NATIONAL SCIENCE FOUNDATION
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NSF 18-047

Dear Colleague Letter: Signals in the Soil (SitS)

February 22, 2018

Dear Colleagues:

The National Science Foundation (NSF) Directorate for Engineering (ENG) in collaboration with its Directorates for Biological Sciences (BIO), Computer and Information Science and Engineering (CISE), and Geosciences (GEO), aims to encourage convergent research that transforms existing capabilities in understanding dynamic near-surface processes through advances in sensor systems and dynamic models. The goal of this Dear Colleague Letter (DCL) is to encourage submission of Early-Concept Grants for Exploratory Research (EAGER) proposals for early-stage, high-risk, high-reward research on technologies, models, and methods to better understand dynamic soil processes, including interactions of the macro- and microbiomes with soil nutrients, the rhizosphere, and various abiotic and biotic processes within the soil. In addition, for proposals that include topics relevant to both this DCL and the NSF "Rules of Life" Big Idea, submissions of Research Advanced by Interdisciplinary Science and Engineering (RAISE) proposals are encouraged. Researchers who are interested in submitting a SitS EAGER or RAISE proposal must first submit a SitS Research Concept Outline, as described below. Selected submitters of these Outlines will be invited to submit full EAGER or RAISE proposals for funding consideration.

Questions about this DCL should be directed to: SitSquestions@nsf.gov.

NATIONAL NEED

Soils are the foundation of terrestrial ecosystems that support economic prosperity and provide services that are essential for humanity. Soils are complex living ecosystems containing billions of organisms that mediate a myriad of biological, chemical, and physical processes, interacting to cycle carbon and nutrients essential for plant growth, food and fiber production, and to remove contaminants from water. Soil is also the foundation material for all structures not supported on rock, and is by orders of magnitude, the most widely-used construction material in the world. Soil ecosystems supply most of the antibiotics used to fight human diseases, control the movement of water and chemical substances between the Earth and atmosphere, and act as source and storage media for gases important to life, such as oxygen, carbon dioxide, and methane. Thus, as the Earth's population grows to nearly 10 billion by 2050, we need a better understanding of soil ecosystems that will continue to play a critical role in feeding the world.

Existing knowledge of dynamic changes in soils under the Earth's surface is hampered by lack of observation capabilities for widespread measurement of key variables over large areas and long periods of time. While, for many applications, the current state of the art is to collect soil core samples at field sites and then transport them to the laboratory to make measurements, scientists and engineers use many geophysical methods to evaluate subsurface stratigraphy and mechanical properties of soil. Scientists and engineers rely on biological, chemical, and physical models to predict soil states where and when they are not measured, but these models are based on limited measurements, particularly time series observations of variables, and assumptions that are not reliable across spatially-variable landscapes over extended time periods. This situation exists globally, and includes relevant Arctic regions where spatially and temporally expansive measurements are needed to better understand the potential influence of warming permafrost on the carbon cycle or the fundamental biogeochemical and hydrological processes in permafrost. The challenge for researchers is to both develop the underlying science and technologies for sensing systems needed to considerably advance current understanding of dynamic soil processes and engineer systems for monitoring these processes. Accomplishing this goal will require major advances in instrumentation for measuring temporal and spatial changes of biological, chemical, and physical processes, in development of methods for placing instrumentation in soil with minimal disturbance, in data transmission protocols, and in the development of a next generation of models to predict key soil variables. Recent advances in miniature, low-powered, wireless sensors show considerable promise for in situ measurements of soil physical, chemical, and biological variables. However, many of these technological advances are occurring in other fields (e.g., health/medicine, energy, and transportation); these advances have not yet been widely explored for novel uses in soil.

This DCL encourages research concepts that integrate fundamental science and engineering knowledge in different disciplines with the aim of developing a next generation of sensor systems capable of in situ measurement of dynamic soil biological, physical, and chemical variables over time and space in managed and unmanaged soils. These sensor systems will also require associated advances in data transmission, ground penetration, data analytics, dynamic models, and visualization tools. If successful, these research concepts will enable scientists to advance basic understanding of dynamic processes in soils and provide the underlying science and engineering to enable others to develop new ways of managing soils and natural resources. Advances in measurement systems, understanding, and models will provide new capabilities that will enable practitioners to use new sensors, models and time series data to achieve higher efficiencies of resource use to help meet societal goals such as less contamination of soil and water supplies and greater food security, as well as address the "National Academy of Engineering Grand Challenge" of managing the Nitrogen cycle.

RESEARCH CONCEPT OUTLINES - DESCRIPTION

Prior to submitting EAGER or RAISE proposals pursuant to this DCL, interested principal investigators (PIs) must prepare Research Concept Outlines. These Research Concept Outlines must include clear statements as to why a given project is appropriate for EAGER funding or RAISE funding. Guidelines for preparing EAGER proposals can be found in Chapter II.E.2 of the NSF Proposal & Award Policies & Procedures Guide (PAPPG) and guidelines for preparing RAISE

proposals can be found in PAPPG Chapter II.E.3. Research Concept Outlines must include the rationale for selecting target soil measurements, why these are important, and a short vision of how the proposed research will ultimately benefit economic activities and not adversely affect environmental sustainability. For proposals focused in the Arctic, investigators must demonstrate a clear understanding of the unique challenges associated with working in regions where winters are characterized by extreme and prolonged cold and high winds, and soils experience significant freeze-thaw activity. For RAISE Research Concept Outlines, there must be a strong link to the NSF "Rules of Life" Big Idea along with topics relevant to SitS. Before submission of a RAISE Research Concept Outline, a preliminary inquiry to SitSquestions@nsf.gov about topic suitability and potential division interests is strongly encouraged.

POTENTIAL RESEARCH THEMES

Research Concept Outlines are encouraged for research that addresses any of the themes outlined below to monitor soil properties over time and space for various managed or unmanaged applications, which may include monitoring soil properties for environmental, agricultural, or construction purposes. **Other topics that meet the goals of this DCL, but are not included in these four themes, are also strongly encouraged.**

1. **Sensors:** Novel sensors and other materials for sensing soil biological/metagenomics, chemical, or physical characteristics to monitor soil health and changes in properties under different uses, and to address needs for inexpensive sensors buried for long time periods in highly variable soil conditions.
2. **Wireless Systems:** Advances in wireless communications to collect and transmit data from sensors buried in soils over extended periods of time.
3. **Advanced Cyber Systems and Data Analytics:** New methods for data fusion and analytics of sensor measurement outputs (data visualization and reporting tools, etc.).
4. **Modeling Soil Ecosystems:** Next-generation models of soil biological, chemical, and/or physical components, making use of new sensing and data communications capabilities that can describe interactions among soil biological, chemical, and physical processes at different temporal and spatial scales.

RESEARCH CONCEPT OUTLINE - SUBMISSION

The NSF ENG directorate as well as the BIO, CISE, and GEO directorates are interested in receiving these Research Concept Outlines. These Research Concept Outlines should be no longer than 2 pages and must be submitted by April 13, 2018. They must contain the following information:

1. Title of the SitS research.
2. The suggested directorate(s) that may be interested in the topic. For a RAISE topic, more than one program must be listed, and there should be a clear link to each of those programs. Please note that these program listings are just suggestions. Multiple programs will view these Research Concept Outlines to determine programmatic fits.
3. Description of and justification for the proposed research.
4. Names and affiliations of researchers.

5. Contact information of the researchers (emails and phone numbers).

The Research Concept Outline should **not exceed 2 pages**. It must be emailed to SitSquestions@nsf.gov. Once NSF program officers have approved the Research Concept Outline, the PI will be invited to submit a full EAGER or RAISE proposal to a specific program. Please note that NSF staff may contact the Research Concept Outline submitter to gather more information prior to selecting those that will be invited to submit a full EAGER or RAISE proposal. PIs of non-selected outlines will be notified that they will not be invited to submit EAGER-SitS or RAISE-SitS proposals.

RESEARCH CONCEPT OUTLINE - REVIEW AND DECISION

Research Concept Outlines that fall within the scope of this DCL may be selected to submit a full EAGER (or RAISE) proposal for NSF review. Decisions on full EAGER or RAISE proposal submissions will be based on research efforts that could lead to major advances in how soils are managed for economic and environmental benefits.

Please note that an invitation to submit a full EAGER or RAISE proposal does not indicate that the proposal will be funded. The invited full EAGER and RAISE proposals will undergo further internal review by the participating divisions before funding decisions are made. The number of Research Concept Outlines invited to submit a full EAGER or RAISE proposal are subject to the quality of concepts received and available funding (up to 30 may be invited). All funding decisions will be made during fiscal year 2018 (FY 2018).

Most requests to PIs to submit proposals will be restricted during FY 2018 to EAGER proposals, which are aimed at exploratory research with a maximum duration of 2 years and maximum budget of $300,000. Research Concept Outlines are expected to adhere to typical proposal budgets and durations for the NSF EAGER funding opportunity (see PAPPG Chapter II.E.2). For Research Concept Outlines that are invited as RAISE proposals, higher budgetary limits are allowed. However, certain criteria must be met to be considered a RAISE proposal. Please see PAPPG Chapter II.E.3 for more information.

Questions concerning this opportunity may be emailed to SitSquestions@nsf.gov.

Sincerely,

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