We also are initiating new manipulations of drought and nutrients to determine their interactions with each other and with decadal-scale changes in ambient temperature and precipitation.

Research Questions and Hypotheses:

Q5) *Do changes in climate and resource supply dampen or amplify each other’s effects on ecosystem attributes and processes?*

H5.1) Because of strong constraints by multiple, co-limiting resources, productivity will respond more positively to elevated CO_2, added N, and warming in wet years (and treatments) than in dry years (and treatments), with water savings from elevated CO_2 (because of lower stomatal conductance) ameliorating effects of dry years, and the water losses from warming (because of greater evaporation) exacerbating them. Similarly, drought treatments will exacerbate the effects of dry years on productivity, as soil water effects are strongly non-linear.

H5.2) Nutrient addition will make plant communities less resistant to drought by decreasing plant diversity and by increasing the abundance of C_3 grasses that have lower instantaneous water-use efficiency, shallower roots, and lower root:shoot ratios.

Q6) *Does increasing biodiversity stabilize ecosystem productivity primarily due to interactions between species and/or differences between species' resistance and resilience to variation in precipitation?*

H6) Greater resistance of ecosystem productivity to year-to-year precipitation variation will result from offsetting asynchronous responses among species (i.e., some species will be impacted by dry or wet years more than others). Competitive species interactions in diverse communities will drive species abundances in opposite directions, thereby stabilizing aggregate abundances through compensatory dynamics, but destabilizing individual species abundances through reduced population stability.

Q7) *How do species composition and biodiversity influence responses of community and ecosystem attributes and processes to global change drivers (climate, CO_2, N)?*

H7) Over time, the response of different plant functional groups to environmental changes (CO_2, N, water, temperature) will be driven increasingly by biotic interactions (among plants, consumers, and mutualists) and by feedbacks involving plants and their effects on resources (light, soil nutrients), and less by their underlying direct metabolic responses (Smith et al. 2009).

Q8) *How does diversity of primary producers interact with variation in structure at higher trophic levels to alter individual, population, community, and ecosystem attributes and processes?*

H8) The strong effects of consumers on the stoichiometry and quantity of plant biomass will have cascading effects on the composition of the soil and endophytic microbial communities and on key ecosystem processes including decomposition and N mineralization.

Study Design:

BioDiv (Biodiversity), BAC (Biodiversity x Climate), and EnRem (Enemy Removal). BioDiv was established in 1994 and consists of 168 plots, each 9m x 9m, planted with ca. 30 replicates of each of five species richness treatments (1, 2, 4, 8, or 16 perennial grassland species) (Tilman et al. 2001). Plots are burned and weeded annually to maintain planted diversity treatments (abundance is allowed to fluctuate). Plots are sampled each year for species biomass and for total aboveground plant biomass. Periodic measurements have also been made of root mass, soil C and N, insect diversity, microbial diversity, microbial biomass, net N mineralization rates, exchangeable cations, soil pH, and fire intensity and extent. The *Biodiversity and Climate* experiment (BAC), begun in 2009, is nested within BioDiv and manipulated warming (Fig. 5) (Cowles et al. 2016). In 2017, we added a crossed rainfall treatment to the BAC experiment. In particular, for 32 of the 168 BioDiv plots (14 monocultures, ten 4-species plots, and eight 16-species plots) we use a subset of the plot area to impose a full-factorial design with two treatments: (1) ambient temperature vs. ~1.5°C warming above- and belowground via infra-red heating lamps (Cowles et al. 2016), and (2) ambient rainfall vs. -40% summer rainfall via a DroughtNet rainout shelter (Gherardi and Sala 2013). The four subplots per main plot thus have all combinations of these two types of treatments. The Enemy Removal experiment (EnRem) experiment is (1) nested with in BioDiv and (2) repeated in a successional old-field. In BioDiv, consumer manipulations were established in 2008 within 33 of the 9 by 9 m plant diversity plots with plant richness treatments of 1 (n=15), 4 (n=9), or 16 (n=9) species. We established five 1.5m x 2m subplots within each of the 33 plots, with each subplots randomly assigned to one of the following treatments: Control, Insecticide, Foliar Fungicide, Soil Fungicide, or All Treatments Combined (Borer et al. 2015, Seabloom et al. 2017). A similar experiment was also established in an old-field and includes a fencing treatment to exclude vertebrates. Work to date has shown that removal of consumers has strong effects on the composition of these plant communities, however there is no evidence for trade-offs in the ability of plants to defend themselves against different sets of consumers. This suggests that plants differ in their overall allocation to defense, but defense investment can offer protection against a wide array of natural enemies (Seabloom et al. 2018).

BioCON (Biodiversity x CO_2 x N) and TeRaCON (Temperature x Rainfall x CO_2). Since 1998, the main BioCON experiment manipulates plant species numbers (1, 4, 9, or 16 perennial grassland species randomly chosen from a pool of 16 species, planted as seed in 1997), soil N (ambient soil vs. ambient soil +4 g N m^{-2} yr^{-1}), and atmospheric CO_2 concentrations (ambient vs. +180 ppm) in a well-replicated split-plot experiment. It includes 296 individual plots (2m x 2m), in six 20-m diameter rings, three exposed to ambient CO_2 and three to elevated CO_2 using free-air CO_2 enrichment. Additional fully factorial (but unnamed) experiments (many plots serve multiple experiments) include tests of species composition (in monoculture) x CO_2 x N (n=128 plots, Reich et al. 2001c), and functional group richness x species richness x CO_2 x N (n=176, Reich et al. 2004, Wei et al. 2017a). The TeRaCON experiment manipulates temperature x rainfall x CO_2 x N in a full factorial manner in the 9-species plots (n=48, Reich et al. 2014, Andresen et al. 2016, Carey et al. 2016). Warming (ambient vs. +3°C) is imposed (since 2012) using feedback control of above- and belowground temperatures (using infrared lamps and vertical soil rods) (cf Rich et al. 2015), and growing season precipitation is manipulated since 2007 (ambient vs. -45% May-July rainfall) using moveable rain shelters (Reich et al. 2014).

Nutrients x Drought. The International Drought Experiment (IDE) is a coordinated, multi-site drought experiment that is designed to quantify the impacts of extreme drought across a wide range of terrestrial ecosystems based on a common experimental design and a comparable suite of measurements. Two stand-alone experiments were recently established at Cedar Creek following the IDE design. Precipitation reduction shelters were established during spring 2017 to simulate a 1 in 100-year dry event, which at our site corresponds to removing 43% of annual precipitation. The sIDE (savanna IDE) study was established in an oak savanna (Field D), consisting of 3 precipitation treatments (precipitation reduction shelter, inverted shelter as an infrastructure control, and no shelter), fully crossed with two fertilization treatments (unamended control or NutNet NPK treatment) (n=5) in 3m by 3m plots covered by 3m by 3m shelters. The tIDE (trait IDE) study was established in the 32-species plots of the BioDiv field. The three precipitation treatments described above were applied at the subplot level and fully crossed with the two existing irrigation treatments (ambient or ambient plus ~2 cm per week of irrigation) and with two of the current fertilization treatments (unamended or 14 g N m^{-2} y^{-1}) (n=6). Standard measurements across IDE include aboveground biomass, soil C and N content, % cover by species, plant traits, and daily precipitation and air temperature. Additional measurements at CDR will include light availability, root biomass, soil moisture, and decomposition rates of tea bags and tongue depressors.

Future Research: The value of both BioDiv/BAC/EnRem and BioCON/TeRaCON has grown over time, for several reasons. First, because the plants are long-lived perennials, changes in abundance because of interactions among treatments and because of biotic interactions and feedbacks can take years to play out, and species abundances and soil processes have not yet equilibrated. Second, despite long records (by ecological research standards), we still have poor sampling of the breadth of historical weather and annual climate regimes, towards assessing treatment interactions with ambient climate variation.

BioDiv/BAC/EnRem. As the world's longest-running biodiversity experiment, BioDiv (and the nested BAC/EnRem experiments) will continue elucidating the interactive effects of plant biodiversity, warming, experimental drought, species composition, and trophic structure on population dynamics and ecosystem attributes and processes. A recent comparison of soil C storage rates during succession (mean of 0.17 tonnes-C ha^{-1} yr^{-1} for the upper 0-20 cm of soil) with rates observed to date in BioDiv (Fig. 20) shows two surprising results. First, the storage rate in the highest diversity treatment in the second decade of BioDiv is three times greater (0.55 tonnes-C ha^{-1} yr^{-1}) for the upper 0-20 cm of soil than during either early or late succession. Second, the rate of soil C storage is much greater in the second decade of BioDiv than for the first decade (Tilman et al. 2006). What led to this great acceleration in the rate of soil C storage and will this continue? We hypothesize that the accelerated rate of soil C storage is related to the much greater root mass (and soil C inputs) during the second decade of the experiment. We will determine the effects of diversity on the distribution of soil C

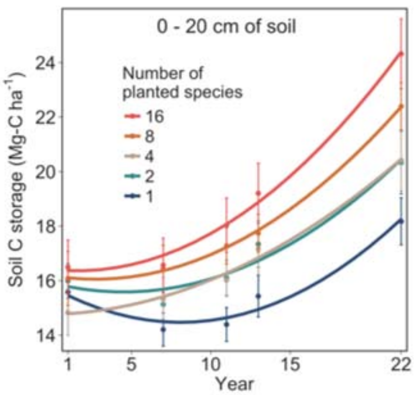


Figure 20. Change in soil C in plots planted with 1, 2, 4, 8 or 16 perennial grassland species over 22 years in the CDR BioDiv experiment. Tilman et al. (In Prep.)

among fast- versus slow-cycling organic matter (OM) fractions (i.e., particulate organic matter, mineral-associated OM, and aggregate-protected OM, Six et al. 2000, Sollins et al. 2009). Additionally, we will compare experimental effects of warming and drought to those of year-to-year climate variation and trends and tease apart the direct effects of climate on species physiology and population dynamics observable in monocultures versus effects mediated through interspecific interactions observable in species mixtures. We will focus on determining the mechanisms by which more diverse plant communities resist and recover from variation in ambient climate. We propose continued annual measurement of plant community, soil biogeochemical, and ecosystem variables across all 168 BioDiv plots and their subplots. For EnRem, we will conduct a one-time intensive sampling to directly measure the interactive effect of plant diversity and consumers on soil and endophytic microbial community composition and functional characteristics, and on ecosystem processes.

BioCON/TeRaCON. As the world's longest running Free-Air CO_2 Enrichment (FACE) experiment, and one of the few to manipulate multiple global change factors for more than three years, BioCON will continue providing valuable insights into the interactive effects of multiple global change factors on population, community, and ecosystem processes. Thus, we propose continued annual measurement of many physiological, plant and soil community, biogeochemical, and ecosystem variables across all 371 plots. New or additionally emphasized facets will include continued and enhanced assessment of soil communities (with P Trivedi, Colorado State University), local high resolution remote sensing of plant and ecosystem properties and processes, and integration of BioCON results in ecosystem to global land surface models (with P Thornton, ORNL, and others; see § II.B.6). BioCON is particularly suited for examining the role of feedbacks involving plants and their effects on resources (light, soil nutrients) because of annual measures of N, soil moisture, and light availability.

Nutrients x Drought. We will test our hypotheses regarding interactions between nutrient and drought manipulations by measuring species abundances and above and belowground biomass, light availability at the soil surface, and soil moisture, annually through 2021.

III.B.4. Effects of Disturbance and Biodiversity on Ecosystems: Interactions between Fire, Consumers, and Succession

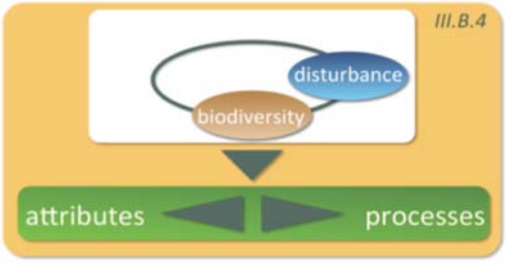


Figure 17. Modified Conceptual Framework showing that studies described in Section III.B.4 largely focus on manipulations of biodiversity (herbivores, disease) and disturbance (fire, land use change) as drivers. These studies are also shown in the corresponding orange section of Table 1.

Background and Key Results: Vegetation and ecosystem dynamics at CDR are dominated by two large-scale disturbances: fire and land use change. The ecosystem effects of altered fire frequency and old-field succession after abandonment from agriculture have been foci of research at CDR since its inception (Table 1). CDR is home to one of the world's longest-running landscape-scale fire experiments, which has been manipulating fire frequency in oak savannas since 1964, and we also maintain fire experiments in old-field ecosystems (Table 1). Studying fire effects is of particular importance, because fire frequency and intensity are changing as temperatures rise, precipitation patterns shift, and human population and infrastructure increases in fire-prone areas. Past work at CDR and elsewhere has demonstrated an overriding influence of fire in maintaining grassland openings and oak savanna at the grassland-forest border (Collins 1992, Briggs and Knapp 1995, Peterson and Reich 2001, Reich et al. 2001b, Staver et al. 2011). At CDR, fire reduces the abundance of woody plants while favoring C4 grasses; reduces soil C and N; and increases light. Together, these effects alter ecosystem and community processes and attributes such as biodiversity, NPP, and biogeochemical cycles (Peterson and Reich 2001, Reich et al. 2001b, Dijkstra et al. 2006, Hernández and Hobbie 2008, Willis et al. 2010, Cavender-Bares and Reich 2012, Pellegrini et al. 2018).

Land use change also has significant effects on ecosystems at CDR. A large portion of CDR is composed of successional old-fields that were abandoned from agriculture over the past 2 to 90 years (Inouye et al. 1987, Knops and Tilman 2000). Researchers at CDR have been investigating the recovery of biodiversity and changes in soil biogeochemistry in these fields for 35 years, and these data combined with the chronosequence of years since abandonment creates nearly a century-long successional history marked by slowly increasing soil C and N; and increasing plant richness and dominance by native C_4 grasses and woody plants; and decreasing abundance of annual species and C_3 grasses (Fig. 21) (Inouye et al. 1987, Tilman and Wedin 1991b, Knops and Tilman 2000, Clark 2017).

While many effects of fire and succession are well known at CDR, we know less about how fire interacts with consumers to alter succession, such as by speeding colonization by C_4 grasses or recovery of plant diversity. For example, in old-fields, burning increased C_4 grass abundance and lowered survival of tree seedlings (Inouye et al. 1994, Davis et al. 1998). Increased cover of C_4 grasses intensifies fires that may further inhibit tree establishment (Wragg 2015). Consumer effects on tree establishment are complex. Deer browsing can directly reduce tree survival (Inouye et al. 1994), whereas bison grazing may increase tree establishment by reducing biomass of C_4 grasses (Vinton et al. 1993, Hartnett et al. 1997, Collins et al. 1998, Knapp et al. 1999) that outcompete oak seedlings (Davis et al. 1998, Davis et al. 1999, Dickie et al. 2007) and by reducing grass-fuel loads and fire intensity (Wragg 2015).

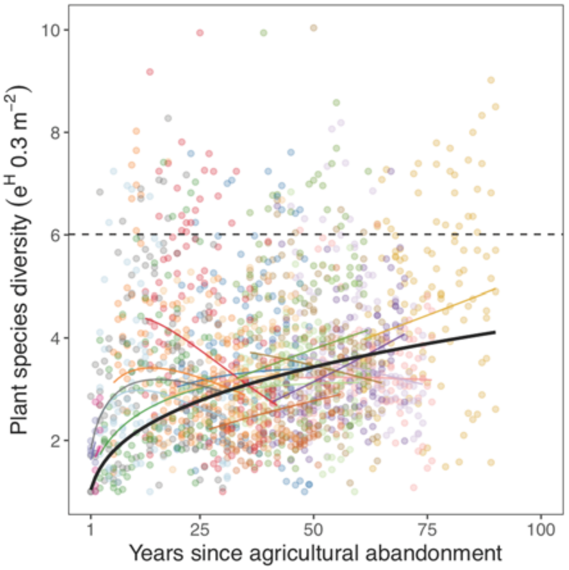


Figure 21. Plant species diversity (e^H=effective number of species) in a chronosequence of old-fields monitored over the last 35 years. Colored lines shown the trajectory of each old field, and the black line represents the mean across all the fields. The dashed line is the mean diversity in an unplowed savanna at CDR. Isbell et al. (In Prep.).

Fire effects in savanna systems are similarly complex, and our 50-year Savanna Fire Experiment has revealed a major fire-related conundrum. While fire is critical to maintaining savannas (Cavender-Bares and Reich 2012), burning alone is leading to their slow demise, because oaks are not replacing themselves (Peterson and Reich 2001). Concurrent with the lack of oak recruitment, adult oak survival is threatened (as it is worldwide) by oak wilt disease, caused by the fungus *Ceratocystis fagacearum*. It remains unclear how fire-dependent oak savanna can be restored and preserved at longer time scales. Interactions between consumers and fire may provide a partial solution. In grasslands, bison promote plant coexistence and enhance plant diversity by preferentially grazing competitively dominant C_4 grasses (Collins et al. 1998) and may similarly promote oak establishment (Davis et al. 1998). However, if bison also browse or trample oak seedlings, they might reduce oak regeneration (Davis et al. 1998). ***We aim to determine how long-term changes in fire frequency interacts with the presence of key consumers (deer, bison, and oak wilt disease) to alter vegetation and ecosystem dynamics (Fig. 17).***

Towards this end, we will maintain our longest-running experiment, a manipulation of fire frequency in oak savanna and grasslands since 1964 (Table 1). We also will layer two new studies onto this experiment: (1) we will manipulate bison presence across the fire frequency gradient to determine how bison influence oak-grass competition and oak regeneration, and (2) we will study the dynamics, spread, and consequences of oak wilt disease. In old-field ecosystems, we will intensively sample a long-term study of the interactive effects of deer herbivory and fire (and nutrients) on woody invasion, and we will continue an experiment started in 2008 that examines the effects of fire along an old field chronosequence.

Research Questions and Hypotheses:

Q9) *How does fire interact with bison grazing and deer browsing to affect savanna and grassland plant community structure, including oak regeneration and woody encroachment?*

H9.1) In savannas, bison grazing will increase oak regeneration by reducing fuels for fires, competition with dominant C_4 grasses, and deer browsing, thereby increasing oak seedling survival.

H9.2) In grasslands, fire will increase C_4 grass dominance, which will prevent woody encroachment through competition and increased fire intensity. Deer will directly reduce tree establishment through browsing, though this effect may be weaker in burned areas dominated low palatability C_4 grasses.

Q10) *How does fire alter pathogen-induced oak mortality?*

H10) In burned savannas, oak wilt will be less prevalent because fire kills the pathogen and because lower stem densities reduce the rate of disease spread.

Study Design:

Old-field Chronosequence and Fire: CDR scientists are studying 322 plots in 23 successional old-fields that were abandoned from agriculture from 1927-2015 (Inouye et al. 1987, Knops and Tilman 2000). Fields have been sampled for plant composition, biomass, and soil chemistry every 5-6 years since 1983, most recently in 2016. Since 2008, half of each field has been burned every two years (Clark 2017).

Savanna Fire Experiment. This experiment comprises 29 landscape units (3 to 27 ha) that were protected from fire from about 1900 to 1963, and since then have received varying fire frequencies. Prescribed spring ground fire treatments range from never burned to near-annual burning, spanning the range of pre-settlement fire frequencies along the forest-prairie border. Permanent sampling plots (50m x 75m) were established in 12 burn units in 1984, and in 17 more by 1995, and are sampled every five years for percent cover of all vascular plant species, assessed at sample quadrats placed at 10-m intervals along four transects in each plot (24 points/plot), most recently in 2015. More than two dozen data files are available for this experiment on CDR's website, including understory, sapling, and shrub community composition; tree species identification, status (alive, dead, snag, fallen), diameter at breast height (dbh), and height; plant biomass and productivity, including plant aboveground biomass by species; litter biomass; light penetration; plant traits; root tissue N and C; and soil N cycling.

GLADES. The Grid for Landscape Analysis and DEmographic Study (GLADES) is a 16 ha gridded (every 10 m) oak savanna plot established between 1989 and 1995 by Mark Davis (Davis et al. 1995, 2007). Soil samples were collected in 1989. All trees ≥5cm DBH were tagged in 1995 and 1996 and the grid was surveyed every five years for health status and growth. There are 11,402 total trees in the grid; 4,615 of these are dead. 90% of the trees are oaks (*Q. ellipsoidalis* and *Q. macrocarpa*). In 2016, AVIRIS NextGen hyperspectral imagery was obtained. In 2017, we geo-located every tree to link individuals to AVIRIS imagery, towards generating models of tree species identity and health status for accurate remote detection of oak wilt.

Bison x Fire. The new bison grazing by fire experiment is being established within a new 85 ha bison grazing enclosure that spans seven savanna burn units, ranging from unburned to burned 8 in every 10 years. The study will have a split-plot design, with existing fire treatments assigned to large burn units (main plots) maintained, and with grazing treatments (grazed or ungrazed by bison) applied to subplots. There will be 42 subplots (7.5m x 7.5m), consisting of six subplots within each of the seven main plots. These six subplots will consist of two ungrazed subplots inside the bison enclosure (surrounded by a bison exclosure fence), two grazed subplots inside the bison enclosure, and two ungrazed (by bison) subplots outside the bison enclosure. Subplots will be paired such that grazed and ungrazed subplots are adjacent to one another within the grazing enclosure. Seedling phytometers of two common oak species, *Q. macrocarpa* and *Q. ellipsoidalis*, will be transplanted into each plot. Perimeter fence construction is completed and exclosure fence installation is underway. Exclosure fences will also be constructed around existing plots of the Savanna Fire Experiment that will be enclosed by the perimeter fence.

N x fire x herbivore. In 2000, we began a long-term experiment in Field B to examine impacts of these three drivers in an area with rapid establishment by *Pinus strobus* (white pine). This full factorial experiment (n=4), manipulates N (0 or 3 g m^{-2} y^{-1}), fire (none or every 4 years), and deer (fenced or open to deer), for a total of 32 plots, each 20 m x 20 m.

Future Research:

Bison x Fire. Bison will graze during the growing season, released in early June and removed in October each year. For each oak seedling phytometer, we will annually measure seedling height growth, and record evidence of herbivory and mortality. Vegetation cover, light interception, acorn predation surveys, and aboveground biomass production and consumption (using moveable exclosures) will be determined annually. Root biomass and productivity, and soil moisture will be measured every five years. Protocols will follow those for the Savanna Fire Experiment.

Oak Wilt. Diseases have been, and are, a major force structiuring the forests of North America. Because Cedar Creek has not conducted oak wilt control activities, its savannas and forests document the impacts of this pathogen. In existing permanent plots (Savanna Fire Experiment and GLADES), we will conduct annual censuses to identify infected trees. Disease attribution combined with recurring censuses (see above) will link changes in structure and function to disease. In addition, we will develop a network of sample points centered on individual trees that differ in disease status and species. We will focus on the two dominant oaks (*Q. ellipsoidalis* and *Q. macrocarpa*), which differ in oak wilt susceptibility, as well as non-oak species. Plots will be centered on healthy and sick or dead individuals (50 plots x 2 species x 2 health treatments = 200 plots + 50 non oak = 250 plots total). Permanent plots will be established in 2019 and sampled every 2 years using a neighborhood approach to characterize forest structure (stem density, basal area, canopy height, leaf area) around trees.

N x Fire x Herbivore. The effects of our factorial N, Fire and Herbivore treatments on grassland succession to forest have been emerging slowly. We sampled vegetation composition, and biomass, soil, and litter C and N pools at establishment in 2000, again in 2009, and we will sample again in 2019. We are expecting dramatic treatment effects in this sampling, based on visual inspection of the plots.

III.B.5. Synthetic and Cross-site Studies

As human impacts increase (Steffen et al. 2015), it is increasingly important to develop a general understanding of how ecosystems will respond to human-induced changes in resources, disturbance, climate, and biodiversity (Box 1). Theory is a powerful tool, but most tests of theory have relied on single site experiments. Synthesis studies using data from multiple experiments or sites (Lortie 2014) allow tests of the conditions under which results from a single site can be extended to larger scales of space and time. Similarly, distributed experiments can offer powerful tests of the generality of empirical and theoretical predictions (Borer et al. 2014, Borer et al. 2017) that overcome of many of the limitations of meta-analyses, by ensuring standard treatments and data collection methods. Below we highlight major synthesis and cross-site efforts for which CDR is providing data and/or intellectual leadership.

Cross-Site Experiments

Nutrient Network Cross-Site Experiment (Borer and Seabloom, PIs; Hobbie, Participant). CDR scientists Borer and Seabloom helped found and now coordinate one of the largest of experimental networks in ecology, the Nutrient Network (NutNet; www.nutnet.org). NutNet comprises two experiments replicated in herbaceous ecosystems at >100 sites in 25 countries: (1) a factorial addition of N, P, and K plus micronutrients (NPK), and (2) a factorial NPK x herbivore exclusion (Borer et al. 2014). CDR supports NutNet coordination and data management. CDR is also the location of one of the oldest NutNet sites (started in 2007), which includes a gradient of N addition treatments in addition to the standard NutNet treatments. NutNet has provided direct tests of predictions arising from CDR research (Borer et al. 2017). For example, the positive effects of plant diversity on ecosystem productivity and stability found in experimental grasslands at CDR are also evident in dozens of naturally assembled grasslands worldwide (Tilman et al. 2006, Hautier et al. 2015, Grace et al. 2016). NutNet data have demonstrated that adding nutrients reduces plant diversity worldwide (Borer et al. 2014, Harpole et al. 2016), as it does at CDR (Clark and Tilman 2008, Isbell et al. 2013a). Additional collaborations among CDR PIs that involve NutNet are testing the ability of plant functional traits and phylogeny to predict species response to global change (Borer, Cavender-Bares, Reich, and Seabloom), the effects of nutrients and herbivores on plant endophyte communities (Borer, Kinkel, and Seabloom), and the effects of nutrients on soil organic matter dynamics (Hobbie) (Riggs et al. 2015). Future work by CDR researchers will continue to test the robustness of generalizations developed from single-site studies in NutNet, for example, whether declining effects of fertilization on NPP due to concurrent losses in biodiversity found at CDR (Fig. 1) (Isbell et al. 2013a) generalize to other sites. NutNet manipulations are now of sufficient duration to determine how human-driven enrichment of terrestrial ecosystems with N and P will alter soil C dynamics, a critical unresolved question for global ecosystem models.

Droughtnet Cross-Site Experiment (Borer, Isbell, Seabloom, Participant). We have recently established two experiments that are part of Drought-Net's distributed experiment, the International Drought Experiment, which will allow further global-scale tests of key results from long-term experiments at CDR. These drought experiments were designed to test whether high plant diversity stabilizes ecosystem productivity in response to experimental drought, a prediction based in part on observational (Tilman and Downing 1994), theoretical (Lehman and Tilman 2000), and experimental (Tilman et al. 2006, Isbell et al. 2015a) studies at CDR. CDR is providing data and intellectual expertise to this international effort, as well as experiments that uniquely cross Drought-Net rainfall reduction treatments with additional treatments to test effects of changes in nutrients, biodiversity, and temperature on ecosystem responses to drought.

Synthesis Activities

In addition to cross-site experiments, CDR researchers are involved in a number of synthetic efforts that bring together data and concepts from LTER and other sites to achieve broader understanding and inform management and policy-making. Below, we highlight those relevant to our renewal period.

Scaling-Up Productivity Responses to Changes in Biodiversity, LTER NCO Working Group (Isbell, PI). Experiments have demonstrated clear effects of local plant diversity on NPP, but whether these relationships can be extended to the regional and global scales at which biodiversity conservation and policy decisions are made remains unclear. This working group is scaling-up results from biodiversity experiments to natural communities by testing theoretical predictions and bridging gaps between experiments and observations (Isbell et al. 2017, Isbell et al. 2018). CDR is contributing data and intellectual leadership.

Advancing soil organic matter research: Synthesizing multi-scale observations, manipulations & models, *LTER NCO Working Group (Hobbie, Participant).* Changes in soil C stocks can have substantial effects on the trajectory of atmospheric CO_2 concentrations. Yet current ecosystem and ESMs are ill equipped to predict future soil C dynamics. This working group will refine and evaluate soil organic matter stabilization theories and produce a dataset that encompasses the impact of experimental manipulations on soil organic matter at different sites. CDR is contributing data from multiple experiments.

Integrating Plant Community and Ecosystem Responses to Chronic Global Change Drivers: Toward an Explanation of Patterns and Improved Global Predictions, LTER NCO Working Group (Isbell and Reich, Participants). Chronic resource enrichment is thought to alter ecosystem functioning partly by altering the numbers of species, their relative abundances, and their identities, a hypothesis being tested by this working group. CDR is contributing data and expertise related to nutrient impacts on plant communities and relationships between biodiversity and ecosystem functioning.

RCN: Cross-Scale Processes Impacting Biodiversity, NSF Research Coordination Network (Cavender-Bares, co-PI; Hobbie and Isbell, Participants). The RCN seeks to develop convergence across biological, spatial, and temporal scales, and scientific fields in the biodiversity sciences by combining expertise, data, and analytical methods in the biological, computational and environmental sciences. Four major areas are addressed: 1) Drivers of biodiversity, 2) Biodiversity detection, 3) Bioinformatics and cyberinfrastructure, 4) Scientific communication. CDR scientists will contribute data from the long-term biodiversity experiments and software tools for analysis of spectral data (Meireles et al. 2017).

Remote Sensing of Biodiversity: Linking Leaf Optical Spectra to Plant Functional Traits and Phylogenetics, NIMBioS Working Group (Cavender-Bares, PI). One of the great challenges in scaling research on the patterns and consequences of variation in biodiversity is to document patterns of biodiversity at large spatial scales. Towards that end, this working group brings together biological and computational experts to develop a framework and tools for linking spectral data, functional traits, and phylogenetics. CDR is contributing leaf spectral data from species in BioDIV and FAB for placement in a spectral library as part of an effort to allow detection and placement of plants in the tree of life from their spectral profiles (Cavender-Bares et al. 2017, Meireles et al. 2017).

Community Assembly and the Functioning of Ecosystems in Open Systems, DFG sDiv Working Group (Isbell, Participant). Local biodiversity experiments are often unable to account for regional dispersal processes that can affect the degree to which ecosystem functioning depends on species diversity and composition. This working group aims to determine the importance of dispersal for determining how the diversity and composition of communities responds to environmental change and how this can have cascading impacts on ecosystem function. CDR is contributing data and to the development of new conceptual frameworks (Bannar-Martin et al. 2018).

Quantifying Biodiversity Change through Time, DFG sDiv Working Group (Isbell, Participant). At the global scale, species extinctions are rapidly advancing. At much smaller spatial scales, however, the spatial homogenization of biota is leading to local species gains that offset, to an unknown degree, local species losses. This working group is advancing theoretical and empirical tools for detecting and attributing local biodiversity gains and losses. CDR is contributing data and expertise related to integrating time series and space-for-time comparisons.

United Nations Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES): Americas Assessment (Cavender-Bares, Coordinating Lead Author; Isbell, Lead Author) and Summary for Policy Makers (Cavender-Bares. Author), Global Land Degradation and Restoration Assessment (Isbell, Lead Author); Global Assessment (Isbell, Contributing Author). These regional and global assessments report the status and trends of anthropogenic drivers of environmental changes, biodiversity, and ecosystem functions underpinning nature's benefit to people. CDR is contributing to coordinating, writing, editing, reviewing, developing figures, and communicating the major findings of the assessments to policymakers.

bioDISCOVERY, Future Earth International Research Programme (Cavender-Bares, Participant, Steering Committee Member). This effort promotes and advances interdisciplinary collaborative research on feedbacks between global change drivers, and the biodiversity, functioning, and services of natural ecosystems to support decision-making and policies that ensure sustainable biodiversity worldwide. CDR is contributing spectral and remotely sensed images and insights from long-term biodiversity experiments.

III.B.6. Theory and Modeling

Ecological models and theory are critical tools for gaining insight into the general mechanisms governing ecological systems, developing hypotheses, and making predictions across large spatial and long temporal scales. A hallmark of the work at CDR has been the tight coupling of ecological theory and experiments. For example, some of the longest running experiments and observational studies at CDR were originally established to test theoretical predictions about competition for limiting resources and the effects of biodiversity on ecosystem productivity and stability (Tilman 1987, Tilman and Wedin 1991a, b, Tilman and Downing 1994, Tilman et al. 1997b, Lehman and Tilman 2000, Tilman et al. 2006). Current research continues to develop and test theory. For example, Adam Clark (recent CDR PhD) used data and theory from CDR to demonstrate the importance of tradeoffs in developing and applying models of community dynamics (Clark 2017, Clark et al. 2018). Among other results, models incorporating tradeoffs in plant species' ability to take up and retain N had improved capacity to predict community dynamics in BioDiv, the world's longest running biodiversity experiment.

Reversibility of N Enrichment. PIs Isbell and Hobbie are collaborating with Professor Richard McGehee (School of Mathematics) and PhD candidate Kate Meyer (Mathematics) to develop theory to investigate mechanisms that obstruct system recovery and perpetuate a eutrophic state in grasslands following cessation of long-term N enrichment (Fig. 19). This work will build on the significant advances in understanding lake eutrophication and recovery (Carpenter et al. 1999) to develop and test theory that bridges nutrient cycling and competition hypotheses to improve understanding of the abiotic and biotic conditions under which N-induced changes in productivity and diversity are readily reversible. Difficult-to-reverse transitions could be caused by (1) high rates of N recycling or (2) strong competition between native and exotic invasive plant species. Predicting whether grasslands will readily recover or not requires knowledge of mechanisms that can obstruct system recovery. For example, systems that tightly recycle nutrients (Carpenter et al. 1999) or have strong interspecific competition (Scheffer 2009) are predicted to be less likely to recover. Specifically, the removal of N by haying might have promoted recovery of the long-term nutrient addition experiment at Rothamsted (Storkey et al. 2015, Tilman and Isbell 2015), similar to how reductions in phosphorus (P) inputs and the removal of P in sediments can disrupt P recycling and promote recovery in some eutrophic lakes (Carpenter et al. 1999). An alternative, though not mutually exclusive, explanation is that strong competition for nutrients and light between native species and an exotic grass, *Elymus repens*, which invades under fertilization and persists decades after fertilization ends, underlies a lack of recovery at Cedar Creek (Isbell et al. 2013b). These generic nutrient cycling and competition hypotheses might operate in many terrestrial and aquatic ecosystems.

Scaling Biodiversity Using Remote Sensing. Recent advances in remote sensing across scales from leaves to ecosystems (Wang et al. 2016, Kothari et al. 2018, Wang et al. 2018) suggest that spectral diversity can be an important metric of biodiversity that can be detected remotely (Figs. 22 & 23). Recent research at CDR has demonstrated that diversity indices based on spectral data were able to predict ecosystem function in BioDiv either from leaf level measurements on the ground or from remotely sensed spectral profiles of pixels from spectroscopic images. This work demonstrates that spectral differences among species is tightly linked to their functional distances and phylogenetic divergence; spectral diversity is thus another dimension of biodiversity that is as, or more, useful than commonly used metrics such as species richness or phylogenetic diversity, but can be detected remotely to predict plant diversity and ecosystem function, even in the absence of knowledge of plant identity or function (Fig. 23) (Cavender-Bares et al. 2017, Gholizadeh et al. 2018, Wang et al. 2018, Schweiger et al. in review). This work has far-reaching implications for deciphering how forthcoming hyperspectral sensors to be launched via satellite can contribute to monitoring biodiversity continuously at the global scale (Jetz et al. 2016).

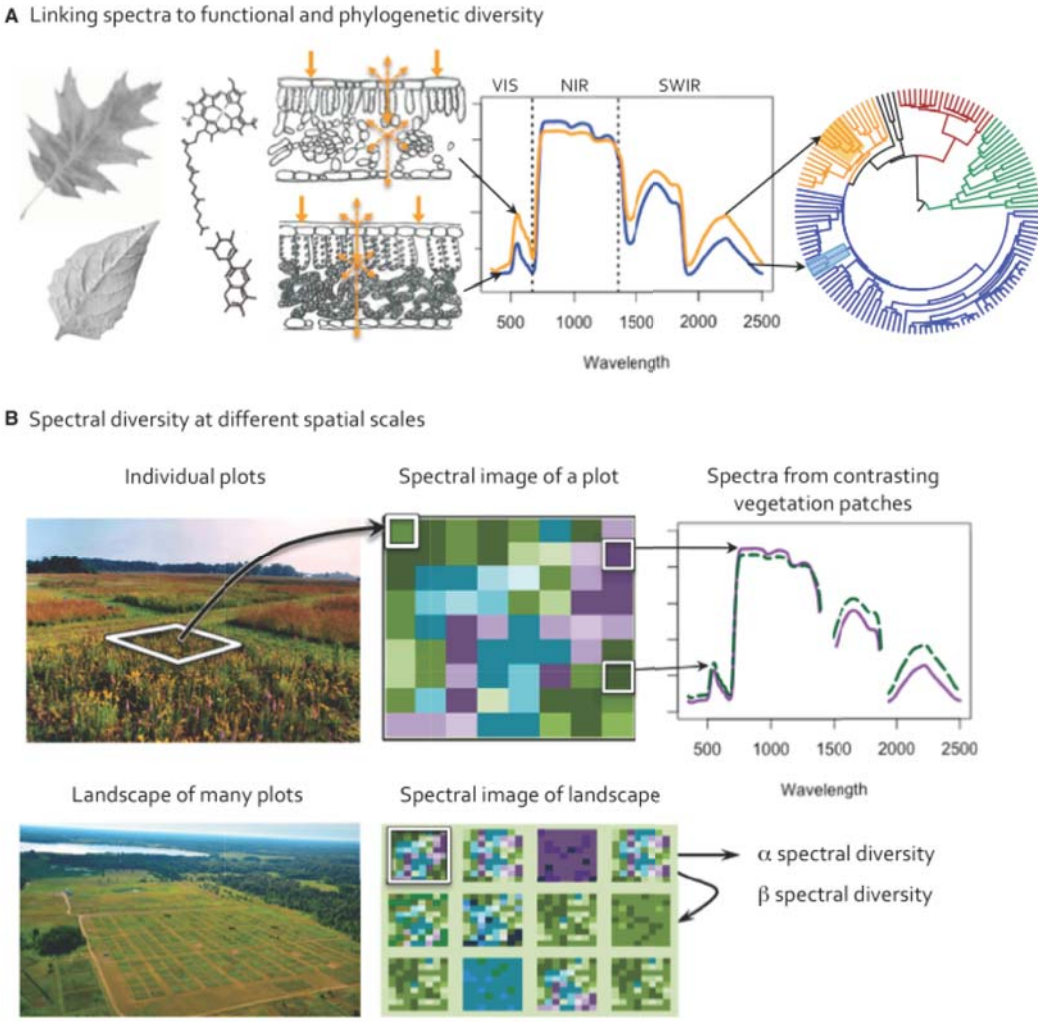


Figure 22. Leaf-level spectral measurements (A) are being combined with hyperspectral data taken at the plot to landscape scales (B) to remotely sense spectral diversity and determine the relationship between directly measured functional and phylogenetic diversity and remotely-sensed spectral diversity across spatial scales in BioDiv and other CDR experiments. Figure modified from Cavender-Bares et al. 2017.

Improving C-N-P Coupling in Process and Earth System Models. While forests are relatively well studied with regard to N effects on soil microbial communities and SOM dynamics, grasslands remain less so, despite their global importance. Hobbie is collaborating with K Hofmockel (PNNL), M Mayes (ORNL), and G. Wang (ORNL) to use LTER and NutNet data to improve the representation of decomposition in the Microbial ENzyme Decomposition (MEND) model (Wang et al. 2015). At nine North American grassland sites that are part of Nutrient Network and include the CDR, HJA, KNZ, and SGS LTER sites, we are elucidating the mechanisms underpinning N and P enrichment effects on SOM dynamics, by measuring the stoichiometry and quantities of plant inputs; the stoichiometry, composition, and activity of soil microbes; and the formation of micro- and macroaggregates. Empirical work on C-N-P interactions will be integrated into a modeling framework, via parameterization, model development, and model evaluation of the MEND model. MEND will be used to explore the combined effects of N and P enrichment on SOM dynamics via altered litter inputs and stoichiometry, microbial communities, microbial biomass, and hydrolytic vs. oxidative enzyme activity, to determine whether the proposed model structure captures the variation in soil C responses to nutrient additions observed across grasslands that vary widely in soil texture and water balance. MEND is being incorporated into the Community Land Model (CLM).

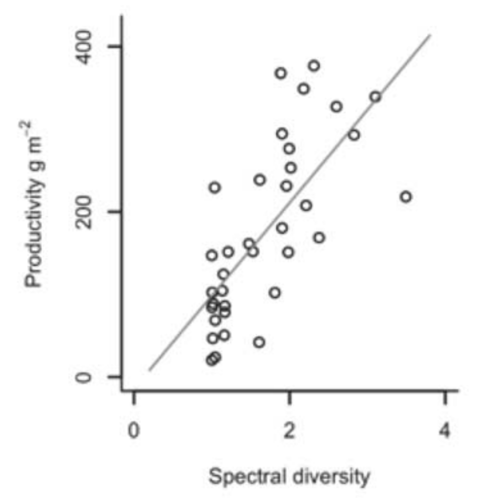


Figure 23. Spectral diversity predicts productivity in the CDR BioDiv experiment. Figure modified from Schweiger et al. (In Review).

Incorporating Trait Variation into Earth System Models. Plant traits influence ecosystem scale properties and processes and thus have become integral components of many ecosystem and land surface models. Often, traits have been parameterized using ca. 4-15 plant functional types (PFTs), each of which is assigned a static set of traits. Despite its extreme oversimplification of Earth's biodiversity, the use of PFTs has persisted because of the challenge of developing alternatives, such as continuous mapped trait surfaces. Most ESMs define a single set of parameter values globally for all cells identified with a PFT for any specific biome. While this simplification was necessary in the past, substantial improvement is now possible, due to better characterization of trait variability and its implementation in models (Butler et al. 2017). In ongoing and proposed research, PI Reich leads a collaboration with scientists at ORNL to advance understanding of terrestrial ecosystem response to global environmental change by improving the representation of plant (above- and belowground) and soil microbial traits and their interactions in terrestrial ecosystem and ESMs, building on CDR plant trait research.

III.C. Synthesis and Intellectual Merit

A wide range of human-driven environmental changes are altering the earth system, including climate, resource supply rates, disturbance rates, and biodiversity (Steffen et al. 2015). Predicting the multi-decadal *interactions among these changes*, is a major uncertainty in our ability to predict future ecosystems, their support for human well being, and role in Earth-system feedbacks. Our proposed research will achieve **intellectual merit** by advancing knowledge of how interactions among altered climate, resource supplies, disturbance, and biodiversity in turn affect the long-term functioning of ecological systems at scales ranging from individuals to ecosystems (Box 1, Table 1). We will maintain our core long-term experiments that independently manipulate unique combinations of plant and trophic biodiversity, CO_2 and nutrient supplies, climate, and disturbance and integrate new initiatives that overlay key treatments on these multi-decadal experiments to resolve critical knowledge gaps. While site-based research at CDR is at the heart of our proposed research, we also aim to expand significantly our understanding of the generality of our findings for ecosystems beyond the boundaries of CDR through cross-site experiments and synthesis activities. We continue to expand the relevance of our research through development of general theory and predictive models that allow us to scale our work.

IV. RELATED RESEARCH PROJECTS

Collaborative Research: Dimensions: Linking Remotely Sensed Optical Diversity to Genetic, Phylogenetic and Functional Diversity to Predict Ecosystem Processes. NSF Dimensions of Biodiversity. Cavender-Bares (PI), Hobbie, Montgomery, Reich (co-PIs). $855,314 to UMN. 5/1/14-4/30/19. The award funds hyperspectral remote sensing and leaf level spectral measurements to establish and understand linkages between plant spectral diversity, functional diversity, phylogenetic diversity, and intraspecific genetic diversity and that predict belowground microbial diversity and microbial function.

Collaborative Research: Elucidating Unifying Principles of Soil C-N Coupling Using a Continental-Scale Grassland Experimental Network. NSF Ecosystems. Hobbie (PI). $842,372 to UMN. 6/10/16-6/9/20. This award funds research examining the effects of N inputs on litter and soil organic matter dynamics at nine

Nutrient Network sites, including Cedar Creek. CDR support will allow expansion of that project to consider P inputs and N x P interactions, in line with our focus on multiple interacting global change factors.

Restoring and Preserving Savanna Using Bison. Legislative-Citizen Commission on Minnesota Resources. Isbell (PI), Tilman (co-PI). $388,000. 7/1/17-6/30/20. This award funds the reintroduction of bison to Cedar Creek's oak savannas. It establishes a new experiment to test how fire and grazing separately and together influence oak regeneration, biodiversity, and ecosystem productivity. Bison grazing is crossed with fire frequency in the Savanna Fire Experiment.

Enhancing research and education at Cedar Creek Ecosystem Science Reserve. USDA NIFA. Isbell (PI). $165,000. 7/1/16-6/30/19. This award funds prescribed fire management and supports the graduate fellows program (see Education and Outreach Activities).

MRI: Acquisition of an Enhanced Climate Change Simulator. NSF MRI. Reich (PI), Hobbie, Isbell (co-PIs). $400,848. 9/1/17-8/31/20. This award funds research infrastructure and equipment for the BioCON and TeRaCON experiments, which consider how biodiversity and ecosystem functioning respond to elevated C dioxide, enriched N, warming, and reduced rainfall.

Minnesota Invasive Terrestrial Plants and Pests Center. Accurate Detection and Integrated Treatment of Oak Wilt (Ceratocystis fagacearum) in Minnesota. Cavender-Bares (PI), Montgomery, Juzwik (Co-PIs). $357,419. 1/1/17 – 12/31/20. Oak wilt causes characteristic symptoms that manifest themselves at the leaf level, canopy level and stand level. These two awards foster work to test how well we can use pre-visual and visual patterns of leaf function, chemistry, pigment composition at all three scales for accurate disease detection. CCESR is a critical focal site for testing these methods.

Global Carbon and Energy Project. Sustainable Energy with Net Negative Carbon Emissions, Larson (PI), Lehman, Tilman, Williams (co-PIs). $1,406,320. 6/2015-6/2018. We are determining the effectiveness of perennial prairie plant mixtures for producing aboveground biomass for energy while sequestering C as soil organic matter. The study uses BioDiv and many additional field plots planted with prairie perennials.

LTREB: Testing paradigms about plant functional responses to global change. Hobbie (PI), Reich, Isbell, Lee (co-PIs). $398,760 (recommended). This funding will support a focus on understanding the long-term responses of plant functional types to the interactive effects of elevated CO_2 and N within BioCON.

V. EDUCATION AND OUTREACH ACTIVITIES AND BROADER IMPACTS

Building scientific literacy and providing a pathway to science. Our goal for the Cedar Creek Schoolyard-LTER (sLTER) program is to connect students, teachers, and the public to CDR's long-term ecological research through exciting hands-on experiences and direct exposure to LTER research and data, and as a result to increase scientific literacy in our local community and beyond. In 2017, our programs reached more than 10,500 people. Cedar Creek is perfectly located to provide a pathway to science learning and careers for members of the local rural community and the nearby urban community, who otherwise would have limited opportunities for direct access to science and scientists. We have built a diversity of meaningful opportunities that support lifelong learning opportunities for K-12 students, undergraduate students, graduate students, and members of the public. This pathway to science allows visitors to build on their early experiences at Cedar Creek, returning year after year to engage with LTER research. Additionally, Cedar Creek's Education and Community Engagement coordinator, Dr. Caitlin Barale Potter, serves as the co-chair of the LTER Education and Outreach Committee and is actively involved with local and national STEM organizations, further extending our collaborations and impacts.

Future plans for education and outreach

*Improved STEM Education and Educator Development***.** The centerpiece of our sLTER is hands-on inquiry-based learning at the K-12 level, with lessons and activities that link LTER experiments with science standards. Younger students inquire and observe, while older students design and conduct their own investigations, working with CDR datasets and scientists. We will expand efforts in three areas: formally evaluating the impacts of existing education programs, broadening participation for women and underrepresented groups, and enhancing the link between education programs and LTER research.

First, we will formally assess the impacts of our education programs in collaboration with a professional evaluation team from the Science Museum of Minnesota and the UMN College of Education and Human Development. We will develop assessments to regularly and efficiently measure the short- and long-term impacts of our existing programs and to expand our offerings in meaningful directions. Assessment data will be archived in CDR's database and used to continue improving sLTER programs.

Second, we will continue to *broaden participation by women and members of groups underrepresented in STEM* by maintaining a privately funded education partnership that brings students from inner-city schools to Cedar Creek for tours of experiments, inquiry and standards-based science activities, and, for many, a first encounter with nature. In the first round of these programs, 53% of participants were female, more than 76% were from low-income households, and 89% were African American, African Immigrant (primarily Somali), American Indian, Hispanic/Latino, Asian (primarily Hmong), or other non-white ethnicities. We also will continue efforts to engage with Native American communities, including a newly funded initiative to incorporate local indigenous knowledge into education programs for the new bison project. Finally, we will empower females in STEM through new work with SciGirls, a MN-based PBS program that showcases middle-school girls and women mentors working on real-world science investigations.

Third, we will enhance links between education programs and LTER research by developing new programs that highlight LTER experiments, integrating long-term data collection into student activities and expanding interactions between researchers and K-12 education staff. As additional experiments are launched, new educational activities will be developed. For example, Borer is working with the UMN Dept. of Biology, Teaching and Learning to implement an educational NutNet site (§ II.B.5). Students now enter data they collect into collaborative spreadsheets and learn how to analyze and draw conclusions from class data. Over time, visiting students and teachers will be able to compare their results to those from previous years. Potter will continue to increase access to some of CDR's classic datasets in student-friendly formats that will be incorporated into Data Jams, field trip programs, and in-school activities. Cavender-Bares and Isbell have recently developed undergraduate courses that include formal analysis of data from many CDR experiments. Formal opportunities for K-12 education staff to engage directly with researchers will occur through annual Spring Lightning Rounds and Summer Field Days, and open house events. These conversations inspire new student activities developed around LTER experiments.

Development of a Diverse, Globally Competitive STEM Workforce. We will continue mentoring undergraduate research interns each summer. Interns conduct a broad suite of measurements and maintain experimental treatments. Additionally, each intern will be encouraged to develop his/her own research project under the supervision of a senior investigator and mentorship by the CDR graduate fellows. They will receive professional development through a weekly seminar and workshop series that provides formal training on writing research proposals, reading journal articles, analyzing data, and delivering scientific presentations; and an August research symposium where they will present findings from their projects. As has been done successfully in the past, students will be encouraged to present their findings at local and national meetings and to co-author publications. In addition, we propose to fund two Research Experience for Undergraduate (REU) positions each summer. The CDR Executive Committee will request REU project proposals from CDR scientists each year. These proposals must be focused on core CDR research areas and must provide meaningful research experiences. Increasing opportunities for underrepresented groups in STEM disciplines will be a priority in filling these positions.

Increased Public Scientific Literacy and Engagement with STEM. We will continue public engagement programming, which has grown rapidly to capacity. Since the 2015 mid-term review, more than 6,000 community members have attended events or interacted with CDR scientists for a total of more than 14,000 contact hours. Potter has expanded community engagement opportunities, including publishing a quarterly newsletter, developing a membership program, coordinating volunteers, and renewing efforts in citizen science, adult education, and arts/humanities partnerships. Isbell, Potter, and site researchers communicate research, event, and site information to local and regional media on a regular basis through press releases, newsletters, and social media. A new wheelchair-accessible Minnesota Ecology Walk will introduce visitors to the major MN biomes. We will continue to seek additional funds to support our education and community engagement programs. Current funding comes from private foundations (e.g., WEM Foundation), other federal agencies (e.g., USDA), and UMN (e.g., College of Biological Sciences).

We will also connect our work on tree diversity (FAB) and disease (oak wilt) to regional resource managers through ongoing engagement with stakeholder groups including the MN Forest Resources Council, MN Society of American Foresters, MN Shade Tree Advisory Committee, MN Department of Natural Resources, and USDA Forest Service. In addition, plans are underway to partner with the newly built Bell Museum of Natural History for exhibits, workshops, public events, and summer programs.

POSTDOCTORAL MENTORING PLAN

We are committed to providing the training and support necessary for postdoctoral researchers to achieve their career goals. In the current professional climate, postdoctoral scholars need to consider the full range of career options, including academia, industry, nonprofit, and governmental; effective mentoring is essential to their success. For this reason, no single training plan will be optimal for any one person. LTER researchers have held professional positions in academia, nonprofit, and governmental agencies, and will provide career counseling for the postdoctoral fellow that includes discussions of the differences among and expectations of these different career tracks. Postdoctoral researchers hired on the LTER grant will complete an Individual Professional Development Plan, a detailed self-assessment of career goals and values and a long-term tailored mentoring plan, designed by the University of Minnesota's career development office. With this tool, mentors and postdocs will jointly design a plan that strikes an effective balance among various career-specific professional development opportunities to meet the goals they identify.

Mentoring. We will encourage best practices for mentoring among all postdoc advisors/advisees. For example, postdocs and advisors will hold weekly to bi-weekly one-on-one meetings to discuss, along with research progress, discipline-specific professional goals, career planning, advice and strategies regarding job applications and interviews (job searches, preparing applications, interviewing, negotiating), time management, alternative careers, work-life balance, publishing, writing proposals, and reviewing.

Professional Development. We will encourage postdocs to take advantage of a large number of professional development opportunities at the University of Minnesota. (1) The highly acclaimed *Preparing Future Faculty (PFF) Program* offers instruction for post-docs in preparing job applications, developing interview skills, creating teaching portfolios, and engages postdocs in pedagogical discussions and activities. Participants also have the opportunity to participate in a teaching practicum that pairs them with a teaching mentor and provides opportunities to lead classroom instruction. (2) The Institute on the Environment's Boreas Leadership program provides training in engaging diverse audiences, conflict resolution, cultural proficiency, systems thinking, communication, and other skills necessary to conduct interdisciplinary research. (3) The UMN Postdoc Association provides training workshops specific to postdocs (e.g., on writing research grants), networking opportunities, and access to other resources. (4) The Office of Equity and Diversity provides a certification program that "helps participants develop tools necessary for advancing equity and diversity in all aspects of their personal and professional lives." (5) The Center for Educational Innovation and the Center for Writing both offer regular workshops on a variety of pedagogical issues.

Publications and Presentations. Postdocs will be expected to be lead author on at least one (preferably several) publication stemming from LTER research each year. The project PIs will provide discussion, feedback, and assistance in this process, and will provide opportunities for postdocs to present work during at least one scientific conference.

Analytical Training. The major challenges facing ecology today span spatial and temporal scales and often require linking datasets collected at different scales with analytical and mathematical models. We will help postdoctoral scholars choose among workshops offered by the Minnesota Supercomputing Institute for Advanced Computational Research (MSI) and the University of Minnesota Genomics Center (UMGC), including advanced training in bioinformatics, data management, programming, and other analytical solutions (https://www.msi.umn.edu/tutorial).

Responsible Conduct of Research. Because University of Minnesota researchers are expected to exemplify the highest standards of integrity and ethical conduct, UMN requires training in the responsible conduct of research. Postdocs must complete training in concepts and best practices of research integrity, including topics such as History and Values Relating to Research and Scholarship; Social Responsibility & Reporting Misconduct; Authorship, Plagiarism & Peer Review; Fiscal Responsibilities; Intellectual Property; Research Data Management; and Conflict of Interest. UMN additionally requires annual continuing education in research ethics.

DATA MANAGEMENT PLAN

The primary goals of data management at CDR are (1) to assure long-term availability of high quality data, and (2) to enhance and promote research by facilitating data access for researchers and other data users globally.

Information Management (IM) at CDR is integrated throughout the site's research, education, and outreach programs, and the IM team is involved in the full life cycle of research projects – from data acquisition, storage, and retrieval to data analysis and publication. This involvement is essential in ensuring that data are collected and documented in a standardized manner, rigorous standards of quality control are followed, and the resultant information is available to researchers as quickly as possible. Our full life-cycle approach to IM includes the maintenance of extensive systems for automated data collection and backup. Funneling data through our centralized collection system allows us to assure the quality, on- and off-site automated backup, and availability of data to the research community. This approach was started for core LTER-funded projects, and is available and is being adopted by most other projects at the Cedar Creek Ecosystem Science Reserve.

CDR's IM team includes two full time professionals, both of whom work 75% time in their information management roles. Dan Bahauddin, who has served as CDR's Information Manager since 2006 and Susan Barrott, who has served as an Information Specialist since 2013, are primarily located at Cedar Creek and on the UMN campus, respectively. Having a full-time presence on campus and at the field site allows the IM team to maximize availability to scientists and be actively involved throughout the research process.

Infrastructure. CDR has developed a cooperative relationship with the University of Minnesota's Office of Information Technology (OIT). OIT's server and database administration groups maintain web and database servers for CDR use, allowing the IM team to focus on IM activities rather than system administration. The database administration group performs weekly maintenance of database systems, ensuring stability and security. OIT provides incremental database backups daily, with weekly full backups stored for 1 month. All local computers are continually backed up through a University of Minnesota (UMN) license with Code42 via CrashPlan, ensuring long-term security and data access. On-site data collection systems utilize remote, mirrored servers for storage of back-ends of databases, so that local failures do not result in data loss or extended downtime. Our on-site resources include a dedicated fiber line managed by UMN, wireless connectivity across the main campus of Cedar Creek, and open computer labs for data capture from instrumentation, data entry, and data quality checking.

IM procedures and protocols are well documented, and are suitable for continuity in the event of personnel turnover. Access to OIT servers and systems is protected, but is transferrable when necessary, as is access to local IM computers and accounts.

Research Planning Support. CDR's IM team works closely with scientists prior to the initiation of new research projects. Prior results, data, and methodologies are made available through our information distribution systems. Education in proper data handling and metadata standards is provided, with personal support available both on the UMN campus and on site at Cedar Creek. Research proposals, and expected data products, are tracked within the IM data systems and used to develop data plans, which include data and metadata capture by the site's data archiving and distribution systems. Researchers are encouraged to meet with the IM team on a regular basis as systems are continually evaluated.

Data Acquisition and Quality Control. CDR employs automated systems for most of its data acquisition. We develop project-specific database systems for lab and handheld field computers, greatly reducing human error and simplifying the QA/QC process. These systems are designed with scalability, usability, and continuity in mind, using common, commercially available software whenever possible. Because the data entry systems are built on a common framework, custom data entry systems can be created on request on short notice, so that the IM tools can better support, rather than restrict, research.

The extensive use of barcodes to track virtually all plant and soil samples and related chemical or physical analyses has helped eliminate data entry, sample labeling, and sample misplacement errors. Moreover, the automated data collection system resident on all CDR computers allows continuous backup of data to central servers, minimizing the danger of data loss and allowing us to run our quality control procedures to rapidly check data. Data generated through devices with integrated data loggers are annotated with unique identification codes, downloaded to local computers, and synchronized with the central databases at OIT. These types of data are generated by our weather station and other instruments, such as light meters, soil CO_2 flux meters, and TDR soil moisture devices.

Data and metadata not captured and processed through automated systems are submitted for archiving and distribution to the information manager. A sample format for submissions is available to researchers online at http://www.cedarcreek.umn.edu/research/informationmanagement. CDR and UMN have made the capture of all data gathered by all researchers at Cedar Creek a top priority. This includes CDR and non-CDR investigators and aims to increase data synthesis and collaboration. Non-CDR investigators at Cedar Creek are encouraged to use CDR data management practices, and we support datasets collected by non-CDR researchers within CDR's data systems. We additionally host and archive non-standard data in the CDR long-term archive.

CDR is committed to increasing the availability and quality of historical datasets. Significant effort is committed towards identifying missing, incomplete, or poorly documented data and towards data forensics to ensure metadata are complete and accurate.

Dataset Management and Archiving. All data, metadata, publication, and site personnel information are stored in a single Oracle relational database, which serves as the backbone for CDR's data archiving and distribution systems, personnel records, and publication catalog. Data are organized by CDR experiment number and data type, and are internally associated with publication and researcher information. We have created a web-based database interface using PHP. The database and interface are specifically designed using best practices standards developed by the LTER IM community for the Ecological Metadata Language (EML), keywords, and units. This simplifies the creation of EML documents for the LTER data catalog. CDR also uses a versioning system to track changes to any data or metadata. This allows us to generate data packages with data and metadata as they were on any given date.

CDR employs multiple data backup procedures to ensure protection from catastrophic data loss. The central database hosted by OIT is mirrored across multiple servers, with daily incremental and weekly full backups. All on-site computers at CDR are continually, incrementally backed up to a remote server (see above). Annually, all data files, along with a copy of our web server directories and text file versions of all database tables, are copied to portable media and stored in fire safes at two different remote locations.

CDR also employs multiple strategies to ensure the long-term accessibility and usability of our data and metadata as the computing and software environment evolves over time. Data archive files are created in a simple, tab delimited, format containing all data and metadata, including methods, attribute information, and personnel information. This format is designed to be easily imported into future databases or other data systems, as well as being printable in a format easily read by optical character recognition or human users. Archive files are created individually via automated scripts immediately upon entry into the relational database. On a biannual basis, automated scripts generate a complete set of archive files for all datasets in the database. CDR also archives a tab delimited text file for each table in our relational database, again via automated scripting on a biannual basis. All archive files are stored on several servers and on backup media.

CDR's metadata system uses standardized units and keywords, as developed by LTER IM working groups. These standards are designed to facilitate data discovery locally, within the LTER network, and globally. We also maintain GIS data, including bounding coordinates for experiments, cover type and soil type layers, and facilities information. These files are stored on local servers and integrated into the relational database where appropriate. Additional GIS data are available by request. As with all CDR data, GIS information is protected with multiple backup systems.

Information on CDR's archive of plant tissues and soils, as well as our insect collection, is available on our website, with instructions for how to request access.

Data Access. CDR has adopted the LTER General Data Use Agreement. All current CDR datasets are categorized as Type 1, as per the LTER Network Data Policy. Data are time-stamped within the database, and automated systems make data publicly available within two years of collection, or earlier with researcher approval. Metadata for datasets archived in our system with not-yet-released data are published and discoverable within CDR's local catalog.

Samples of datasets and associated metadata are available without a login requirement at http://www.cedarcreek.umn.edu/research/data. CDR requires users to register with our authentication system (which assists in finding publications that use CDR data) and agree to our data use policy prior to accessing full datasets. All CDR data are available with the Creative Commons Attribution license (CC BY 4.0 https://creativecommons.org/licenses/by/4.0/) to provide the greatest support for data use and synthesis. Data and metadata are available as HTML, downloadable text files, or as EML with data inline. Data and metadata files are generated dynamically on request from our Oracle database through a PHP based web interface.

All datasets available through CDR's online data catalog are also available through the Environment Data Initiative (EDI) Data Portal (494 total). Datasets are uploaded into EDI's system, or updated with new data, when data become available within the two-year time frame prescribed by LTER's Network Data Policy. New versions of all datasets occur with improvements to or expansions of CDR's collected metadata (e.g. updating the site's data sharing license). The Supplementary Document *Electronically Available Datasets* tabulates all datasets in the EDI Data Portal.

Analysis. CDR's IM personnel actively support analysis of CDR data by providing assistance with data manipulation, scripting, and advisement on prior research. The IM team also serves as a conduit to other external resources, for example arranging for server space with OIT or supercomputing resources at the Minnesota Supercomputing Institute.

Integration with Site Science, Education, and Outreach. CDR's IM team works closely with education and outreach personnel. Datasets and analysis techniques are cooperatively designed for visiting students and on-site teacher training. CDR's web site is used to communicate current research and findings to a variety of audiences. Our image archives, containing more than 10,000 photos with associated information, of plants, birds, mammals, and insects (http://www.cedarcreek.umn.edu/florafauna) have proven to be a valuable resource for the public. Images of experiments are used regularly in classes for undergraduates and graduate students and by researchers for public presentations.

IM personnel also assist with site use metrics, maintaining online systems for researchers to log their site access. Research proposals and annual reporting are captured by IM systems for archiving.

LTER Network Activity. CDR has been dedicated to network-level IM activities through participation in meetings, network committees, and working groups. Our information manager, Dan Bahauddin, has served on the IM executive committee, EML Best Practices working group, and various other teams and working groups to develop LTER-wide standards.

Data from Major Activities. Ongoing long-term datasets will be updated annually in both CDR's local data catalog and EDI's data portal. Data will be released locally and updated in the data portal within 2 years of collection. All proposed data are of Type 1, as defined in the LTER Network Data Policy. Although CDR's local data systems and EDI's data portal are not ideally suited for distribution of LIDAR and genomic data, these data will be discoverable though both catalogs, with digital pointers describing how the data may be accessed. Genomic data will be distributed though the NIH GenBank sequence database. An external data archive for LIDAR and other imagery data has yet to be determined, but will available upon request from CDR.

Anticipated Major Activities Datasets

Project Description Section	*Experiment or Initiative*	*Datasets*
III.B.1	FAB I	Tree height and diameter growth, Fruit and cone production, Herbivory, Disease, Leaf spectra
	FAB II	Tree height and diameter growth, Fruit and cone production, Herbivory, Disease, Phenology, Leaf Spectra, Soil Moisture, Soil pH, Light penetration, Net N mineralization, Plant tissue chemistry, Fungal endophyte abundance and diversity, LIDAR, Soil microbe genomic sequences, Soil C, N, exchangeable cations

III.B.2	Old Field N Addition	Aboveground plant biomass, Plant percent cover
	Old N Cessation	Aboveground plant biomass, Plant percent cover, Light interception
	New N Cessation (x Fire)	Aboveground plant biomass, Plant percent cover, Light interception
	N Addition across Forests & Grasslands	Litter decomposition, Necromass decomposition, Litter and necromass microbial genomic sequences
III.B.3	BioDiv	Above and belowground plant biomass, Plant percent cover, Soil C and N pools
	Enemy Removal	Above and belowground plant biomass, Plant percent cover, Microbial genomic sequences, Endophyte genomic sequences
	BioDiv-BAC	Above and belowground plant biomass, Plant percent cover, Soil C and N pools
	BioCON	Above and belowground plant biomass, Plant percent cover, Soil CO_2 flux, Net N mineralization, Soil C and N pools, Plant spectra, Microbial genomic sequences
	BioCON-TeRaCON	Above and belowground plant biomass, Plant percent cover, Soil CO_2 flux, Net N mineralization, Soil C and N pools, Plant spectra, Microbial genomic sequences, Soil Moisture
	BioDiv-BAC-Drought	Above and belowground plant biomass, Plant percent cover, Soil C and N pools, Soil Moisture
	Droughtnet x Nutrients	Above and belowground plant biomass, Plant percent cover, Soil C and Nutrient pools
III.B.4	Old Field Chronosequence	Above and belowground plant biomass, Plant percent cover
	Savanna Fire Experiment	Plant percent cover
	GLADES	Tree species identity, height, growth, mortality
	Bison x Fire	Seedling height, Herbivory, Mortality, Plant percent cover, Light interception, Acorn predation, Aboveground and belowground biomass, Aboveground biomass consumption
	Oak Wilt	Stem density, basal area, canopy height, leaf area
	N x Fire x Deer	Vegetation composition, Aboveground and belowground biomass, soil, and litter C and N pools
III.B.5	CDR Nutrient Network*	Plant percent cover, Aboveground biomass, Light interception, Soil C and N, Soil C fractions, Litter and root decomposition, N mineralization, Microbial biomass, Microbial genomic sequences

*International Drought Experiment (Droughtnet) datasets are included under III.B.3.

Future Activities. CDR recognizes the need for improved usability of datasets for data synthesis activities. As such, we propose to establish a data-synthesis working group (Synthesis Committee) to examine all aspects of CDR's data practices, with a focus on discoverability and metadata consistency. This committee will include IM professionals, graduate students, post-docs, and faculty from both within and outside CDR's research community. We expect that recommendations from this committee will form the basis of a major restructuring of CDR's data systems, including standardization of formats for common data types and keywords.

To better support research and synthesis, CDR also will create a repository for commonly needed scripts, maps, and other research planning and analysis tools and files. We will work with the Synthesis Committee to identify those tools and files that are most useful.

CDR recognizes that some aspects of our current data systems are not ideally suited to large, non-tabular, datasets, such as genomic and imaging data (e.g., remote sensing images, LIDAR), which will become increasingly common. We intend to identify these data types and develop strategies and data systems to either allow us to archive and distribute from our local systems or ensure they are available through other nationally recognized data catalogs with links to our data system. For example, leaf spectral data will be contributed to the Ecosystem Spectral Information System (EcoSIS) - Spectral Library (https://ecosis.org) following standards that are actively being developed and improved. EcoSIS is a publicly accessible NASA-funded database that includes NEON participation.

PROJECT MANAGEMENT PLAN

The Cedar Creek LTER project (CDR) conducts most of its research within the 2,094 ha of grassland, savanna, hardwood and mixed forest, boreal forest, bog, wetland, lake, and stream ecosystems that make up the Cedar Creek Ecosystem Science Reserve (CCESR). CDR and CCESR have worked closely together since the inception of the LTER in 1982, and both have grown and benefitted from close cooperation during the last 35 years.

Leadership of CCESR

The management of the facilities and habitats of the CCESR is performed by the staff of CCESR under the authority of the Dean of the College of Biological Sciences of the University of Minnesota (UMN). The CCESR Director (Dr. David Tilman) and Associate Director (Dr. Forest Isbell) are responsible for planning and oversight of all activities at CCESR, with Isbell being primarily responsible for day-to-day management decisions and budgets related to CCESR facilities and their use for research, education, outreach, and community relations. Isbell also chairs the CCESR Research Review Committee that evaluates all proposals for research done at CCESR and leads the Summer Research Intern program.

The staff and facilities of CCESR, funded by the University of Minnesota, provide many types of support that are vital to the success of the CDR LTER, as discussed in the Facilities section of this proposal. For example, CCESR pays for the salary of the CCESR Associate Director and Dr. Caitlin Barale-Potter, the coordinator of education and engagement activities at CDR and CCESR, including the Schoolyard LTER, which funds seasonal staff that help provide K-12 programs.

CCESR leadership is also responsible for workplace safety and training for all staff, researchers, and students who work on CDR projects. A particular focus has been to ensure that CCESR and CDR provide a safe and supportive work environment. As part of this, CCESR leadership has taken an active role in ensuring the workplace is free from sexual misconduct. UMN has recently implemented a new policy on Sexual Harassment, Sexual Assault, Stalking and Relationship Violence (https://policy.umn.edu/hr/sexharassassault), which requires all employees to report sexual misconduct to the UMN Title IX office and prohibits retaliation against people who make a complaint. To ensure a compassionate and discreet response to any reports of sexual misconduct, the UMN Title IX office will follow the impacted person's wishes for disclosure unless there is a significant threat to campus safety. CCESR leadership will ensure that all staff, students, and visitors are aware of this policy and the confidential resources offered by UMN including victim-survivor advocates, health center employees, and counselors.

The CCESR and CDR leadership work together closely, and have a long history of collaboration. CCESR Director Tilman served as the LTER PI for many years, and CCESR Associate Director Isbell has served on the CDR Executive Committee. Isbell and Tilman also are members of the LTER research team. In turn, CDR co-leaders Hobbie and Seabloom are members of the CCESR Advisory Committee that provides broad guidance for the CCESR Director and Associate Director.

Leadership of the CDR LTER

In 2012, Tilman (then sole lead PI), having led the LTER for 30 years, put into place a deliberate long-term plan to transition leadership of the LTER. In response to a leadership workshop offered by the LTER Science Council, Tilman brought on Seabloom as co-lead PI. Lead-PI duties at CDR were split between Tilman and Seabloom from 2012-2015. Hobbie, who had represented CDR on the LTER Executive Board, played a close advisory role to both PIs, including helping to coordinate the mid-term review, in anticipation of taking over the co-leadership role mid-cycle. In 2015, Tilman stepped down and Seabloom and Hobbie have been co-leads from 2015 to the present. Co-leaders Hobbie and Seabloom plan to continue in their current roles for at least the duration of the proposed renewal. This co-leadership model has been very effective and has increased the intellectual and administrative diversity in the leadership role, lowered the administrative burden on the leaders, and made for a seamless leadership transition following Tilman's stepping down. The current co-leaders (Hobbie and Seabloom) will maintain the long-standing philosophies of our LTER: open, honest, and respectful communication among all PIs, co-PIs, and Senior Personnel (CDR investigators hereafter), as well as commitment to intellectual diversity.

Among other duties, the co-leaders Hobbie and Seabloom will continue to share responsibility for supervising CDR staff; tracking CDR budgets, publications, and other products and contributions from the CDR; preparing annual and final reports for NSF; organizing the Summer Field Days and Spring Lightning Round, meetings of the CDR Executive Committee, and meetings of PIs and staff during the field season. They also will represent CDR at the National LTER Science Council meetings and one of them will serve on the LTER Executive Board at stated intervals (currently Seabloom, with Hobbie filling in as needed).

The co-leaders will receive advice and guidance from the CDR Executive Committee, which is composed of the lead PIs plus three CDR investigators (currently Borer, Cavender-Bares, and Reich). Executive Committee members serve a 2-3 year term with one member rotating off each year. The Executive Committee will meet at least once quarterly to discuss and reach consensus on all matters related to the project, focusing especially on strategic issues related to science, personnel, and their responsibilities and budgets. The Associate Director of CCESR (Isbell) will serve as an *ex officio* member of this committee. As has been our tradition, the co-lead PIs will manage based on the consensus of the CDR Executive Committee with possible rare exceptions. Other investigators at CDR will continue to have ample opportunity for involvement in management of CDR especially during discussion of new experiments, syntheses, site visits, or other research projects.

We have found that CDR research projects run most efficiently when managed by small, overlapping groups of investigators who are closely tied to each project (Table 1). To reflect this approach, budgets are allocated based on input from the all research investigators, but the day-to-day management of each project is based on the decisions of the smaller subset of investigators dedicated to each project. In addition to the research project budgets, there is a budget managed by the co-lead PIs that covers general support for research at CDR. Our proposed budget reflects the allocations made to support the research plans formulated by our full team.

Table 1. Research teams for CDR initiatives described in the Project Description.

Project Description Section	***Experiment or Initiative***	***CDR Investigators***
III.B.1	FAB I	JCB, RM, SH, PR
	FAB II	JCB, RM, SH, PR, PK
III.B.2	Old Field N Addition	FI, DT
	Old N Cessation	FI, DT
	New N Cessation (x Fire)	FI, DT, SH
	N Addition across Forests & Grasslands	SH, PK
III.B.3	BioDiv	DT, FI, LK
	Enemy Removal	ES, EB, LK
	BioDiv-BAC	DT, FI
	BioCON	PR, SH, FI, RM
	BioCON-TeRaCON	PR, SH, FI, RM
	BioDiv-BAC-Drought	DT, FI
	Droughtnet x Nutrients	FI, ES, EB
III.B.4	Old Field Chronosequence	DT, JK, FI
	Savanna Fire Experiment	PR, SH, RM, JCB
	GLADES	RM, JCB
	Bison x Fire	FI, PR
	Oak Wilt	JCB, RM
	N x Fire x Deer	JK
III.B.5	CDR Nutrient Network*	EB, ES, SH

EB, Elizabeth Borer; JCB, Jeannine Cavender-Bares; SH, Sarah Hobbie; FI, Forest Isbell; PK, Peter Kennedy; LK, Linda Kinkel; JK, Johannes (Jean) Knops; RM, Rebecca Montgomery; PR, Peter Reich; DT, David Tilman.
*International Drought Experiment (Droughtnet) datasets are included under III.B.3.

While conflict is rare at CDR, we have multiple strategies for resolving conflicts about resource allocation, personnel, or other topics. First, by rotating investigators through the Executive Committee, everyone develops a sense of responsibility for the integrity of the LTER project as a whole. In addition, there is overlap in the research teams managing larger projects, such that every LTER investigator is involved in planning multiple projects (Table 1). The overlap in the team membership encourages cooperation among projects when making larger decisions. When conflicts do arise, the LTER co-leaders are the primary contacts. The co-leadership model provides a second path for conflict resolution, because one of the co-leaders can recuse him/herself from a decision to avoid concerns about conflicts of interest. Finally, if there are conflicts that cannot be resolved by the co-leaders, they will be referred to the Executive Committee for discussion and consideration. We note here that the LTER team has moved smoothly through major leadership transitions, the addition of new LTER investigators, and turnover in the CCESR leadership without major conflict and with continued high research productivity during the duration of the current award.

Recruitment and Participation of Scientists

New members of the LTER team of investigators is composed of scientists that have shown a long-term commitment to having work at the LTER as a core of their research. Borer and Seabloom joined the LTER team in 2010, and Isbell joined in 2015. In this proposal, we are adding Peter Kennedy to the LTER team. Kennedy has been working at CDR since his arrival at UMN in 2013. His participation will greatly enhance the LTER team's expertise in microbial ecology, as he brings expertise in mycorrhizal ecology, and fungal biology more broadly, including culturing, sequencing, and a variety of other laboratory and field techniques.

The LTER investigators represent only a fraction of the scientists working at the CCESR site and in the LTER experiments, and the diverse perspective of these scientists add greatly to the innovative nature of CDR research. During the 2013-2018 LTER, 10 visiting graduate students and postdocs and more than 25 senior scholars have worked with the CDR team, with about 75% of these individuals being faculty at other institutions. The scientists are welcomed and given access to the facilities at CCESR, opportunities to start new research projects, and opportunities to sample LTER experiments and use LTER data. In particular, the BioCON/TeRaCON, BioDiv, Savanna Fire, Nutrient Network, and Old Field Chronosequence experiments have served and continue to serve as research platforms for numerous non-LTER investigators, from the US and abroad.

SUPPLEMENT: ELECTRONICALLY AVAILABLE DATASETS

The following table lists all CDR datasets available through the Environmental Data Initiative (EDI) Data Portal (494 total). Datasets are organized by establishment date of the experiment in which they were collected. Each citation includes the DOI for the dataset at the EDI repository. Datasets that have contributed to CDR's 10 Most Significant Papers (see Project Description) include the paper citations below the dataset citations. LTER Core Research Areas are listed for each dataset, where PP=Primary Production, PS=Population Studies, MI=Movement of Inorganic Matter, MO=Movement of Organic Matter, and DP=Disturbance Patterns.

EDI Package ID	Citation	LTER Core Area
knb-lter-cdr.1.8	Percent light penetration: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/3da36e293c52fdb1803f16ed0b9ffbb7	PP, MI
knb-lter-cdr.10.8	Soil Calcium: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/34302124ab9cc53fb476a7991830ab7e	MO, MI
knb-lter-cdr.11.8	Soil potassium: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/5f158b48d22289bf6cdd6e05913818ae	MO, MI
knb-lter-cdr.14.8	Plant aboveground biomass data: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/93b27926879861815ebb021bfd6f14ae Significant Publication: Hautier, Y.; Tilman, D.; Isbell, F.; Seabloom, E. W.; Borer, E. T.; Reich, P. B.; Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science, 2015, 348, 6232, 336-340 DOI:10.1126/science.aaa1788 Significant Publication: Isbell, Forest; Reich, Peter B.; Tilman, David; Hobbie, Sarah E.; Polasky, Stephen; Binder, Seth. Nutrient enrichment, biodiversity loss, and consequent declines in ecosystem productivity. Proceedings of the National Academy of Sciences of the United States of America. 2013 110 (29):11911-11916.	PP, PS, MO, MI
knb-lter-cdr.15.8	Root biomass data: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/fc9615d8efb17e1a81579336c6f5f3a9	PP, MI
knb-lter-cdr.16.8	Average soil nitrogen: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/32c88507095e009b6694b480093bc92f	MO, MI
knb-lter-cdr.2.8	Soil magnesium: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/41e57c8008948350fa3e52d3dcbdd55b	MO, MI
knb-lter-cdr.3.8	Small mammal abundance: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/7f4afa24abfd4a195afffc981b3c4bb7	PS, MI
knb-lter-cdr.4.8	Soil nitrogen: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/c0a773345bae978f6917624bc6e01ffa	MO, MI
knb-lter-cdr.406.8	Soil pH: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/b9f94e6da793edcdf7fc9aadc057f579	MO, MI
knb-lter-cdr.443.8	Root Carbon and Nitrogen: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/6d4167b8297c5418a8bef12b42c532fa	MO, MI
knb-lter-cdr.444.8	Plant aboveground biomass carbon and nitrogen: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/ccd31a0dd5bc81a7eceefc4412574fe3	MO, MI
knb-lter-cdr.472.8	Soil carbon: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018	MO, MI

	doi:10.6073/pasta/84650d56a78421d0c5eb0585397b8f99	
knb-lter-cdr.5.8	Soil ammonium: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/912c6a516168b4e0dfd3c67d20b7335c	MO, MI
knb-lter-cdr.516.8	Field C Microplot Arthropod Sweepnet Sampling: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/e3a82e3eac7e395584116a8ebfb560e3	PS, MI
knb-lter-cdr.7.8	Soil nitrate and ammonium: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/0ca0c86c968e2ed912f54d34b761265e	MO, MI
knb-lter-cdr.8.8	Soil phosphorous: Long-Term Nitrogen Deposition: Population, Community, and Ecosystem Consequences; Tilman, David; 2018 doi:10.6073/pasta/b7e75736a1fe48eda3dcee8c596cde04	MO, MI
knb-lter-cdr.18.8	Plant aboveground biomass data: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/81d5e8f28aa9ec0aeeb362e83d7dc594 Significant Publication: Hautier, Y.; Tilman, D.; Isbell, F.; Seabloom, E. W.; Borer, E. T.; Reich, P. B.; Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science, 2015, 348, 6232, 336-340 DOI:10.1126/science.aaa1788 Significant Publication: Isbell, Forest; Reich, Peter B.; Tilman, David; Hobbie, Sarah E.; Polasky, Stephen; Binder, Seth. Nutrient enrichment, biodiversity loss, and consequent declines in ecosystem productivity. Proceedings of the National Academy of Sciences of the United States of America. 2013 110 (29):11911-11916.	PP, MO, MI, DP
knb-lter-cdr.19.8	Root biomass data: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/5195df99eee76fc22fac2c210121cd98	PP, MI, DP
knb-lter-cdr.21.8	Percent light penetration: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/f947c0d8e264a87360043d4029370845	PP, MI, DP
knb-lter-cdr.22.8	Soil magnesium: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/7df8d3acb10a05bb3d87ccbfa08d3a96	MO, MI, DP
knb-lter-cdr.23.8	Small mammal abundance: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/f7121cef3e13be067c9dfaeddf53af9e	PS, MI, DP
knb-lter-cdr.24.8	Soil nitrogen: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/659e1e45fb1b36b40957e5d20ce4d49a	MO, MI, DP
knb-lter-cdr.27.8	Soil nitrate and ammonium: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/64fee0c2966e32a0703b3d7eb9b5c2b3	MO, MI, DP
knb-lter-cdr.28.8	Soil phosphorous: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/03326330aa4c2d19b3819897bf9f942b	MO, MI, DP
knb-lter-cdr.29.8	Soil Calcium: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/87a249806d5569882a0c880b5c72a55f	MO, MI, DP
knb-lter-cdr.30.8	Soil potassium: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/2a9071670a81c5db6e7533abdbc653bb	MO, MI, DP
knb-lter-cdr.407.8	Soil pH: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/77744a7ca66e9e3ae7c98f053192332a	MO, MI, DP
knb-lter-cdr.445.8	Litter carbon and nitrogen: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/239cf62449c6788d402660f77b94e0a1	MO, MI, DP
knb-lter-cdr.446.8	Root Carbon and Nitrogen: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/806338e7be5858ef6a2162f3674c560b	MO, MI, DP

knb-lter-cdr.449.8	Soil carbon: Long-Term Nitrogen Deposition During Grassland Succession; Tilman, David; 2018 doi:10.6073/pasta/eeedc0eeec318e50c3ffe9cb411e9634	MO, MI, DP
knb-lter-cdr.32.8	Soil trace metals: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/d8ab17200098ce031328745aabda1241	MI
knb-lter-cdr.33.8	Percent light penetration: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/512562d561590a28d7ca921fe907685a	PP, MI
knb-lter-cdr.35.8	Soil pH: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/3e68921cde053f1a2ab8fc5b1cfdf538	MO, MI
knb-lter-cdr.36.8	Plant aboveground biomass data: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/2ca9214185a14ef2bb253cad172874d5 Significant Publication: Hautier, Y.; Tilman, D.; Isbell, F.; Seabloom, E. W.; Borer, E. T.; Reich, P. B.; Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science, 2015, 348, 6232, 336-340 DOI:10.1126/science.aaa1788	PP, MI
knb-lter-cdr.37.8	Small mammal scatter counts: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/217a1507da9d43bd9df8a4a36bf3bf25	PS, MI
knb-lter-cdr.38.8	Soil nitrogen: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/f9d494dc199f486a38d5d16178e253e2	MO, MI
knb-lter-cdr.39.8	Soil ammonium: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/6d5cb1b7a709508e4fa94eb757d50e55	MO, MI
knb-lter-cdr.40.8	Soil nitrate: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/d89213f71506badbdccfc0344f877bfc	MO, MI
knb-lter-cdr.41.8	Soil nitrate and ammonium: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/50a0e2f1beef2bb7ed97ff55aba2f6a0	MO, MI
knb-lter-cdr.42.8	Soil phosphorous: Effects of Various Nutrients and Water on Vegetation; Tilman, David; 2018 doi:10.6073/pasta/375b70fc4ce4f17a2f27bbe94484f53c	MO, MI
knb-lter-cdr.45.8	Percent light penetration: Effect of Herbivores on Vegetation Treated with Different N Levels and the Effect of N Addition on Herbivore Populations.; Huntly, Nancy; 2018 doi:10.6073/pasta/73336bcd3d02352a2b10f06ddf5957c7	PP, MI, DP
knb-lter-cdr.46.8	Plant aboveground biomass data: Effect of Herbivores on Vegetation Treated with Different N Levels and the Effect of N Addition on Herbivore Populations.; Huntly, Nancy; 2018 doi:10.6073/pasta/80ba7727340882a73ec9f73020b0fc5a	PP, MI, DP
knb-lter-cdr.48.8	Tree data: Effects of Deer on Growth and Establishment of Woody Vegetation in Old Fields; Inouye, Richard; 2018 doi:10.6073/pasta/2cf8eef36c3f2d84a4cc9a84784271c3	PP, PS
knb-lter-cdr.49.8	Deer browse: Effects of Deer on Growth and Establishment of Woody Vegetation in Old Fields; Inouye, Richard; 2018 doi:10.6073/pasta/be6abe681a853e7d2c68cb4e28622d83	PP, PS
knb-lter-cdr.50.8	Soil nitrogen: Effects of Deer on Growth and Establishment of Woody Vegetation in Old Fields; Inouye, Richard; 2018 doi:10.6073/pasta/123d0f6699665b3aa5968124a63024ad	MO
knb-lter-cdr.52.8	Percent light penetration: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018 doi:10.6073/pasta/194d5873ebef3dd454a97b580186e4eb	PP, PS, MI
knb-lter-cdr.53.8	Plant aboveground biomass data: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018 doi:10.6073/pasta/88d0575ddac74ab12554c61c51295542	PP, PS, MI
knb-lter-cdr.54.8	Small mammal abundance: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018	PS, MI

	doi:10.6073/pasta/94aaeebed0d0174a3fe0c164370b4fe3	
knb-lter-cdr.55.8	Soil nitrogen: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018 doi:10.6073/pasta/ee2dcdf48bcec81e569d2ab9b4ba5799	MO, MI
knb-lter-cdr.56.8	Soil ammonium: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018 doi:10.6073/pasta/b8302fe5dd6873097a6aec57c5a24a75	MO, MI
knb-lter-cdr.57.8	Soil nitrate: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018 doi:10.6073/pasta/67821156dd7ffb6f628b1ef809624bc2	MO, MI
knb-lter-cdr.58.8	Average soil nitrogen: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018 doi:10.6073/pasta/35853027eefbe0220e44a0d55d87f02a	PS, MO, MI
knb-lter-cdr.59.8	Gopher mounds: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018 doi:10.6073/pasta/680acef2390a073b66d7056bf8fb61cb	PS, MI, DP
knb-lter-cdr.60.8	Grasshopper data: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018 doi:10.6073/pasta/22adb3f69621cb2502f57beee9b05c26	PS, MI, DP
knb-lter-cdr.61.8	Grasshopper individual characteristics: Effect of N Addition on Vegetation with Mammalian Herbivory; Huntly, Nancy; 2018 doi:10.6073/pasta/7ed95122028b0497dd0a194548b5cc1b	PS, MI
knb-lter-cdr.64.8	Plant aboveground biomass data: Effect of N Addition on Vegetation With Mammalian Herbivory Initially on Disked Ground; Huntly, Nancy; 2018 doi:10.6073/pasta/4ab3ea990b27404d5d7794911d19d6c8	PP, MI, DP
knb-lter-cdr.65.8	Small mammal abundance: Effect of N Addition on Vegetation With Mammalian Herbivory Initially on Disked Ground; Huntly, Nancy; 2018 doi:10.6073/pasta/049b92c48d068e0a88c8aaf151cec45c	PS, MI, DP
knb-lter-cdr.66.8	Soil nitrogen: Effect of N Addition on Vegetation With Mammalian Herbivory Initially on Disked Ground; Huntly, Nancy; 2018 doi:10.6073/pasta/71e2cdb37e2494363bfeedbbc138f87e	MO, MI, DP
knb-lter-cdr.67.8	Percent light penetration: Effect of N Addition on Vegetation With Mammalian Herbivory Initially on Disked Ground; Huntly, Nancy; 2018 doi:10.6073/pasta/d4ec046b9629ee8af1a6ff343aedc48a	PP, MI, DP
knb-lter-cdr.68.8	Gopher mounds: Effect of N Addition on Vegetation With Mammalian Herbivory Initially on Disked Ground; Huntly, Nancy; 2018 doi:10.6073/pasta/b2c2efe0a5ad7e1012917305857f6639	PS, MI, DP
knb-lter-cdr.69.8	Grasshopper data: Effect of N Addition on Vegetation With Mammalian Herbivory Initially on Disked Ground; Huntly, Nancy; 2018 doi:10.6073/pasta/48ba7ae8a9c05d4093e176ce6b655183	PS, MI, DP
knb-lter-cdr.70.8	Grasshopper individual characteristics: Effect of N Addition on Vegetation With Mammalian Herbivory Initially on Disked Ground; Huntly, Nancy; 2018 doi:10.6073/pasta/e063c85a6e84bbdabc2e4746fc3090bd	PS, MI, DP
knb-lter-cdr.72.8	Plant aboveground biomass data: Herbivore Effects on a Large, Unmanipulated Area; Huntly, Nancy; 2018 doi:10.6073/pasta/7d13cf084716c7900815d81c44c0aab1	PP, PS
knb-lter-cdr.74.8	Gopher mounds: Herbivore Effects on a Large, Unmanipulated Area; Huntly, Nancy; 2018 doi:10.6073/pasta/a9af0c0763ad54f39022b4d588c5ce80	PS
knb-lter-cdr.75.8	Grasshopper data: Herbivore Effects on a Large, Unmanipulated Area; Huntly, Nancy; 2018 doi:10.6073/pasta/bd264dd316811a91a91a03967e341e79	PS
knb-lter-cdr.76.8	Grasshopper individual characteristics: Herbivore Effects on a Large, Unmanipulated Area; Huntly, Nancy; 2018 doi:10.6073/pasta/fd05e2627feccb1492c97816ab2e5ece	PS
knb-lter-cdr.78.8	Percent light penetration: Herbivore Effects on a Large, Unmanipulated Area; Huntly, Nancy; 2018 doi:10.6073/pasta/e0ecd26d20288b44e0c724d9f069481b	PP, PS
knb-lter-cdr.79.8	Small mammal abundance: Herbivore Effects on a Large, Unmanipulated Area; Huntly, Nancy; 2018 doi:10.6073/pasta/9afb0b3e70dba1743fa342403508d67b	PS

knb-lter-cdr.80.8	Soil nitrogen: Herbivore Effects on a Large, Unmanipulated Area; Huntly, Nancy; 2018 doi:10.6073/pasta/8ad0849776fc4722af978fdc8a022604	MO
knb-lter-cdr.81.8	Plant aboveground biomass data: Effects of Nitrogen on Vegetation Under Herbivore Pressure; Inouye, Richard; 2018 doi:10.6073/pasta/7c13367fdfc236f585eec93c549f4ad5	PP, MI
knb-lter-cdr.83.8	Average soil nitrogen: Effects of Nitrogen on Vegetation Under Herbivore Pressure; Inouye, Richard; 2018 doi:10.6073/pasta/2b950ea137b077c867b3b43e0e50577c	PS, MI
knb-lter-cdr.84.8	Gopher mounds: Effects of Nitrogen on Vegetation Under Herbivore Pressure; Inouye, Richard; 2018 doi:10.6073/pasta/10b5fda6c0bbb8d12c39d030e20abf76	PS, MI, DP
knb-lter-cdr.85.8	Grasshopper data: Effects of Nitrogen on Vegetation Under Herbivore Pressure; Inouye, Richard; 2018 doi:10.6073/pasta/d53d73dcfcea3fbb67f48dd5429a0153	PS, MI
knb-lter-cdr.86.8	Grasshopper individual characteristics: Effects of Nitrogen on Vegetation Under Herbivore Pressure; Inouye, Richard; 2018 doi:10.6073/pasta/0d707bbcd3d3cd05afead5e32fce5a03	PS, MI
knb-lter-cdr.88.8	Percent light penetration: Effects of Nitrogen on Vegetation Under Herbivore Pressure; Inouye, Richard; 2018 doi:10.6073/pasta/07be4ff5e8226d5a72de9d37406bbc97	PP, MI
knb-lter-cdr.89.8	Soil nitrogen: Effects of Nitrogen on Vegetation Under Herbivore Pressure; Inouye, Richard; 2018 doi:10.6073/pasta/95037b7633badb0d948a2b1bc7519308	MO, MI
knb-lter-cdr.343.8	Soil nitrate and ammonium: Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/3593b6204768a66a62b5bda10fa1ff56	MO, DP
knb-lter-cdr.594.8	Root biomass:Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/7ace0ffaa2ce41608e81e57aceb5d64a	PP, DP
knb-lter-cdr.595.8	Root carbon and nitrogen:Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/6361e4daf4200727ecff7c2d25efcb3a	MO, DP
knb-lter-cdr.596.8	Plant aboveground biomass carbon and nitrogen:Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/1df56940b5b088a561f8d07ca20e5369	MO, DP
knb-lter-cdr.597.8	Soil bulk density:Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/8c8a8764801052d6dafb7a6938efa365	MO, DP
knb-lter-cdr.598.8	Soil carbon and nitrogen:Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/9b426dead4b6dfa57975a47ecf63ea11	MO, DP
knb-lter-cdr.599.8	Soil Nitrogen Cycling:Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/916594ff4566006f45b0bf9999ad7539	MO, DP
knb-lter-cdr.94.8	Plant species percent cover data: Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/0496cc0fd5bd68da780da66df779406d	PS, MO, MI, DP
knb-lter-cdr.95.8	Plant aboveground biomass data: Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/3f51f677f8a81e35dbbc74797e28bca4 Significant Publication: Hautier, Y.; Tilman, D.; Isbell, F.; Seabloom, E. W.; Borer, E. T.; Reich, P. B.; Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science, 2015, 348, 6232, 336-340 DOI:10.1126/science.aaa1788	PP, DP
knb-lter-cdr.96.8	Percent light penetration: Effect of Fire Frequency on Grassland Vegetation and Soils; Knops, Johannes; 2018 doi:10.6073/pasta/3b9cd516eca8e4c25806aa342afc389e	PP, DP
knb-lter-cdr.100.8	Small mammal abundance: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/bd761ec2c398fa992f744f3edeef61a5	PS, MO, DP

knb-lter-cdr.101.8	Soil nitrogen: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/cdb18a7bb4b03178b0efabb95389e7b7	MO, DP
knb-lter-cdr.102.8	Soil organic matter: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/b88c793cc4fdc0eeb232a46b3ddd169d	MO, DP
knb-lter-cdr.104.8	Maximum plant height along transects: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/0698ab5f186d54c823a76af4b3f5fff1	PP, MO, DP
knb-lter-cdr.106.8	Core Old Field Grasshopper Sampling:Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/239b3023d75d83e795a15b36fac702e2	PS
knb-lter-cdr.107.8	Plant species percent cover data: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/aa029df8f7a6091ea879ceb5c6673963	PS, MO, DP
knb-lter-cdr.108.8	Soil pH: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/94dc9be11e76058cffc5f97c58d96451	MO, DP
knb-lter-cdr.362.8	Shrub data: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/65784d398cbaeab4764982473c11241a	PS, MO, DP
knb-lter-cdr.421.8	Soil carbon: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/23447d791e2fac364d29f0888f92eb67	MO, DP
knb-lter-cdr.519.8	Supplemental Old Field Grasshopper Sampling:Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/866fecdc18d04791fc577425408e5233	PS, MO, DP
knb-lter-cdr.98.8	Percent light penetration: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/d145de38c27723e3e51c588b1dae751e	PP, MO, DP
knb-lter-cdr.99.8	Nitrogen mineralization rate: Successional Dynamics on a Resampled Chronosequence; Knops, Johannes; 2018 doi:10.6073/pasta/53bdd9e610753b151b3c8d19c407ade7	MO, DP
knb-lter-cdr.114.8	Shrub data: Effect of Burning patterns on Vegetation in the Fish Lake Burn Compartments; Tester, John; 2018 doi:10.6073/pasta/330ad5018dba507204761eac0d5c0af6	PS, MO, DP
knb-lter-cdr.344.8	Tree data: Effect of Burning patterns on Vegetation in the Fish Lake Burn Compartments; Tester, John; 2018 doi:10.6073/pasta/29f5e0b070aea4b52479b40ffe968be9	PS, MO, DP
knb-lter-cdr.360.8	Plant species percent cover data: Effect of Burning patterns on Vegetation in the Fish Lake Burn Compartments; Tester, John; 2018 doi:10.6073/pasta/fcf38058e0c4947f7817ec176df74f0c	PS, MO, DP
knb-lter-cdr.117.8	Plant aboveground biomass data: The Seasonal Effects of Nitrogen Addition in the Spring on Vegetation at Differing Times of the Growing Season; Wedin, David; 2018 doi:10.6073/pasta/0319e0cd9bc70681a416eb5d0d9928d8	PP, MI
knb-lter-cdr.120.8	Soil pH: The Effect of Nitrogen Addition and Different pH Levels on Microorganism Populations; Hankinson, Tom; 2018 doi:10.6073/pasta/db143f8f681640e65272434aa22c6862	MI
knb-lter-cdr.121.8	Plant aboveground biomass data: The Effect of Nitrogen Addition and Different pH Levels on Microorganism Populations; Hankinson, Tom; 2018 doi:10.6073/pasta/14ce64d8c94fbd4456c8c26beb0005ed	PP, MI
knb-lter-cdr.122.8	Soil ammonium: The Effect of Nitrogen Addition and Different pH Levels on Microorganism Populations; Hankinson, Tom; 2018 doi:10.6073/pasta/072f7eb016e3615ed4984209b255de73	MI
knb-lter-cdr.123.8	Soil nitrate: The Effect of Nitrogen Addition and Different pH Levels on Microorganism Populations; Hankinson, Tom; 2018 doi:10.6073/pasta/5c70355c879244229d9e223c8ea3cf24	MI
knb-lter-cdr.124.8	Percent light penetration: The Effect of Nitrogen Addition and Different pH Levels on Microorganism Populations; Hankinson, Tom; 2018 doi:10.6073/pasta/30f9418f3ca438ad32d8fcf095804649	PP, MI

knb-lter-cdr.126.8	Plant aboveground biomass data: The Effects of Adding Different Levels of Nitrogen at Different Times During the Growing Season; Inouye, Richard; 2018 doi:10.6073/pasta/e7510db34fbb68cd4ce82cb6b75cf6c5	PP, MI
knb-lter-cdr.128.8	Reproductive output: Traits: Competition and Resource Reduction for Five Grass Species Grown in Monoculture and Competition in Soils with Different Nitrogen Availabilities; Wedin, David; 2018 doi:10.6073/pasta/f04600e98398aeff0900588c079ca613	PP, PS, MI
knb-lter-cdr.130.8	Weed biomass: Traits: Competition and Resource Reduction for Five Grass Species Grown in Monoculture and Competition in Soils with Different Nitrogen Availabilities; Wedin, David; 2018 doi:10.6073/pasta/00e4b7ea6611519cc72e2d2de28b4a8a	PP, PS, MI
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knb-lter-cdr.137.8	Seed weight: Traits: Competition and Resource Reduction for Five Grass Species Grown in Monoculture and Competition in Soils with Different Nitrogen Availabilities; Wedin, David; 2018 doi:10.6073/pasta/78dbfb37d5deabca3c719753baa1fac5	PP, PS, MI
knb-lter-cdr.138.8	Available light at soil surface: Traits: Competition and Resource Reduction for Five Grass Species Grown in Monoculture and Competition in Soils with Different Nitrogen Availabilities; Wedin, David; 2018 doi:10.6073/pasta/e23354c325dfbb4d660cffcf2946430d	PP, PS, MI
knb-lter-cdr.139.8	Microbial nitrogen: Schizachyrium scoparium Nutrient Uptake Profiles; Tilman, David; 2018 doi:10.6073/pasta/30c02b4515f05930209e284d64f8bebd	PS, MO
knb-lter-cdr.140.8	Soil ammonium: Schizachyrium scoparium Nutrient Uptake Profiles; Tilman, David; 2018 doi:10.6073/pasta/302d86d4fa03254fc96ab5a1579365b7	PS, MO
knb-lter-cdr.142.8	Plant aboveground biomass data: Schizachyrium scoparium Nutrient Uptake Profiles; Tilman, David; 2018 doi:10.6073/pasta/842037839d58a80a1db8adf1543684b5	PP, PS, MO

knb-lter-cdr.143.8	Soil nitrate: Schizachyrium scoparium Nutrient Uptake Profiles; Tilman, David; 2018 doi:10.6073/pasta/127663f2da138406962810833f51d5fa	PS, MO
knb-lter-cdr.144.8	Soil ammonium: Traits: Biomass Allocation Trends in Old Field in Relation to Gradients of Succesional Age and Soil Nitrogen; Gleeson, Scott; 2018 doi:10.6073/pasta/7bab4aaf8283d26cd57d74852994811c	MO, DP
knb-lter-cdr.145.8	Soil nitrate: Traits: Biomass Allocation Trends in Old Field in Relation to Gradients of Succesional Age and Soil Nitrogen; Gleeson, Scott; 2018 doi:10.6073/pasta/791fc785606de5d4167c266c943f7d58	MO, DP
knb-lter-cdr.146.8	Plant tissue nitrogen: Traits: Biomass Allocation Trends in Old Field in Relation to Gradients of Succesional Age and Soil Nitrogen; Gleeson, Scott; 2018 doi:10.6073/pasta/7e1f90e4311db707dedbdbff51d575f1	PS, MO, DP
knb-lter-cdr.147.8	Root biomass data: Traits: Biomass Allocation Trends in Old Field in Relation to Gradients of Succesional Age and Soil Nitrogen; Gleeson, Scott; 2018 doi:10.6073/pasta/1f6292959d4d915b1f7bcadbd9c864b6	PP, PS, MO, DP
knb-lter-cdr.148.8	Plant biomass allocation: Traits: Biomass Allocation Trends in Old Field in Relation to Gradients of Succesional Age and Soil Nitrogen; Gleeson, Scott; 2018 doi:10.6073/pasta/2083c3dd5b605aae8c02a6123fc981b7	PP, PS, MO, DP
knb-lter-cdr.149.8	Plant aboveground biomass data: Traits: Biomass Allocation Trends in Old Field in Relation to Gradients of Succesional Age and Soil Nitrogen; Gleeson, Scott; 2018 doi:10.6073/pasta/13b3d4abe695f2cc08a2ec329e77ab29	PP, PS, MO, DP
knb-lter-cdr.151.8	Seedling growth: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/945004de42753293f64c001f2740306f	PS, MI, DP
knb-lter-cdr.153.8	Seedling condition: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/ea6ac424cfd6724b0d5639b587ac3ac7	PS, MI, DP
knb-lter-cdr.154.8	Maximum plant height along transects: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/e7ec33ba19c8f7bbae03a673eb4902eb	PS, MI, DP
knb-lter-cdr.155.8	Full aboveground harvest data: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/a5688f71c8485d69842fad592067e47e	PP, PS, MI, DP
knb-lter-cdr.157.8	Leaf length data: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/4b8e57202a65b5192134494f39c944ea	PS, MI, DP
knb-lter-cdr.158.8	Seedling planting information: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/62b5c31b14e8644170b059728a384d8a	PS, MI, DP
knb-lter-cdr.159.8	Seedling data: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/0fb95bec6c8cfcae3d60103a00e68e44	PS, MI, DP
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knb-lter-cdr.161.8	Root biomass data: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/ac992660a4e821907033995a0e232f60	PP, MI, DP
knb-lter-cdr.162.8	Percent light penetration: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/80e431673a0ed13bf07dd367bf50e012	PP, MI, DP
knb-lter-cdr.163.8	Soil nitrogen: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/b7e971f775ca7b7b101051d6bd33effb	MO, MI, DP
knb-lter-cdr.164.8	Soil nitrate and ammonium: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/0c411779c01345ea0853adb60087653c	MO, MI, DP
knb-lter-cdr.165.8	Plant species percent cover data: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/b64fe3151f3faec2a8c3c134e1b0ed02	PS, MI, DP
knb-lter-cdr.166.8	Soil pH: Interactive Effects of Fertility and Distribution on Plant Community Diversity	MO, MI,

	and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/9f5e4b1861e5b95ff3a458ac6f067368	DP
knb-lter-cdr.167.8	Plant aboveground biomass data: Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/398629079bf080659492f5328f051d7e	PP, MI, DP
knb-lter-cdr.520.8	e052 Field B Microplot Arthropod Sweepnet Sampling:Interactive Effects of Fertility and Distribution on Plant Community Diversity and Structure; Wilson, Scott; 2018 doi:10.6073/pasta/b2d9f547c446c6a51a50d7e81ed6a3ad	PS, MI, DP
knb-lter-cdr.168.8	Soil nitrate and ammonium: Components of Plant Competition Along an Experimental Gradient of Nitrogen Availability; Wilson, Scott; 2018 doi:10.6073/pasta/6b9265d6a2ee1afbd2796771a7ee20f5	PS, MO, MI
knb-lter-cdr.170.8	Percent light penetration: Components of Plant Competition Along an Experimental Gradient of Nitrogen Availability; Wilson, Scott; 2018 doi:10.6073/pasta/ede78eae04dff22c5868730cfaa57770	PP, PS, MI
knb-lter-cdr.174.8	Soil nitrate and ammonium: Old-Field Chronosequence: Plant Productivity; Tilman, David; 2018 doi:10.6073/pasta/dac38d41c00195f10288083196db7980	MO, DP
knb-lter-cdr.175.8	Plant aboveground biomass data: Old-Field Chronosequence: Plant Productivity; Tilman, David; 2018 doi:10.6073/pasta/84614d63ec31f1ada6076dfe8c3a6aea	PP, MO, DP
knb-lter-cdr.177.8	Percent light penetration: Plant Competition Under Different Nitrogen Levels:A Garden Experiment; Tilman, David; 2018 doi:10.6073/pasta/7d77eae633781859c18856ce89dfde74	PP, PS, MI
knb-lter-cdr.178.8	Soil nitrogen: Plant Competition Under Different Nitrogen Levels:A Garden Experiment; Tilman, David; 2018 doi:10.6073/pasta/d6b908fda52a5750735992d2f98d0952	PS, MO, MI, DP
knb-lter-cdr.179.8	Soil nitrate and ammonium: Plant Competition Under Different Nitrogen Levels:A Garden Experiment; Tilman, David; 2018 doi:10.6073/pasta/98176d544ff562ee93c1e27e87fbe6f7	PS, MO, MI, DP
knb-lter-cdr.180.8	Plant species percent cover data: Plant Competition Under Different Nitrogen Levels:A Garden Experiment; Tilman, David; 2018 doi:10.6073/pasta/29bfc8e1d0060ee979e6b8d31dc9b3cf	PS, MI
knb-lter-cdr.181.8	Plant aboveground biomass data: Plant Competition Under Different Nitrogen Levels:A Garden Experiment; Tilman, David; 2018 doi:10.6073/pasta/1d1796b2473876b4df1979de92ef02c5	PP, PS, MI
knb-lter-cdr.182.8	Belowground plant biomass data: Plant Competition Under Different Nitrogen Levels:A Garden Experiment; Tilman, David; 2018 doi:10.6073/pasta/e053180815864d1ddf953269121b903f	PP, PS, MI, DP
knb-lter-cdr.183.8	Weed biomass: Plant Competition Under Different Nitrogen Levels:A Garden Experiment; Tilman, David; 2018 doi:10.6073/pasta/eb82b9369fa04ba9f88b9d7e9b73cc73	PP, PS, MI, DP
knb-lter-cdr.184.8	Reproductive biomass: Plant Competition Under Different Nitrogen Levels:A Garden Experiment; Tilman, David; 2018 doi:10.6073/pasta/df412a98f4da7b086d73da16b8887e45	PP, PS, MI
knb-lter-cdr.185.8	Root biomass data: Plant Competition Under Different Nitrogen Levels:A Garden Experiment; Tilman, David; 2018 doi:10.6073/pasta/e1456460a23ce1309cdcf333cb36055d	PP, PS, MI, DP
knb-lter-cdr.187.8	Grasshopper cage data: Vegetation Phenology and Grasshopper Competition; Ritchie, Mark; 2018 doi:10.6073/pasta/1881b259ceed0b20196bf38d5bf3ce14	PS, MI
knb-lter-cdr.188.8	Plant aboveground biomass data: Vegetation Phenology and Grasshopper Competition; Ritchie, Mark; 2018 doi:10.6073/pasta/14a7531e783dd2c740131385f0fb8254	PP, PS, MI
knb-lter-cdr.190.8	Plant aboveground biomass data: Effect of Bird Predation on Grasshopper and Plant Communties; Ritchie, Mark; 2018 doi:10.6073/pasta/c2f9e980e071a59131a60f108689fd00	PP, PS, MI
knb-lter-cdr.191.8	Soil nitrate and ammonium: Effect of Bird Predation on Grasshopper and Plant Communties; Ritchie, Mark; 2018 doi:10.6073/pasta/ac7404f4d043514c64ffc211b1a92330	MO, MI
knb-lter-cdr.192.8	Grasshopper cage data: Effect of Bird Predation on Grasshopper and Plant Communties; Ritchie, Mark; 2018	PS, MI

	doi:10.6073/pasta/8e4dccb877ed9c77e3524dd107eb5f8a	
knb-lter-cdr.195.8	Plant aboveground biomass data: Selective Herbivory and Plant Allocation; Ritchie, Mark; 2018 doi:10.6073/pasta/eff67b18af9cfaa4d7ad20e36db02087	PP, PS, DP
knb-lter-cdr.196.8	Shrub data: Effects of Deer and Pocket Gophers on Vegetation and Soils; Inouye, Richard; 2018 doi:10.6073/pasta/e0c04df5208c256ce26b423ed326f164	PP, PS
knb-lter-cdr.197.8	Plant tissue nitrogen: Effects of Deer and Pocket Gophers on Vegetation and Soils; Inouye, Richard; 2018 doi:10.6073/pasta/990602ca6d96c2846addad37e4b534f5	PS, MO
knb-lter-cdr.198.8	Soil nitrate and ammonium: Effects of Deer and Pocket Gophers on Vegetation and Soils; Inouye, Richard; 2018 doi:10.6073/pasta/9d25ae8a9980e43865117963f17b36f1	PS, MO
knb-lter-cdr.199.8	Tree data: Forest Deer Exclosures Near the Cornea Cabin; Inouye, Richard; 2018 doi:10.6073/pasta/0f40a9f5f81f903fc581bf7576c317cb	PP, PS
knb-lter-cdr.200.8	Plant species percent cover data: Seed Size and Establishment; McGinley, Mark; 2018 doi:10.6073/pasta/826f1f84ac0b2f1c016edb2c14efa2d7	PP, PS, DP
knb-lter-cdr.201.8	Maximum plant height along transects: Seed Size and Establishment; McGinley, Mark; 2018 doi:10.6073/pasta/e474161632dd55e103089396e47f1958	PP, PS, DP
knb-lter-cdr.202.8	Soil nitrogen: Tree Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/0e8e60703b07b521fc51c1790af67cfd	MO, MI, DP
knb-lter-cdr.203.8	Plant aboveground biomass carbon and nitrogen: Tree Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/260e48b6c8a26c5ae81f7f9a337ba483	PP, PS, MI, DP
knb-lter-cdr.204.8	Root carbon/nitrogen data: Tree Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/23d6c5dafe856e0750c15d59a9127ec2	PS, MO, MI, DP
knb-lter-cdr.205.8	Plant aboveground biomass data: Tree Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/3366c91fde17e10daa93fecc0ef128a0	PP, PS, MI, DP
knb-lter-cdr.206.8	Soil nitrate and ammonium: Tree Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/8abe8d929075243dd5f2cfcd1ee89f89	MO, MI, DP
knb-lter-cdr.207.8	Soil bulk density: Tree Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/3be0dc1d4384d31612e9263046e77521	MO, DP
knb-lter-cdr.208.8	Root biomass data: Tree Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/f4e419beb5fe2d4acdeb5faa9cf2d31e	PP, PS, MI, DP
knb-lter-cdr.209.8	Plant aboveground biomass data: Legume Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/96dc2d38d56472e2728257b36fbdb9c3	PP, PS, MI, DP
knb-lter-cdr.210.8	Soil nitrate and ammonium: Legume Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/1e9d5dee4a8aab9c3ffdb85f1b16380a	MO, MI, DP
knb-lter-cdr.211.8	Weed biomass: Legume Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/a93f772e2b2f4cb3d4e7d6ccfb0097ac	PP, PS, MI, DP
knb-lter-cdr.212.8	Root biomass data: Legume Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/7116def629eefb814c65474f1b967a9c	PP, PS, MI, DP
knb-lter-cdr.213.8	Reproductive biomass: Legume Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/54e694a10780074240ea73aec9ff1b46	PS, MI, DP
knb-lter-cdr.215.8	Soil bulk density: Legume Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/890f60f94a88487032c15d2ace744311	MO
knb-lter-cdr.216.8	Root carbon/nitrogen data: Legume Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/3e82c9e86bbd026ed563e25f73276476	PP, PS, MO, MI, DP
knb-lter-cdr.217.8	Soil nitrogen: Legume Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/1f815b9d7f96bd0aa1a360f648f691fe	MO, MI, DP
knb-lter-cdr.218.8	Plant aboveground biomass carbon and nitrogen: Legume Competition Garden; Tilman, David; 2018 doi:10.6073/pasta/fae2e85c691d9ce33ca52a2a9f39d3a3	PP, PS, MO, MI, DP
knb-lter-cdr.219.8	Soil nitrate and ammonium: Mechanisms of Grasshopper-Plant Interactions; Ritchie, Mark; 2018 doi:10.6073/pasta/de40feecea987b562123963b661927c9	MO, MI, DP
knb-lter-cdr.221.8	Plant aboveground biomass data: Mechanisms of Grasshopper-Plant Interactions;	PP, PS,

	Ritchie, Mark; 2018 doi:10.6073/pasta/2fedbf2f3977db87dc380e3da25ddadb	MI, DP
knb-lter-cdr.222.8	Grasshopper cage data: Mechanisms of Grasshopper-Plant Interactions; Ritchie, Mark; 2018 doi:10.6073/pasta/9e6257a495582bbc06364dcfc2dfab6d	PS, MI, DP
knb-lter-cdr.223.8	Soil nitrate and ammonium: Long-Term Grasshopper-Plant Interactions; Ritchie, Mark; 2018 doi:10.6073/pasta/5c4640195faa97e8cba434e5020ea17c	PS, MO
knb-lter-cdr.224.8	Plant species percent cover data: Distribution of Wetland Plant Species in Relation to the Level of the Water Table; Phillips, Martha; 2018 doi:10.6073/pasta/63efc1c11189038c2da48e565074f078	PS, DP
knb-lter-cdr.382.8	Hourly climate data: Meterologic Measurements at Cedar Creek Natural History Area; Seeley, Mark; 2018 doi:10.6073/pasta/ac1b5f99b4cb838860adf30545da9413	DP
knb-lter-cdr.419.8	Daily climate summary: Meterologic Measurements at Cedar Creek Natural History Area; Seeley, Mark; 2018 doi:10.6073/pasta/e43868ad74e7734e87151758ff599f18	DP
knb-lter-cdr.420.8	Monthly precipitation from Fort Snelling near MPLS airport: Meterologic Measurements at Cedar Creek Natural History Area; Seeley, Mark; 2018 doi:10.6073/pasta/295b45d40ac7956ae51f8d21dc4cb99c	DP
knb-lter-cdr.226.8	Depth to water table; Basiletti, Mark; 2018 doi:10.6073/pasta/ebb842499dfdbc6e542b03e3f17741a9	DP
knb-lter-cdr.227.8	Plant species percent cover data: Plant Colonization and Species Diversity in an Old Field; Tilman, David; 2018 doi:10.6073/pasta/756e0b8c5d5273ab537cfd58e6bc97eb	PS
knb-lter-cdr.228.8	Seedling data: Plant Colonization and Species Diversity in an Old Field; Tilman, David; 2018 doi:10.6073/pasta/3c24aa099b56060e3b1bb1e6521412cd	PS
knb-lter-cdr.229.8	Soil nitrate and ammonium: Plant Colonization and Species Diversity in an Old Field; Tilman, David; 2018 doi:10.6073/pasta/c4e111ee60c75e40dace53377064153d	PS, MO
knb-lter-cdr.230.8	Reproductive output--number of flowering heads: The Diversity and Abundance of Prairie Plant Communties; Vincent, Tania; 2018 doi:10.6073/pasta/3c1546f58105aed94bf9e734833dcbd2	PS, MI, DP
knb-lter-cdr.231.8	Plant species percent cover data: The Diversity and Abundance of Prairie Plant Communties; Vincent, Tania; 2018 doi:10.6073/pasta/0d0ce9234c65bb1bb7569345c907acef	PS, MI, DP
knb-lter-cdr.232.8	Percent light penetration: The Diversity and Abundance of Prairie Plant Communties; Vincent, Tania; 2018 doi:10.6073/pasta/edeed56fcd51b3f34a0ce0572161b883	PP, PS, MI, DP
knb-lter-cdr.233.8	Soil nitrate and ammonium: Litter Quality and Landscape Controls of Decomposition; Wedin, David; 2018 doi:10.6073/pasta/4e9a940c5a2dce1617d302810fc8b2ea	MO
knb-lter-cdr.234.8	Soil nitrate and ammonium: Grasshopper removals; Ritchie, Mark; 2018 doi:10.6073/pasta/8ec301e1eb6c6727bbe0953e5d36b905	PS, MO, MI
knb-lter-cdr.236.8	Plant aboveground biomass data: Grasshopper removals; Ritchie, Mark; 2018 doi:10.6073/pasta/6dbfe2d8fb32450e4c6255e43ca4fa3a	PP, PS, MI
knb-lter-cdr.237.8	Seedling density: The Effect of Seed Addition on Biodiversity in an Oak Savanna; Tilman, David; 2018 doi:10.6073/pasta/69bb054870d265bb88dc59fe9a4c1fd0	PS
knb-lter-cdr.238.8	Mean percent cover--average of 2 survey groups: The Effect of Seed Addition on Biodiversity in an Oak Savanna; Tilman, David; 2018 doi:10.6073/pasta/379707473c3456718a5311b3d8081359	PS
knb-lter-cdr.239.8	Plant species percent cover data: The Effect of Seed Addition on Biodiversity in an Oak Savanna; Tilman, David; 2018 doi:10.6073/pasta/fcb3d617c223381b4c21e514b7cd8d8e	PS
knb-lter-cdr.240.8	Soil nitrate and ammonium: The Effect of Seed Addition on Biodiversity in an Oak Savanna; Tilman, David; 2018 doi:10.6073/pasta/c2bfd8ae98e6ac110b668ca61bb49520	PS, MO
knb-lter-cdr.241.8	Soil nitrate and ammonium: Soil Heterogeneity and Plant Diversity in an Oak Savanna; Tilman, David; 2018	PS, MO, DP

	doi:10.6073/pasta/78100adf8d3c08b94e7a99b1b6b9cc84	
knb-lter-cdr.242.8	Percent light penetration: Soil Heterogeneity and Plant Diversity in an Oak Savanna; Tilman, David; 2018 doi:10.6073/pasta/c29fc077547e21a68773e7292b0905ee	PP, PS, MO, DP
knb-lter-cdr.244.8	Seedling density: Soil Heterogeneity and Plant Diversity in an Oak Savanna; Tilman, David; 2018 doi:10.6073/pasta/a5ed7df0dc0dc3f81dd0fc123356dbb2	PS, MO, DP
knb-lter-cdr.247.8	Plant species percent cover data: Soil Heterogeneity and Plant Diversity in an Oak Savanna; Tilman, David; 2018 doi:10.6073/pasta/5e8a4b70b14b0e2c5a9460b2635f4939	PS, MO, DP
knb-lter-cdr.450.8	Plant aboveground biomass data: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/ef24de9bc55442766123fc02a405c13f	PP, PS, MI, DP
knb-lter-cdr.452.8	Root biomass data: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/76314e948c101eedca4f4bf83624450a	PP, PS, MI, DP
knb-lter-cdr.454.8	Percent light penetration: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/be7b084830161d1eeaf2af4d90a87ab2	PP, PS, MI, DP
knb-lter-cdr.457.8	Small mammal abundance: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/15cb85943049e3d4c51a0f196c2a4941	PS, MI, DP
knb-lter-cdr.459.8	Soil Calcium: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/ddfe7bcdb391d349e794f4ddabc677f5	MO, MI, DP
knb-lter-cdr.461.8	Soil magnesium: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/ae59e6c40de6e224e734abfabc5dc527	MO, MI, DP
knb-lter-cdr.463.8	Soil nitrate and ammonium: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/2c3271a18d05932c288dab437a351cdf	MO, MI, DP
knb-lter-cdr.465.8	Soil phosphorous: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/3303ab380c44fa0701bd0ed87b84d138	MO, MI, DP
knb-lter-cdr.466.8	Soil potassium: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/a116a1eb8eb0321a9f4c6a714d2957c3	MO, MI, DP
knb-lter-cdr.467.8	Soil pH: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/0878b44d6950a871af90f4c7235a3b5c	MO, MI, DP
knb-lter-cdr.468.8	Soil carbon: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/5eebb84a5bfa40b373756824c60df9f1	MO, MI, DP
knb-lter-cdr.471.8	Soil nitrogen: Nitrogen Addition and Dynamics of Recovery from Cessation of N Addition; Tilman, David; 2018 doi:10.6073/pasta/05b5020dc7beda5c967b42f25567dec6	MO, MI, DP
knb-lter-cdr.250.8	Soil pH: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/7cc272c11b93b4c7b227b9be048d81f4	MO, MI, DP
knb-lter-cdr.251.8	Plant aboveground biomass data: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/4a7de95329c5b96cbef4f45fcbe16334 Significant Publication: Hautier, Y.; Tilman, D.; Isbell, F.; Seabloom, E. W.; Borer, E. T.; Reich, P. B.; Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science, 2015, 348, 6232, 336-340 DOI:10.1126/science.aaa1788	PP, PS, MI, DP
knb-lter-cdr.451.8	Litter carbon and nitrogen: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/94e8f767ac1cfd56cb52e39faad0df79	MO, MI, DP
knb-lter-cdr.453.8	Root biomass data: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018	PP, PS, MI, DP

	doi:10.6073/pasta/55da007695bbc606e2ccf75e5f089e34	
knb-lter-cdr.455.8	Percent light penetration: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/d56c1909870e0154d3e228ba34bf04e5	PP, PS, MI, DP
knb-lter-cdr.456.8	Root carbon/nitrogen data: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/692a231520a188923dd8f2a4dd98c426	MO, MI, DP
knb-lter-cdr.458.8	Small mammal abundance: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/ad017efadfac7b4696f74b7b3e45ed04	PS, MI, DP
knb-lter-cdr.460.8	Soil Calcium: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/2de702631c2bde6c69c24414febb7f71	MO, MI, DP
knb-lter-cdr.462.8	Soil magnesium: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/acbfd6d39aa258ee45d46bf987e62b59	MO, MI, DP
knb-lter-cdr.464.8	Soil nitrate and ammonium: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/55740f22471edc80e9371f68f4673d3b	MO, MI, DP
knb-lter-cdr.469.8	Soil carbon: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/7256322e63d2a808ec62643f1e0c906e	MO, MI, DP
knb-lter-cdr.470.8	Soil nitrogen: Fire X Nitrogen: Interactive Effects in a Prairie-Like Grassland; Tilman, David; 2018 doi:10.6073/pasta/501eaf15adffa5bb44406782eae371b2	MO, MI, DP
knb-lter-cdr.253.8	Soil nitrate and ammonium: Total C and N Storage Along Wetland-Upland Gradients; Bryant, Charlotte; 2018 doi:10.6073/pasta/f1eb6e347758344c2d079e984c95b3d8	MO, MI
knb-lter-cdr.255.8	Reproductive output--number of flowering heads: Soil Heterogeneity With Disturbance; Vincent, Tania; 2018 doi:10.6073/pasta/f0684d35e9e749904d8df98db348dad2	PP, PS, DP
knb-lter-cdr.256.8	Reproductive output--number of flowering heads: Soil Disturbance Gradient; Vincent, Tania; 2018 doi:10.6073/pasta/266ad698d435c61851e9429b3b384d33	PP, PS, DP
knb-lter-cdr.257.8	Plant species percent cover data: Soil Disturbance Gradient; Vincent, Tania; 2018 doi:10.6073/pasta/98dc730b73cae3bb1591ec16ab1044da	PS, DP
knb-lter-cdr.258.8	Percent light penetration: Soil Disturbance Gradient; Vincent, Tania; 2018 doi:10.6073/pasta/8dc235bcb1f37d65c62f98e8e2521966	PP, PS, DP
knb-lter-cdr.259.8	Soil nitrate and ammonium: Multiple Traits of Multiple Plant Species Measured in Monoculture Gardens; Tilman, David; 2018 doi:10.6073/pasta/1e71fe0fa33a31c84a0405c47991a799	MO, DP
knb-lter-cdr.260.8	Root carbon/nitrogen data: Multiple Traits of Multiple Plant Species Measured in Monoculture Gardens; Tilman, David; 2018 doi:10.6073/pasta/38c67027fec5f523045ceb74bc396e86	PS, MO, DP
knb-lter-cdr.261.8	Plant aboveground biomass carbon and nitrogen: Multiple Traits of Multiple Plant Species Measured in Monoculture Gardens; Tilman, David; 2018 doi:10.6073/pasta/5b1b32428f7b50e43aae00bda7c8fd63	PS, DP
knb-lter-cdr.262.8	Plant aboveground biomass data: Multiple Traits of Multiple Plant Species Measured in Monoculture Gardens; Tilman, David; 2018 doi:10.6073/pasta/eb753e73357b1e1ef46545faf4cdc0bc	PP, PS, DP
knb-lter-cdr.264.8	Percent light penetration: Seedling Addition Experimant in Field D; Tilman, David; 2018 doi:10.6073/pasta/5653fb7a5e57de15a397a03b47403af9	PP, PS, MO, DP
knb-lter-cdr.358.8	Plant species inventory: Seedling Addition Experimant in Field D; Tilman, David; 2018 doi:10.6073/pasta/d30620e547b1f7b2c7589e79034dc81a	PS, MO, DP
knb-lter-cdr.266.8	Plant species percent cover data: Seed Addition in Lawrence Strips; Tilman, David; 2018 doi:10.6073/pasta/76f7d19cb2d1aa810b145106c3fe681f	PS, DP
knb-lter-cdr.267.8	Plant species percent cover data: Addition of Schizachyrium scoparium Seeds to the Lawrence Strips; Tilman, David; 2018	PS

	doi:10.6073/pasta/167e416b80d9716e7ef0e5b95215d36c	
knb-lter-cdr.518.8	Arthropod D-Vac Sampling:Simplification functional groups; Symstad, Amy; 2018 doi:10.6073/pasta/56da7ca26dc23493c30864ea0c7ab023	PS
knb-lter-cdr.270.8	Root biomass data: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/0479da667672693c3cf2a6b2c8d14002	PP, PS
knb-lter-cdr.271.8	Root carbon/nitrogen data: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/94d0dc2aa637ed3fd524be1c8b345fef	PS, MO, MI, DP
knb-lter-cdr.272.8	Plant species percent cover data: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/ae57e6e9d87dd5fd204422eeec37b442 Significant publication: Cavender-Bares, J., J. A. Gamon, S. E. Hobbie, M. D. Madritch, J. E. Meireles, A. K. Schweiger, and P. A. Townsend. 2017. Harnessing plant spectra to integrate the biodiversity sciences across biological and spatial scales. American Journal of Botany.	PS
knb-lter-cdr.273.8	Plant aboveground biomass data: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/341cc088f591a5dc7dfb27e517ecfc5d Significant publication: Hautier, Y.; Tilman, D.; Isbell, F.; Seabloom, E. W.; Borer, E. T.; Reich, P. B.; Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science, 2015, 348, 6232, 336-340 DOI:10.1126/science.aaa1788 Significant Publication: Isbell, Forest; Reich, Peter B.; Tilman, David; Hobbie, Sarah E.; Polasky, Stephen; Binder, Seth. Nutrient enrichment, biodiversity loss, and consequent declines in ecosystem productivity. Proceedings of the National Academy of Sciences of the United States of America. 2013 110 (29):11911-11916. Significant Publication: Cavender-Bares, J., J. A. Gamon, S. E. Hobbie, M. D. Madritch, J. E. Meireles, A. K. Schweiger, and P. A. Townsend. 2017. Harnessing plant spectra to integrate the biodiversity sciences across biological and spatial scales. American Journal of Botany.	PP, PS
knb-lter-cdr.275.8	Invasion strip soil nitrogen: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/78c4c9eec76cfbe1b082d917eec41c48	PS, MO, MI, DP
knb-lter-cdr.276.8	Invasion strip root biomass: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/0397200b4b2357878fe21435b848e0a8	PP, PS, MO, MI, DP
knb-lter-cdr.277.8	Percent light penetration: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/7db06751aa2929482052ea5721a7f989	PP, PS, MO, MI, DP
knb-lter-cdr.278.8	Soil nitrogen: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/c2bc09303d540666cdcd2cd3a98121fe	PS, MO, MI, DP
knb-lter-cdr.279.8	Plant aboveground biomass carbon and nitrogen: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/c950656fedfb084437bffcbe0b3107fa Significant publication: Cavender-Bares, J., J. A. Gamon, S. E. Hobbie, M. D. Madritch, J. E. Meireles, A. K. Schweiger, and P. A. Townsend. 2017. Harnessing plant spectra to integrate the biodiversity sciences across biological and spatial scales. American Journal of Botany.	PS, MO, MI, DP
knb-lter-cdr.280.8	Soil nitrate and ammonium: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/bd6e75e8d6c7b261c35e9006e59a37e9	PS, MO
knb-lter-cdr.414.8	Plant traits: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/67d59b1ad2739791ced5606d7f512ae9	PS, MO, MI, DP
knb-lter-cdr.418.8	Main Plots All Arthropod Insect Sweepnet Sampling 1996-200: Biodiversity II:	PS, MO,

	Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/4c1795e6769bf78e3c947e92db75eef6	MI, DP
knb-lter-cdr.423.8	Soil carbon: Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/894575c81819a8d89b6b648de13581b2	PS, MO, MI, DP
knb-lter-cdr.548.8	Developing seedheads treated with fungicide and insecticide:Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/90dcdc8e0106aea77239ed0ec118666d	PS, MO, DP
knb-lter-cdr.558.8	Local plant diversity and soybean biological control 2011 Aphid and Enemy Surveys:Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/cd1bb2d0a2ea5f29d5d09e181afa083f	PS, MO, MI, DP
knb-lter-cdr.560.8	Local plant diversity and soybean biological control 2011 Harvest Measures:Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/a9fa7938a901d005d47bec5a7edd3add	PP, PS, MO, MI, DP
knb-lter-cdr.572.8	Local plant diversity and soybean biological control 2012 Aphid Surveys:Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/1a63f77b32d6d6d5a08a63ca44482982	PP, PS, MO, MI, DP
knb-lter-cdr.573.8	Local plant diversity and soybean biological control 2012 Enemy Surveys:Biodiversity II: Effects of Plant Biodiversity on Population and Ecosystem Processes; Tilman, David; 2018 doi:10.6073/pasta/3c61cfd04c7114c51cc8c170f1d5de28	PS, MO, MI, DP
knb-lter-cdr.363.8	Arachnida species (spiders) abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/90c59068b520e906e1be4f328430c811	PS, DP
knb-lter-cdr.364.8	Coleoptera species abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/32ea3e975e56f29297d4bc1cb0050873	PS, DP
knb-lter-cdr.365.8	Diptera species abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/c32e438a3ed8851d458ba4a7a2218808	PS, DP
knb-lter-cdr.366.8	Hemiptera species abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/4d1405e335234e240ac4180055cea1ca	PS, DP
knb-lter-cdr.367.8	Homoptera species abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/5c797fa63ac7e9d8ecaf3e7ccfc03fc8	PS, DP
knb-lter-cdr.368.8	Hymenoptera species abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/5c049e9ae218504b7dece455db525931	PS, DP
knb-lter-cdr.369.8	Abundance and Body size of Insects Collected: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/7dda449b17758f618faa9404a1e68069	PS
knb-lter-cdr.370.8	Insects caught in pitfall traps: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/8880f15b7a39a33530db5e92ca35ed75	PS, DP
knb-lter-cdr.371.8	Lepidoptera species abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/c3fa9e268fe10bf6ea8ce63f351c2026	PS, DP
knb-lter-cdr.372.8	Miscellaneous inscet species abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/f2972b9248f68274ebd6ab86f60d9a44	PS, DP
knb-lter-cdr.373.8	Orthoptera species abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/11223e0d49d878ddd211f934ddef86c7	PS, DP
knb-lter-cdr.374.8	Formicidae species (ants) abundance: Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/f16b35230c0b2d869d985c519e35b6fe	PS, DP

knb-lter-cdr.521.8	All Insect Savanna Sweepnet Sampling 2004:Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/ef5a419db17cc69fcd5e729a03edfd9d	PS, DP
knb-lter-cdr.522.8	Old Field All Arthropod Sweepnet Sampling 2004 :Trophic Structure: Insect Species Diversity, Abundance and Body Size; Haarstad, John; 2018 doi:10.6073/pasta/bb2401abab854e3c55a6b6b35ed92e78	PS, DP
knb-lter-cdr.281.8	Root biomass data: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/8a0cb6a8467f756d07c53ed7240b4207	PP, PS
knb-lter-cdr.282.8	Soil nitrate and ammonium: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/3b8e0650d9dd8d0d2935ecfa68aae0e4	PS, MO
knb-lter-cdr.283.8	Soil nitrate, ammonium, moisture and nitrogen mineralization: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/c0961d3354ca7db8497d3650ff571380	PS, MO
knb-lter-cdr.284.8	Litter carbon and nitrogen: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/158e28a0bed554ddca37b9cbe36f8ec3	PS, MO
knb-lter-cdr.285.8	Plant aboveground biomass carbon and nitrogen: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/674021d442ee1fca11ba107c8711396a	PS, MO
knb-lter-cdr.286.8	Soil nitrogen: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/a4b3e52bff7a665bd58f1cdfa16eb7e6	PS, MO
knb-lter-cdr.287.8	Percent light penetration: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/df4f25aee0a133f7646812006ba0d11a	PP, PS
knb-lter-cdr.289.8	Root carbon/nitrogen data: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/d75285c65147d4fb6d6fab0caf663958	PS, MO
knb-lter-cdr.290.8	Plant species percent cover data: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/42fddca0a715893fc7b02976c059ac01	PS
knb-lter-cdr.291.8	Plant aboveground biomass data: The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/002f99b3e702e08e6f97ccc65b87a695	PP, PS
knb-lter-cdr.580.8	Vac Sampling arthropod community:The Small Biodiversity Experiment; Tilman, David; 2018 doi:10.6073/pasta/9988f892fe563b5fdcd3fa56190b5471	PS
knb-lter-cdr.110.8	Soil percent organic matter: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/085a8134a642ec62229eff7a793c641a Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	MO, DP
knb-lter-cdr.111.8	Soil nitrogen: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/f4c83f9858abe6b25a107dc0b23e62f2 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	MO, MI, DP
knb-lter-cdr.112.8	Plant density: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/fe139acf2f45e75fcbe684284952d93b	PP, MI, DP
knb-lter-cdr.294.8	Herb Survey: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/ece9a82aeaf8154efe03355c0b725feb	PS, DP
knb-lter-cdr.295.8	Shrub Survey: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/18422d1556efef3823ac54b09a7ef6ac	PP, PS, MI, DP
knb-lter-cdr.296.8	Percent light penetration: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/565f217e57a88425f07a9a1d5eb0d9d0	PP, MI, DP
knb-lter-cdr.345.8	Plant aboveground biomass data: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/c979b6d92410de32c714bd9d92ecd373	PP, MI, DP
knb-lter-cdr.346.8	Root biomass data: Effect of Burning Patterns on Vegetation in the Fish Lake Burn	PP, MI,

	Compartments; Reich, Peter; 2018 doi:10.6073/pasta/add76a347d92d2031ad009bcf0b0f166 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	DP
knb-lter-cdr.347.8	Soil potassium: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/6cf1cb42ea1e968e0f6c2f680e019c95	MO, MI, DP
knb-lter-cdr.348.8	Soil Calcium: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	MO, MI, DP
knb-lter-cdr.349.8	Soil magnesium: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/a88c350cd7464faeed59929b016b67c7	MO, MI, DP
knb-lter-cdr.350.8	Soil sodium: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/0725cfb673a6991496a647a410caa7f3	MO, MI, DP
knb-lter-cdr.351.8	Litter biomass: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/62c1f306e79cf6eac26e58f4bd855ca4 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	PP, MI, DP
knb-lter-cdr.352.8	Root ingrowth biomass: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/fae127d3c9dbcfa7fc20b343ce13ac0f	PP, MI, DP
knb-lter-cdr.353.8	Sapling survey: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/242a776eccb831cdadfcea073be69d06	PP, PS, MI, DP
knb-lter-cdr.354.8	Soil carbon flux: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/2655fb48c101a9a17de9668d8ab55ccf	MO, MI, DP
knb-lter-cdr.355.8	Soil moisture: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/b0399f31c494d435a846bc769b2047ef	DP
knb-lter-cdr.356.8	Bulk density, Soil:Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/bb2e68787e62bb25558a69f0b6bb3b47	DP
knb-lter-cdr.359.8	Soil pH: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/e57045b8243c06a2d21444493756f894	DP
knb-lter-cdr.415.8	Plant traits: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/5814d764417a40dd80e56434b13a10b9	PS, MI, DP
knb-lter-cdr.422.8	Tree survey: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/017b4d18fb35d811434a86781905af21	PP, PS, DP
knb-lter-cdr.615.8	Plant traits SLA CN percent cover:e133: Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/41c51bd6efd7225a1d92329cdeedf109 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	PS, MI, DP
knb-lter-cdr.637.8	Root tissue carbon and nitrogen:Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/ee7f16f6f1196777c215c965b117d244 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling:	MI, DP

	revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	
knb-lter-cdr.638.7	Aboveground plant tissue carbon and nitrogen:Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/275fbe95ef1ec5ae2b8a4809a78aeaed Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	PP, MO, MI, DP
knb-lter-cdr.639.7	Annual oak leaf canopy litter percent carbon and nitrogen:Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/468e10089d71c1df790b9f73a841eaea Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	PP, MO, MI, DP
knb-lter-cdr.640.7	Soil phosphorous:Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/1e41ef7b0402905f9a31141ae24c08a1 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	MO, MI, DP
knb-lter-cdr.642.7	Soil bulk density:Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/2f0744d99e48c6350d6427a878601172	PS, MO, MI, DP
knb-lter-cdr.656.9	Soil net N mineralization over five incubation periods:Effect of Burning Patterns on Vegetation in the Fish Lake Burn Compartments; Reich, Peter; 2018 doi:10.6073/pasta/02f57c86b556b47f8127a98990a4bae7	MO, DP
knb-lter-cdr.604.8	Acorn production:Acorn survey; Knops, Johannes; 2018 doi:10.6073/pasta/f856dc4ef3e1ea586bcfb841be7a4700	PP, MI, DP
knb-lter-cdr.606.8	Oak diameter at breast height:Acorn Survey; Knops, Johannes; 2018 doi:10.6073/pasta/b8fadecb11d795bbcdb22db4130bbb59	PP, MI, DP
knb-lter-cdr.298.9	Root carbon/nitrogen data: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/cfc4c93aee56a6d8bb60b5fb206cca0d	PS, MO, MI, DP
knb-lter-cdr.299.9	Root ingrowth biomass: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/ed71184bbd4806aed19424c5cb68b500	PP, PS, MO, MI, DP
knb-lter-cdr.300.8	Soil carbon flux: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/7378dc1bf52efbcd45dbf9741c925081	MO, MI, DP
knb-lter-cdr.301.8	Plant species percent cover data: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/824c69205d68fd7cf4b693b03188f1ac	PS, MO, MI, DP
knb-lter-cdr.302.8	Plant aboveground biomass data: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/e4cf8a6444f9a722aa2e32da21329798 Significant publication: Hautier, Y.; Tilman, D.; Isbell, F.; Seabloom, E. W.; Borer, E. T.; Reich, P. B.; Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science, 2015, 348, 6232, 336-340 DOI:10.1126/science.aaa1788 Significant Publication: Isbell, Forest; Reich, Peter B.; Tilman, David; Hobbie, Sarah E.; Polasky, Stephen; Binder, Seth. Nutrient enrichment, biodiversity loss, and consequent declines in ecosystem productivity. Proceedings of the National Academy of Sciences of the United States of America. 2013 110 (29):11911-11916.	PP, MO, MI, DP
knb-lter-cdr.304.8	Nitrogen mineralization rate: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/168445e7e05f4dd4bf7159df3c021b2f Significant publication: Reich, Peter B.; Hobbie, Sarah E.; Lee, Tali D.; Plant growth enhancement by elevated CO2 eliminated by joint water and nitrogen limitation; Nature Geoscience, 2014; 2014, 7, 12, 920-924	PS, MO, MI, DP
knb-lter-cdr.305.9	Plant aboveground biomass carbon and nitrogen: BioCON : Biodiversity, Elevated	PS, MO,

	CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/4922002b6bc68b8947bf9f8f6905516f	MI, DP
knb-lter-cdr.306.8	Soil ammonium: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/616d5bcac773d482dfb8128af1d7ba1a	PS, MO, MI, DP
knb-lter-cdr.322.8	Specific Leaf Area: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/f6b9ea23444419af83878b65eb4a4857 Significant publication: Butler, E. E., A. Datta, H. Flores-Moreno, M. Chen, K. R. Wythers, F. Fazayeli, A. Banerjee, O. K. Atkin, J. Kattge, B. Amiaud, B. Blonder, G. Boenisch, B. Bond-Lamberty, K. A. Brown, C. Byun, G. Campetella, B. E. L. Cerabolini, J. H. C. Cornelissen, J. M. Craine, D. Craven, F. T. de Vries, S. Diaz, T. F. Domingues, E. Forey, A. Gonzalez-Melo, N. Gross, W. Han, W. N. Hattingh, T. Hickler, S. Jansen, K. Kramer, N. J. B. Kraft, H. Kurokawa, D. C. Laughlin, P. Meir, V. Minden, U. Niinemets, Y. Onoda, J. Penuelas, Q. Read, L. Sack, B. Schamp, N. A. Soudzilovskaia, M. J. Spasojevic, E. Sosinski, P. E. Thornton, F. Valladares, P. M. van Bodegom, M. Williams, C. Wirth and P. B. Reich. "Mapping local and global variability in plant trait distributions." Proceedings of the National Academy of Sciences. published ahead of print December 1, 2017, doi:10.1073/pnas.1708984114	PS, MO, MI, DP
knb-lter-cdr.323.8	Plant Photosynthesis: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/453650a2895a52711d5897c1ff9675cf	PS, MO, MI, DP
knb-lter-cdr.324.8	Soil nitrate and ammonium: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/5840e303c819c311b663928e0a66bef2	PS, MO, MI, DP
knb-lter-cdr.325.8	Root biomass data: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/ad0f2aa1570a4003fc8da6d954e54799 Significant publication: Reich, Peter B.; Hobbie, Sarah E.; Lee, Tali D.; Plant growth enhancement by elevated CO2 eliminated by joint water and nitrogen limitation; Nature Geoscience, 2014; 2014, 7, 12, 920-924	PP, MO, MI, DP
knb-lter-cdr.326.8	Soil moisture: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/21a06853caa6228fb33e8bb0eff7fc6b Significant publication: Reich, Peter B.; Hobbie, Sarah E.; Lee, Tali D.; Plant growth enhancement by elevated CO2 eliminated by joint water and nitrogen limitation; Nature Geoscience, 2014; 2014, 7, 12, 920-924	PS, MO, MI, DP
knb-lter-cdr.327.8	Soil pH: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/1a512be63d4721eec61d71f4df37b945	PS, MO, MI, DP
knb-lter-cdr.328.8	Plant Nitrogen Isotopes: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/474ff111717db0b75cd52505419eb2e7	PS, MO, MI, DP
knb-lter-cdr.329.8	Seed weight : BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/1b5d816c11b64f42ad1e73d6eb559529	PS, MO, MI, DP
knb-lter-cdr.330.8	Reproduction data for Lespedeza capitata: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/6894827489fe31589733cae5e3062db3	PS, MO, MI, DP
knb-lter-cdr.331.8	Reproduction data for Lupinus perennis: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/ed5a983c67865e61f11c320dd588b4cb	PS, MO, MI, DP
knb-lter-cdr.332.8	Reproduction data for Solidago rigida: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/fb2ea712153e6c111942ed99ebf8491d	PS, MO, MI, DP
knb-lter-cdr.334.8	Reproduction data for Asclepias tuberosa: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018	PS, MO, MI, DP

	doi:10.6073/pasta/021fad4a757df91dbea63d0ae6ee80b2	
knb-lter-cdr.335.8	Reproduction data for Petalostemum villosum: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/933f4491092c6d2af241030a68faa951	PS, MO, MI, DP
knb-lter-cdr.336.8	Reproduction data for Achillea millefolium: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/e1ee00f48476a39bc9c54386725582f7	PS, MO, MI, DP
knb-lter-cdr.337.8	Reproduction data for grasses: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/86d3752cf1535abeb893844f2031e155	PS, MO, MI, DP
knb-lter-cdr.338.8	Reproduction data for Amorpha canescens: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/ae6cbee1448b7bc3df1842fce71110a6	PS, MO, MI, DP
knb-lter-cdr.339.8	Soil percent nitrogen and carbon: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/8fe02cded3d5d2979e4596d465b0e470	PS, MO, MI, DP
knb-lter-cdr.340.8	Soil bulk density: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/f3456c1f564d6f20ed003e8c590fc629	PS, MO, MI, DP
knb-lter-cdr.341.8	Lysimeter data: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/487c0fa3dc2825d787f7eab3010b9ebc	PS, MO, MI, DP
knb-lter-cdr.342.8	Percent light penetration: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018	PS, MO, MI, DP
knb-lter-cdr.427.8	Lupinus Transgenerational Effects: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/9c1c5410632afa16f2eebdf9e4a9227d	PS, MI, DP
knb-lter-cdr.428.8	Poa Transgenerational Effects: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/d46a4734dcad266cb3ae7188b7ff17e7	PS, MO, MI, DP
knb-lter-cdr.429.8	Schizachyrium Transgenerational Effects: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/27eeb13cc4c89a25f9903d763f726a04	PS, MO, MI, DP
knb-lter-cdr.523.8	acae141:BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/2a6b2e4d5fd328d0aa086eed7d0f8dae	PS, MO, MI, DP
knb-lter-cdr.524.8	Vac Sampling aphids:BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/32d384ec18e0f9b780afc41e2526b8f6	PS, MO, MI, DP
knb-lter-cdr.525.8	Photosynthesis Leaf Chemistry:BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/69f37e0c8546c8f1b899b6f41ce73b72	PS, MO, MI, DP
knb-lter-cdr.528.8	Lysimeter - Water Treatment Plots:BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/e24f28b7d18491f805884eabb5dc5a9f	MO, MI, DP
knb-lter-cdr.531.8	Total and non-hydrolyzable soil carbon and nitrogen:BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/a2996ed69e53c0a394f9eb74e9064b5e	PS, MO, MI, DP
knb-lter-cdr.532.8	Carbon respiration from soil incubation:BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/9d6be3c4237c916dee636c8992f5fbc2	PS, MO, MI, DP
knb-lter-cdr.538.8	Photosynthesis (Amax, etc.): BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/b5f1574f8149b4c433a942c9f278b800	PS, MO, MI, DP
knb-lter-cdr.539.8	Photosynthesis Leaf Carbon and Nitrogen:BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/5a1cd935bc053f1072e8a6ab613de156 Significant publication: Butler, E. E., A. Datta, H. Flores-Moreno, M. Chen, K. R. Wythers, F. Fazayeli, A. Banerjee, O. K. Atkin, J. Kattge, B. Amiaud, B. Blonder, G. Boenisch, B. Bond-Lamberty, K. A. Brown, C. Byun, G. Campetella, B. E. L.	PS, MO, MI, DP

	Cerabolini, J. H. C. Cornelissen, J. M. Craine, D. Craven, F. T. de Vries, S. Diaz, T. F. Domingues, E. Forey, A. Gonzalez-Melo, N. Gross, W. Han, W. N. Hattingh, T. Hickler, S. Jansen, K. Kramer, N. J. B. Kraft, H. Kurokawa, D. C. Laughlin, P. Meir, V. Minden, U. Niinemets, Y. Onoda, J. Penuelas, Q. Read, L. Sack, B. Schamp, N. A. Soudzilovskaia, M. J. Spasojevic, E. Sosinski, P. E. Thornton, F. Valladares, P. M. van Bodegom, M. Williams, C. Wirth and P. B. Reich. "Mapping local and global variability in plant trait distributions." Proceedings of the National Academy of Sciences. published ahead of print December 1, 2017, doi:10.1073/pnas.1708984114	
knb-lter-cdr.540.8	N15 isotope in plants: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/d1c6d798b4b4881dbb24eacce4bb505d	PS, MO, MI, DP
knb-lter-cdr.563.8	1996 Ring soil texture, pH and Cation Exchange Capacity (CEC):BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/4b96667566d10f40b529b80e5f3311b1	MO
knb-lter-cdr.593.8	Oak leaf water potential:BioCON: Biodiversity, CO2, and Nitrogen; Reich, Peter; 2018 doi:10.6073/pasta/91fcb556a50f191bb0e2eeb0ddb99cb7	PS, MO, MI, DP
knb-lter-cdr.605.8	Light and heavy soil fraction total N and delta 15N:BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/dcf208e176aab4fc31c4bebca2901502	MO, MI, DP
knb-lter-cdr.607.8	Monoculture species green leaf total N and delta 15N: e141: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/d050c96fb74b60264e89558a6d5719e0	MO, MI, DP
knb-lter-cdr.608.8	Leaf 15N isotope, total N and delta 15N from 9 species water treatment plots:e141: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/f06356ca7be1fb2994511e9e02b8f29a	PP, MO, MI, DP
knb-lter-cdr.609.8	Leaf delta 13C and total C from 9 species water treatment plots:e141: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/6ec3fd02179860d7e76c0d032651780f	PP, MO, MI, DP
knb-lter-cdr.610.8	15N isotope, total N and delta 15N from June aboveground shoot tissues:e141: BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/501cb79ac7712d282c6953c831660793	PP, MO, MI, DP
knb-lter-cdr.613.8	Leaf net photosynthesis in CO2 x N x water treatment combinations:BioCON : Biodiversity, Elevated CO2, and N Enrichment; Reich, Peter; 2018 doi:10.6073/pasta/004d9c870e11d4ca03fa1ac9c5fa5e05	PP, MO, MI, DP
knb-lter-cdr.617.8	Soil Organisms:BioCON: Biodiversity, CO2, and Nitrogen; Reich, Peter; 2018 doi:10.6073/pasta/f264d210e738f76402f54e9b15d1d9dd	PS, MO, MI, DP
knb-lter-cdr.627.7	Litter biomass carbon nitrogen from water treatment plots:BioCON: Biodiversity, CO2, and Nitrogen; Reich, Peter; 2018 doi:10.6073/pasta/336ec2b71e58f8b69bdd606469dd0c15	MO, MI, DP
knb-lter-cdr.581.8	Tree survey:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/70d605595207ae41fc2aa5ea8df17ccc	PP, PS, MI, DP
knb-lter-cdr.582.8	Canopy litter biomass:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/64bbff0a419af2cb509329bd1b07f210	PP, PS, MI, DP
knb-lter-cdr.583.8	Shrub survey:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/b431ed7b4463b2ab6bbba77a9de04d29	PP, PS, MI, DP
knb-lter-cdr.584.8	Plant aboveground biomass:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/f39091ecf3f90b806c1c5e61ccb8cb4a	PP, PS, MI, DP
knb-lter-cdr.585.8	Plant belowground biomass:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/e3065cb3ce26a84ec6fbe9ce869a81ea	PP, MO, MI, DP
knb-lter-cdr.586.8	Herbaceous Vegetation Survey:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/4cce744874a842d4e319444bd297bce5	PP, PS, MI, DP
knb-lter-cdr.587.8	Plant aboveground biomass carbon and nitrogen:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage,	PS, MO, MI, DP

	Keith; 2018 doi:10.6073/pasta/561f58eb8860e8381293d93c85590011	
knb-lter-cdr.588.8	Plant belowground biomass carbon and nitrogen:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/d02ce2c0fdb3b015d1b79f3fe949d0d2	PS, MO, MI, DP
knb-lter-cdr.589.8	Effects of Long Term Canopy litter biomass carbon and nitrogen:Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/a7f719e43759185a3dc356cd7166bab1	PS, MO, MI, DP
knb-lter-cdr.590.8	Soil carbon flux:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/9b3b5da11be571cb698aae0dc3daec1a	MO, MI, DP
knb-lter-cdr.655.8	Greenhouse test of plant ecophysiological traits or responses to nitrogen:Effects of Long Term Fertilization and Oak Canopy Cover on Plant Communities and Ecosystem Processes; Wrage, Keith; 2018 doi:10.6073/pasta/ec0815cffd15ab5c6565b8df884e292e Significant publication: Butler, E. E., A. Datta, H. Flores-Moreno, M. Chen, K. R. Wythers, F. Fazayeli, A. Banerjee, O. K. Atkin, J. Kattge, B. Amiaud, B. Blonder, G. Boenisch, B. Bond-Lamberty, K. A. Brown, C. Byun, G. Campetella, B. E. L. Cerabolini, J. H. C. Cornelissen, J. M. Craine, D. Craven, F. T. de Vries, S. Diaz, T. F. Domingues, E. Forey, A. Gonzalez-Melo, N. Gross, W. Han, W. N. Hattingh, T. Hickler, S. Jansen, K. Kramer, N. J. B. Kraft, H. Kurokawa, D. C. Laughlin, P. Meir, V. Minden, U. Niinemets, Y. Onoda, J. Penuelas, Q. Read, L. Sack, B. Schamp, N. A. Soudzilovskaia, M. J. Spasojevic, E. Sosinski, P. E. Thornton, F. Valladares, P. M. van Bodegom, M. Williams, C. Wirth and P. B. Reich. "Mapping local and global variability in plant trait distributions." Proceedings of the National Academy of Sciences. published ahead of print December 1, 2017, doi:10.1073/pnas.1708984114	MO, MI, PP
knb-lter-cdr.309.8	Litter Decomposition and Nitrogen Dynamics: Effects of Nitrogen Fertilization on Litter and Soil Decomposition; Hobbie, Sarah; 2018 doi:10.6073/pasta/249ce00cfafda52ada8cba6e3a80c81c	MO, MI
knb-lter-cdr.321.8	Extracellular enzyme: Effects of Nitrogen Fertilization on Litter and Soil Decomposition; Hobbie, Sarah; 2018 doi:10.6073/pasta/2d82eaaaf6ecfe6ee4f49cbd3584b965 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	MO, MI
knb-lter-cdr.310.8	Arthropod sweepnet sampling: Interactive Effects of Deer, Fire and Nitrogen; Knops, Johannes; 2018 doi:10.6073/pasta/a79b1120729dffc992897de58a2c5408	PS, MI, DP
knb-lter-cdr.311.8	Plant aboveground biomass data: Interactive Effects of Deer, Fire and Nitrogen; Knops, Johannes; 2018 doi:10.6073/pasta/eb3e39057322af596d451353930cec0d	PP, PS, MI, DP
knb-lter-cdr.312.8	Soil bulk density: Interactive Effects of Deer, Fire and Nitrogen; Knops, Johannes; 2018 doi:10.6073/pasta/d7c5fff687e1b5df26b2c397f80fb1d9	MO, MI
knb-lter-cdr.314.8	Root biomass data: Interactive Effects of Deer, Fire and Nitrogen; Knops, Johannes; 2018 doi:10.6073/pasta/7602bf0305eb87d4d5a851c37adfa8d7	PP, MI, DP
knb-lter-cdr.315.8	Skink trapping: Interactive Effects of Deer, Fire and Nitrogen; Knops, Johannes; 2018 doi:10.6073/pasta/0a6fea012763dc88ccfe570fed0baf9d	PS, MI, DP
knb-lter-cdr.317.8	Small mammal abundance: Interactive Effects of Deer, Fire and Nitrogen; Knops, Johannes; 2018 doi:10.6073/pasta/a7621ce3f1f956dd39279fa76469d32a	PS, MI, DP
knb-lter-cdr.318.8	Plant species inventory: Interactive Effects of Deer, Fire and Nitrogen; Knops, Johannes; 2018 doi:10.6073/pasta/45ae630c67eb5081ec370c2911e3503d	PS, MI, DP
knb-lter-cdr.319.8	Tree data: Interactive Effects of Deer, Fire and Nitrogen; Knops, Johannes; 2018	PP, PS,

	doi:10.6073/pasta/2314691667b5131f9c2447c65d63895c	MI, DP
knb-lter-cdr.357.8	Plant species percent cover data: Interactive Effects of Deer, Fire and Nitrogen; Knops, Johannes; 2018 doi:10.6073/pasta/c635f42a419e92e16e4c42a4057b5df6	PS, MI, DP
knb-lter-cdr.447.8	Belowground fungal community presence in savanna and oak forest: Causes of change in ectomycorrhizal communities; Dickie, Ian; 2018 doi:10.6073/pasta/4d034db5b92c0cdc2b52cc93e0561576	PS, MO, DP
knb-lter-cdr.448.8	Sporocarp count aboveground fungal communities in savanna and oak forest: Causes of change in ectomycorrhizal communities; Dickie, Ian; 2018 doi:10.6073/pasta/c784ecf295e6f7f7a66b496bee35db32	PS, MO, DP
knb-lter-cdr.473.8	Plant aboveground biomass data: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/a3821172228451b43eae6721793c9c86	PP, MI, DP
knb-lter-cdr.474.8	Percent light penetration: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/a651cdb893c72d2aeeda858f57385f20	PP, MI, DP
knb-lter-cdr.475.8	Plant aboveground biomass carbon and nitrogen: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/1537bdc7a20c0c021338cee89acfe4f5	MO, MI, DP
knb-lter-cdr.476.8	Root biomass data: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/2d7fc4c5a770d4d9dd47fb85a30a5cc2	PP, MI, DP
knb-lter-cdr.477.8	Root carbon/nitrogen data: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/e9df71a280191ad2914cedb0a531649b	MO, MI, DP
knb-lter-cdr.478.8	Small mammal abundance: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/3920d3b852fe7353644df899b815b46b	PS, MI, DP
knb-lter-cdr.479.8	Soil Calcium: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/df3f514415d009ddef60cd714f0978b0	MO, MI, DP
knb-lter-cdr.480.8	Soil carbon: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/5e88002d25d20da51d554f052c4ad1be	MO, MI, DP
knb-lter-cdr.481.8	Soil magnesium: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/e539724ffaacfabdb4907b3ea255e139	MO, MI, DP
knb-lter-cdr.482.8	Soil nitrate and ammonium: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/b276be5b2ed0ff6c09cd989365cdba85	MO, MI, DP
knb-lter-cdr.483.8	Soil nitrogen: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/170f5ad03f238f426f0134bb8d45b693	MO, MI, DP
knb-lter-cdr.484.8	Soil phosphorous: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/6268248fe8f2cf81f743ef667b6ad29c	MO, MI, DP
knb-lter-cdr.485.8	Soil potassium: Herbivory by Nitrogen Interactive Effects on Community and Ecosystem Processes and Dynamics; Tilman, David; 2018 doi:10.6073/pasta/f28c0653944ac25590759ce91f7d57b2	MO, MI, DP
knb-lter-cdr.425.8	Arabidopsis Phenologyunder: Arabidopsis BioCON evolutionary study; Tiffin, Peter; 2018 doi:10.6073/pasta/2e55730f790ca567b228530087a2e393	PS, MI, DP
knb-lter-cdr.426.8	Herbivory of Arabidopsis: Arabidopsis BioCON evolutionary study; Tiffin, Peter; 2018 doi:10.6073/pasta/5447fbdd92abb6f1043447c61b09fdc0	PS, MI, DP
knb-lter-cdr.430.8	Lespedeza herbivory: Arabidopsis BioCON evolutionary study; Tiffin, Peter; 2018 doi:10.6073/pasta/69d6b61d4287ad7a396a5ace90137414	PS, MO, MI, DP
knb-lter-cdr.542.8	Arabidopsis BioCON evolutionary study:Arabidopsis thaliana, Bromus inermis phenotypic selection analysis; Tiffin, Peter; 2018 doi:10.6073/pasta/134d603e279c105a1bf2def63cd5dcac	PS, DP

knb-lter-cdr.543.8	Arabidopsis BioCON evolutionary study:Arabidopsis thaliana, Bromus inermis phenotypic selection analyses standardized across trtmnts; Tiffin, Peter; 2018 doi:10.6073/pasta/ab5064247d52424b5b5c36d76b2f12b0	PS, DP
knb-lter-cdr.544.8	Phenology, growth, and fitness of Arabidopsis under ambient and elevated CO2 and in the presence/absence of competitors: Arabidopsis BioCON evolutionary study; Tiffin, Peter; 2018 doi:10.6073/pasta/ac7a4fa0fec849c5ffe6df6f413325a8	PS, DP
knb-lter-cdr.545.8	Arabidopsis Tolerance to herbivory: Arabidopsis BioCON evolutionary study; Tiffin, Peter; 2018 doi:10.6073/pasta/9138a9a1ce5a3061026f82ff7d2bcbb0	PS, DP
knb-lter-cdr.546.8	Phenology, growth, and fitness of Arabidopsis under ambient and elevated CO2: Arabidopsis BioCON evolutionary study; Tiffin, Peter; 2018 doi:10.6073/pasta/e764393caadf5192493e881209a9eaef	PS, DP
knb-lter-cdr.547.8	Lespedeza herbivory census: Arabidopsis BioCON evolutionary study; Tiffin, Peter; 2018 doi:10.6073/pasta/0a04b10a3a7e86b46b221794aae6070e	PS, DP
knb-lter-cdr.409.8	Initial Substrate Chemistry: Nitrogen limitation in decomposition; Hobbie, Sarah; 2018 doi:10.6073/pasta/77ff064fa5d86ee7b7edb4959e88005a Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	PS, MO, MI, DP
knb-lter-cdr.410.8	Substrate mass, nitrogen, extracellular enzyme, and microbial biomass and stoichiometry dynamics: Nitrogen limitation in decomposition; Hobbie, Sarah; 2018 doi:10.6073/pasta/40d40cc17935bfc78f6a84aa83dbb662 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	PS, MO, MI, DP
knb-lter-cdr.411.8	O horizon extracellular enzyme activity: Nitrogen limitation in decomposition; Hobbie, Sarah; 2018 doi:10.6073/pasta/3de066e8d2a1830f0e444049b0c889a6 Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	PS, MO, MI, DP
knb-lter-cdr.412.8	Decomposition Model Parameters : Nitrogen limitation in decomposition; Hobbie, Sarah; 2018 doi:10.6073/pasta/678ec75c5d801e48a48c754e5419fa1c Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	PS, MO, MI, DP
knb-lter-cdr.413.8	Phospholipid fatty acids (PFLA) on decomposed litter: Nitrogen limitation in decomposition; Hobbie, Sarah; 2018 doi:10.6073/pasta/575a40246d79ae65183cea41c96d7a0f Significant publication: Hobbie, S. E. 2015. Plant species effects on nutrient cycling: revisiting litter feedbacks. Trends in Ecology & Evolution 30:357-363.	PS, MO, MI, DP
knb-lter-cdr.431.8	UV Litter Decomposition: The role of photodegradation in surface litter decomposition in grasslands along UV-B gradient; Brandt, Leslie; 2018 doi:10.6073/pasta/1ce01c3368b8c430f88391509008bc1a	MO
knb-lter-cdr.432.8	Photoprotective leaf pigments and chlorophyll fluorescence measurements during a greenhouse drought experiment: An evolutionary perspective on functional diversity in co-occuring willow(salix) species; Cavender-Bares, Jeannine; 2018 doi:10.6073/pasta/33568c288add471af9db3eaf091e81aa	PS, DP
knb-lter-cdr.434.8	Phospholipid fatty acids (PFLA) on decomposed litter: An evolutionary perspective on functional diversity in co-occuring willow(salix) species; Cavender-Bares, Jeannine; 2018 doi:10.6073/pasta/034a60af5419d466e054bba2e5f747c3	PS, MO, DP
knb-lter-cdr.437.8	Gas exchange, dieback, leaf water potential and chlorophyll content during a greenhouse drought experiment: An evolutionary perspective on functional diversity in co-occuring willow(salix) species; Cavender-Bares, Jeannine; 2018 doi:10.6073/pasta/f1dfd3f1b848e51eb1955b3597971460	PS, DP

knb-lter-cdr.601.8	Soil Carbon and Nitrogen analysis:Effects of white pine invasion of old fields on biogeochemical processes; Hobbie, Sarah; 2018 doi:10.6073/pasta/5f38a1909891358c7576023d1e08fd35	PS, MO
knb-lter-cdr.602.8	Litter decomposition:Effects of white pine invasion of old fields on biogeochemical processes; Hobbie, Sarah; 2018 doi:10.6073/pasta/1c3c0a2aa731ae0601c5c882136be1fa	PS, MO
knb-lter-cdr.603.8	Soil cation analysis:Effects of white pine invasion of old fields on biogeochemical processes; Hobbie, Sarah; 2018 doi:10.6073/pasta/631cc4dd10d46240928b407f40d37f4e	PS, MO
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knb-lter-cdr.438.8	Sequences of the nuclear gene ADH for thirteen species of willows and two poplars: Investigating patterns of habitat specialization in fifteen co-occurring willow and poplar species.; Savage, Jessica; 2018 doi:10.6073/pasta/233ddb50525abe54044329670bbcf1c0	PS
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knb-lter-cdr.383.8	Plant aboveground biomass data: Natural Enemies, Plant Diversity and Plant Community Composition; Kinkel, Linda; 2018 doi:10.6073/pasta/a654a4eee3f1b19d6ce971c7399eb467 Significant publication: Seabloom, E. W., Kinkel, L., Borer, E. T., Hautier, Y., Montgomery, R. A., Tilman, D., & Casper, B. (2017). Food webs obscure the strength of plant diversity effects on primary productivity. Ecology Letters, doi:10.1111/ele.12754	PP, PS, MO, DP
knb-lter-cdr.399.8	Root biomass data: Natural Enemies, Plant Diversity and Plant Community Composition; Kinkel, Linda; 2018 doi:10.6073/pasta/0f99a4ca3dd321ed948c965990f7b626 Significant publication: Seabloom, E. W., Kinkel, L., Borer, E. T., Hautier, Y., Montgomery, R. A., Tilman, D., & Casper, B. (2017). Food webs obscure the strength of plant diversity effects on primary productivity. Ecology Letters, doi:10.1111/ele.12754	PP, PS, DP
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knb-lter-cdr.592.8	Leaf carbon, nitrogen and phosphorus:Natural Enemies, Plant Diversity and Plant Community Composition; Kinkel, Linda; 2018 doi:10.6073/pasta/0e0ffb546008df4b9e8a375c95a5f14b	PS, MO, DP
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knb-lter-cdr.550.8	Biofuels Harvest:Biodiversity: A field test of biofuel production and ground-water quality; Lehman, Clarence; 2018 doi:10.6073/pasta/c58414c32ca5c95cb3bec8f3d6426531	PP, PS, MI, DP
knb-lter-cdr.551.8	Plant species percent cover data:Biodiversity: A field test of biofuel production and ground-water quality; Lehman, Clarence; 2018 doi:10.6073/pasta/86e6320ae06d5dd6215e808ca20dab9e	PS, MI, DP
knb-lter-cdr.552.8	Root harvest biomass:Biodiversity: A field test of biofuel production and ground-water quality; Lehman, Clarence; 2018 doi:10.6073/pasta/c1493fcdfb65e35aa1cbe24ffffc9ec6	PP, PS, MI, DP
knb-lter-cdr.553.8	Soil carbon and nitrogen:Biodiversity: A field test of biofuel production and ground-water quality; Lehman, Clarence; 2018 doi:10.6073/pasta/d955983c8aa00facd0b7650a2615290c	PS, MI, DP
knb-lter-cdr.555.8	Soil moisture:Biodiversity: A field test of biofuel production and ground-water quality.; Lehman, Clarence; 2018 doi:10.6073/pasta/4e97e895c0cfd595fae10fcc08db8891	PP, PS, MI, DP
knb-lter-cdr.556.8	Plant community light interception:Biodiversity: A field test of biofuel production and ground-water quality; Lehman, Clarence; 2018 doi:10.6073/pasta/a79bf2ed531757dfbfcb599a86c29da3	PP, PS, MI, DP
knb-lter-cdr.567.8	Plant Species Composition percent cover:Nutrient Network: A cross-site investigation of bottom-up control over herbaceous plant community dynamics and ecosystem function.; Seabloom, Eric; 2018 doi:10.6073/pasta/d6b5b711f818d245ff4edbbe0553a95c	MI
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knb-lter-cdr.570.8	2007 pre-treatment soils pH, nutrients, texture:Nutrient Network: A cross-site investigation of bottom-up control over herbaceous plant community dynamics and ecosystem function.; Seabloom, Eric; 2018 doi:10.6073/pasta/eca0dd7e2894d1efb64c45d544c33517	PP, PS, MO, MI, DP
knb-lter-cdr.571.8	Aboveground Standing Crop Biomass:Nutrient Network A cross-site investigation of bottom-up control over herbaceous plant community dynamics and ecosystem function; Seabloom, Eric; 2018 doi:10.6073/pasta/6b3fe6df7bf0416ad79783fb5b8366a3 Significant publication: Hautier, Y.; Tilman, D.; Isbell, F.; Seabloom, E. W.; Borer, E. T.; Reich, P. B.; Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science, 2015, 348, 6232, 336-340 DOI:10.1126/science.aaa1788	MO, MI, DP
knb-lter-cdr.611.8	Multi-site grassland plant biomass, species richness and light (PAR):e247: Nutrient Network: A cross-site investigation of bottom-up control over herbaceous plant community dynamics and ecosystem function.; Seabloom, Eric; 2018 doi:10.6073/pasta/cc80df6c28f6d2a1d0af209d17d64c61	PP, PS, MO, MI, DP
knb-lter-cdr.385.8	Plant biomass: The Effect of Nitrogen Addition and Irrigation in High Diveristy Prairies; Tilman, David; 2018 doi:10.6073/pasta/f66caa61048d80691a934c5f9389570e	PP, PS, MO, DP
knb-lter-cdr.403.8	Plant aboveground biomass data: The Effect of Nitrogen Addition and Irrigation in High Diveristy Prairies; Tilman, David; 2018 doi:10.6073/pasta/2084358774121b95e98e237b7a6181ae Significant publication: Hautier, Y.; Tilman, D.; Isbell, F.; Seabloom, E. W.; Borer, E. T.; Reich, P. B.; Anthropogenic environmental changes affect ecosystem stability	PP, MI

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knb-lter-cdr.386.8	Plant aboveground biomass data: BAC: Biodiversity and Climate; Tilman, David; 2018 doi:10.6073/pasta/214b327bc6fc0a240ec705b339e6dd83 Significant publication: Cowles, Jane M.; Wragg, Peter D.; Wright, Alexandra J.; Powers, Jennifer S.; Tilman, David; Shifting grassland plant community structure drives positive interactive effects of warming and diversity on aboveground net primary productivity. Global Change Biol. 2016 22(2) 741 - 749 DOI10.1111/gcb.13111	PP, PS, MO, MI, DP
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knb-lter-cdr.526.8	Legume shoot N15 13C Isotopes:BAC: Biodiversity and Climate; Tilman, David; 2018 doi:10.6073/pasta/bec4c9799732787f834f9bf41c7eebe7	PS, MO, DP
knb-lter-cdr.527.8	Net nitrogen mineralization:BAC: Biodiversity and Climate; Tilman, David; 2018 doi:10.6073/pasta/1eb5f1ad9a542aac25e4abf2f9be082d	MO, DP
knb-lter-cdr.574.8	Normalized Difference Vegetation Index (NDVI):BAC: Biodiversity and Climate; Tilman, David; 2018 doi:10.6073/pasta/67872b8c34fe0d3908fbd15e6884d0a3	PS, MO, MI, DP
knb-lter-cdr.575.8	Phenology of individuals:BAC: Biodiversity and Climate; Tilman, David; 2018 doi:10.6073/pasta/354fdde8a6780d96a076cd7be7cc9f7d	PP, PS, MO, DP
knb-lter-cdr.576.8	Population level phenology:BAC: Biodiversity and Climate; Tilman, David; 2018 doi:10.6073/pasta/62615b3e7e10fa1eb9dd980109d4750d	PS, DP
knb-lter-cdr.591.8	Soil microbial functions and enzyme activity:BAC: Biodiversity and Climate; Tilman, David; 2018 doi:10.6073/pasta/119d926e639cca06b93b5f1ec6c040f1	MO, DP
knb-lter-cdr.600.8	Ant responses to experimental warming and plant diversity:BAC: Biodiversity and Climate; Tilman, David; 2018 doi:10.6073/pasta/1991371638f8e2efc783f6bdd04cf80c	PS, DP
knb-lter-cdr.612.8	Root ingrowth biomass:BAC: Biodiversity and Climate; Tilman, David; 2018 doi:10.6073/pasta/3614b22f890d5ca30e54501c51974c69	PP, PS, DP
knb-lter-cdr.623.8	Soil moisture near the surface measured by Thetaprobe:BAC: Biodiversity and Climate; Tilman, David;; 2018 doi:10.6073/pasta/db6d85b879b7e48ba2cee74b26ea0e1f Significant publication: Cowles, Jane M.; Wragg, Peter D.; Wright, Alexandra J.; Powers, Jennifer S.; Tilman, David; Shifting grassland plant community structure drives positive interactive effects of warming and diversity on aboveground net primary productivity. Global Change Biol. 2016 22(2) 741 - 749 DOI10.1111/gcb.13111	PP, PS, MO, MI, DP
knb-lter-cdr.632.8	Daily mean iButton soil and air temp, air relative humidity:BAC: Biodiversity and Climate; Tilman, David;; 2018 doi:10.6073/pasta/1333b6c2cda080536479b918d8caa483 Significant publication: Cowles, Jane M.; Wragg, Peter D.; Wright, Alexandra J.; Powers, Jennifer S.; Tilman, David; Shifting grassland plant community structure drives positive interactive effects of warming and diversity on aboveground net primary productivity. Global Change Biol. 2016 22(2) 741 - 749 DOI10.1111/gcb.13111	PP, PS, MO, MI, DP
knb-lter-cdr.493.9	Energy Choices Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/75c8e9885945b0d5f40d31dbcfeb964b	DP
knb-lter-cdr.494.9	Energy Use Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/ddefe76623cb90a6230ce1c0bd62bad0	DP
knb-lter-cdr.495.9	Energy Efficiency Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018	DP

	doi:10.6073/pasta/d07b36c517f871e751a999fa2f26c0d7	
knb-lter-cdr.496.9	Household Member Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/b612ba3114d3e160639c4b0066c60107	DP
knb-lter-cdr.497.9	Individual Tree Data Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/16646d91b0c802510919fbf8c447f6aa	DP
knb-lter-cdr.501.9	Pets Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/b060f4be8e15ea1de4db6b43a443187f	DP
knb-lter-cdr.502.9	Transportation Choices Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/0791bcf59b648cef5b907e868a371b62	DP
knb-lter-cdr.503.9	Vegetation Choice Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/b36acc79da958d875738051bdaed8526	DP
knb-lter-cdr.504.9	Vehicles Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/2e22613a076a503fa1e23c35a40c166c	DP
knb-lter-cdr.505.9	Household Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/ebb6fdc21855ab96018139870e8d680c	DP
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knb-lter-cdr.507.9	Lawn Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/4a0f39a234bb63769b00f8baf95d6098	DP
knb-lter-cdr.508.9	Paper Plastic Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/82cb3ccf1b00652c1a68d18f49431a7e	DP
knb-lter-cdr.509.9	Air Travel Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/4d16969237c692fcfec4536834480729	DP
knb-lter-cdr.510.9	Commute Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/3c2b4f53099b58ec4aa3dbd909124fea	DP
knb-lter-cdr.511.9	Diet Choices Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/7cc0eb0569fddc8ceb72f68f8fadddff	DP
knb-lter-cdr.512.9	Diet Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/b2b12a4a862427878e0536efcd218806	DP
knb-lter-cdr.513.9	Dispose Leaves Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/b2036864adef165b6695498d3d524b72	DP
knb-lter-cdr.514.9	Education and Work Survey: Twin Cities Household Ecosystem Project; Hobbie, Sarah; 2018 doi:10.6073/pasta/ad9086775275f1785edb47941031adad	DP
knb-lter-cdr.441.8	National Phenology Network tree phenology: Phenology, the timing of biological events such as bud break, plant flowering times and bird migration; Montgomery, Rebecca; 2018 doi:10.6073/pasta/6140f736006c2b86e0d745eef40963b4	PS
knb-lter-cdr.614.9	Sapling Census:FAB 1: Forests and Biodiversity Experiment - High density diversity experiment; Cavender-Bares, Jeannine; 2018 doi:10.6073/pasta/8753a2030c3940cc9ee525528bcacec4 Significant publication: Grossman, J.J., Cavender-Bares, J., Hobbie, S.E., Reich, P.B. and Montgomery, R.A. (2017). "Species richness and traits predict overyielding in stem growth in an early-successional tree diversity experiment." Ecology 98(10): 2601-2614.	PS
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knb-lter-cdr.529.8	Streptomyces pathogen suppressive activity in plant communities varying in	PS

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