The International Drought Experiment: A Coordinated, Multi-site Experiment to Assess Terrestrial Ecosystem Sensitivity to Extreme Drought

Call for Participants

With support from the US National Science Foundation, we are organizing an international network of scientists with expertise in a wide range of terrestrial ecosystems and a common interest in drought. Our goal is to build this network – hereafter referred to as **Drought-Net** –over the next five years (2014-2018) to **comprehensively and comparatively assess the sensitivity of a broad range of terrestrial ecosystems to drought.** A central activity of Drought-Net is to design and establish a coordinated, multi-site experiment - **The International Drought Experiment (IDE).** We are inviting participants from all geographic regions to join Drought-Net and to consider hosting an IDE site in one or more terrestrial ecosystems. ***We especially encourage participation by investigators with experimental sites in ecosystems where little is known of their sensitivity to drought*** (although all sites are encouraged to participate).

Purpose of IDE. To implement a highly coordinated, multi-site drought experiment requiring (in most cases) only a moderate investment of time and resources by investigators. This coordinated, distributed experiment will allow for the quantification of the impacts of extreme drought across a wide range of terrestrial ecosystems based on a common experimental design and a comparable suite of measurements.

Proposed Start Date. IDE is planned to start in **January 2015** (southern hemisphere)/**May 2015** (northern hemisphere) with sites collecting one year of pre-treatment data. Drought treatments will be initiated in 2016.

Guidelines for participation in IDE. Network participants are expected to:

1) fund project infrastructure and implementation at their own site,
2) implement common experimental protocols and core data collection, and
3) openly share data associated with the project in a central repository supported by Drought-Net.

Steering Committee. The Drought-Net steering committee serves to coordinate network activities and establish general guidelines for IDE, including protocols, data use, and timelines. Network participants with an interest in assisting with the design and management of IDE are welcomed to join the Steering Committee.

Data Use. Data will become available to all network members once compiled by the Drought-Net data manager. Data will be made available more broadly (to the public) on a 3-year moving window, although requests for access to new data will be considered by the Drought-Net Steering Committee as long as there are no conflicts with ongoing papers or proposals. Ongoing IDE papers and proposals will be posted on the Drought-Net website.

Manuscript Authorship. By contributing data to Drought-Net according to data submission protocols, IDE participants will be automatically included as a co-author on the core IDE papers (i.e., those addressing hypotheses in Box 1), as long as the participants remain engaged and in contact with the lead authors of each paper. In addition, we strongly encourage network members to take advantage of the unique data set Drought-Net will provide to write additional papers. If a participant wishes to write a paper using IDE data, a working title and abstract must first be submitted to the Drought-Net website one month prior to manuscript preparation. The Drought-Net Steering Committee will provide feedback regarding any potential overlap with ongoing and planned papers and then post the title/abstract on the IDE listserv for more general review. Inclusiveness in authorship will be strongly encouraged on all manuscripts.

If you are interested in joining Drought-Net and/or establishing an IDE site, please visit the Drought-Net website (www.drought-net.org) or contact Melinda Smith (melinda.smith@colostate.edu) for further details.

Steering Committee: Melinda Smith (PI, Colorado State U.), Richard Phillips (co-PI, Indiana U.), Osvaldo Sala (co-PI, Arizona State U.), Claus Beier (Norwegian Inst. of Water Research, Norway), Scott Collins (U. New Mexico), Jeff Dukes (Purdue U.), Lauchlan Fraser (Thompson Rivers U., Canada), Anke Jentsch (Univ. Bayreuth, Germany), Alan

Knapp (Colorado State U.), Michael Loik (UC-Santa Cruz), Fernando Maestre (Rey Juan Carlos U., Spain), Laura Yahdjian (U. Buenos Aires, Argentina).

RATIONALE. Our decision to focus on assessing terrestrial ecosystem sensitivity to drought is based on forecasts that droughts will become more frequent and intense in the future, with the potential for rapid and significant impacts on ecosystem services globally (IPCC 2012). Further, because droughts often interact with other global changes, the socio-economic costs that are incurred amplify the need for enhanced understanding. Our current mechanistic understanding of how terrestrial ecosystems are impacted by drought, which is the knowledge base we must draw from to forecast impacts in the future, is founded primarily on opportunistic studies and site-based experiments. Opportunistic studies, conducted after a natural drought has occurred, tend to capture only those events that have large ecological impacts. While these studies have been invaluable for identifying potential mechanisms underlying observed ecosystem responses, they are limited because the timing and magnitude of natural droughts are not controlled nor coupled with a non-drought reference from within the same ecosystem, making it difficult to separate drought effects from confounding factors that also may affect ecosystem responses and sensitivity (e.g., pest outbreaks, fire, etc.).

Field experiments allow for greater control and are better able to reveal mechanisms of ecosystem response. Although past and ongoing field experiments manipulating precipitation are numerous, these were conceived for the most part with a site-based focus, rather than with a larger scale, comparative perspective in mind. Thus, comparisons of results are challenging due to differences in the magnitude of drought imposed, the methods employed to achieve it (e.g., chronic rainfall reduction vs. pulsed drought years), and the response variables measured. Meta-analysis can partially alleviate this problem by allowing disparate studies to be combined in a quantitative way. However, even when there are sufficient studies to identify differential responses with meta-analyses, there is still the possibility that these differences are due to the unique methodologies employed by individual researchers rather than differences in ecosystems *per se*. As a result, we are ultimately left not knowing how much these disparate research approaches contribute to the apparent differential sensitivities observed among terrestrial ecosystems to drought. Thus, despite their large number, experiments to date have significant limitations for elucidating mechanisms of ecosystem sensitivity, as well as extrapolating to larger spatial scales.

A PROPOSED NETWORK-BASED SOLUTION. Assessing differential sensitivity among ecosystems to drought will be facilitated if responses of multiple types of ecosystems can be directly contrasted within an explicitly comparative experimental context. This will require ecologists to adopt a coordinated research approach – one that minimizes differences in research protocols and methodologies to overcome the limitations identified above. To achieve this goal, a new multi-site **International Drought Experiment (IDE)** is proposed - with a common design and standardized measurement protocols**.**

RESEARCH APPROACH. The primary goals of IDE are to: **(1) assess patterns of differential terrestrial ecosystem sensitivity to drought,** and **(2) identify potential mechanisms underlying those patterns**. IDE will significantly expand the scope of past drought experiments by including as broad a range of ecosystem types as possible, ensuring that these experiments are accessible to as many investigators as possible, and overcoming the limitations of past drought experiments (i.e., lack of coordination, differences in approaches and methodologies, etc.). IDE will follow in the pioneering footsteps of the Nutrient Network (NutNet; http://www.nutnet.umn.edu/), in that: 1) network design will be

Box 1. IDE Research Hypotheses. With IDE, we can address a number of hypotheses concerning the relative sensitivity of terrestrial ecosystem structure and functioning to drought. Here, we provide key hypotheses of how aboveground productivity and plant community responses may differ in their sensitivity to drought. Although, many more hypotheses and responses will be considered, we will initially focus on distinguishing potential abiotic vs. biotic determinants of ecosystem sensitivity to drought.

Abiotic

- Xeric systems are more sensitive to drought than mesic and moist systems (Huxman et al. 2004, Sala et al. 2012).
- Warmer sites will be more sensitive to drought than colder sites (effective water vs. energy limitation; but see Wu et al. 2011).
- Ecosystems with higher historical climatic variability will be less sensitive than ones with lower climatic variability (Grime et al. 2000).
- Edaphic constraints on resources, such as soil N or water, will determine sensitivity to drought (Maestre & Reynolds 2007, Sowerby et al. 2008, St Clair et al. 2009).

Biotic

- Ecosystems dominated by stress tolerant, slow growing species will be less sensitive to drought than those dominated by species with high growth rates (Grime et al. 2000)
- Specific traits of the dominant species, such as deep root systems, will decrease ecosystem sensitivity to drought (Canadell et al. 1996, Maegth et al. 2013).
- More diverse systems (traits, species, etc.) will be less sensitive to drought than less diverse systems (Diaz and Cabido 2001, Tilman et al. 2006, Bloor et al. 2012).

hypothesis driven (Box 1), 2) the experiment will be designed with simplicity in mind to minimize fiscal and logistical constraints, and 3) an important feature of the network will be accessibility to all investigators that want to participate, with a universal experimental design to be used at all sites, a clear set of guidelines for data sharing, intellectual participation in network-level data analyses, and authorship of manuscripts.

Here, we define drought as "a prolonged absence or marked deficiency of precipitation". With climate change, droughts are expected to increase in frequency and magnitude, and thus become more extreme. IDE will impose a drought that represents a statistically extreme deviation in annual precipitation relative to long-term records (occurring $\leq$1% of the time based on annual precipitation amounts recorded over the past 100-yrs for a site). Given that sites can vary dramatically in historic variation in precipitation, the percentage reduction in annual precipitation imposed by each site will differ (e.g., Fig. 1). The amount of deviation imposed will be determined based on analysis of long-term climate data for each individual site (either long-term climatological data or interpolated data). Thus, although the percentage reduction will vary among sites, the "statistical extremity" of drought will be comparable across sites, because it will be standardized based on each site's historic climatic variability.

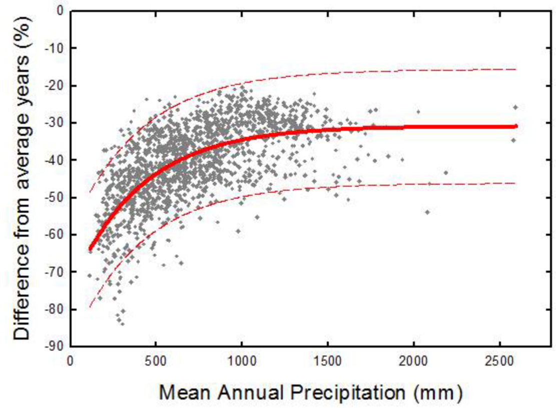

Fig. 1. Relationship between the difference (%) in precipitation amounts between normal years (amounts between the 45-55th % for a 100 year record) and extremely dry years (amounts in the lowest 10th % for a 100-yr record) years and mean annual precipitation. Data are from 1614 climate stations arrayed across the globe, representing 12 ecoregions (grey dots). Shown is the predicted relationship (solid red line) with upper and lower bounds of the 95% confidence interval (dashed red) lines).

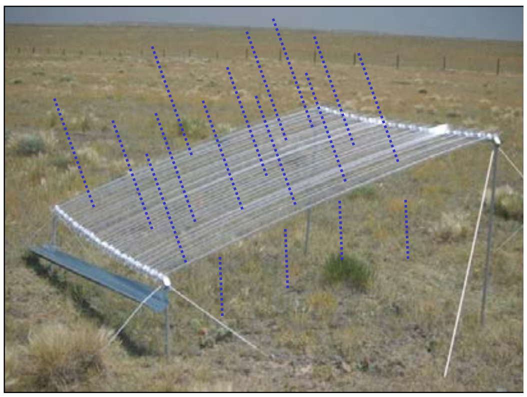

Fig. 2. Example of a simple, passive precipitation reduction shelter that removes a fixed proportion of each rain event (blue dotted lines represent rainfall) from reaching experimental plots. This basic design, modified in scale and placement (i.e., below the canopy in forests), has been used successfully in a wide range of ecosystems.

The drought treatment will be imposed year-round (though in some cases it may need to be restricted to the growing season) over a 4-year period. Infrastructure that passively reduces each rainfall event by a fixed percentage will be deployed at each site (Fig. 2). We have found that this approach does an excellent job of capturing key characteristics of dry years across a broad range of ecosystem types (Smith et al. in prep.). Thus, we can use relatively simple, low maintenance, and low cost approach to impose an equivalent magnitude drought across a broad range of terrestrial ecosystems.

We are currently finalizing the design of the infrastructure to impose drought in different ecosystem types. However, key features of IDE are summarized in Box 2.

Box 2. Key Features of the IDE Design

- Percent reduction of annual precipitation based on the historical precipitation record for an individual site (equivalent to a 1 in 100 year drought)
- Drought imposed over a 4-year period
- Passive reduction using shelters with roofs consisting of a number of transparent troughs (or corrugated polycarbonate strips) to exclude a specific amount of each rainfall event (Fig. 2; Yahdjian and Sala 2002)
- Infrastructure control and trenching strongly encouraged but not required
- Recommended replication (minimum n=3; preferred, n =5/treatment)
- Flexible size of passive reduction shelters (minimum size: 2.5 × 2.5 m; forests: to be determined)
- Pre-treatment data collection
- Core measurements: aboveground productivity, plant community composition, light availability, meteorological measurements (daily precipitation, air temperature), and soil characteristics

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