NEON is seeding the next revolution in ecology

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The National Ecological Observatory Network (NEON) became fully operational across 81 terrestrial and aquatic sites in May 2019, marking a key moment in the history of ecology. With the cost of construction and maintenance over the next 30 years projected to exceed $2.4 billion, this is an unparalleled investment in continental-scale ecology. We believe NEON will precipitate the next big shift in the discipline, akin to the launch of long-term ecological research four decades ago, the rise of ecological synthesis two decades ago, and the leveraging of big data for ecology within the past decade. We urge the current and emergent community to help accelerate this revolution.

Early NEON adopters are already exploring biodiversity and environmental change across space and time scales, with over 80 publications using NEON assets and over 22,000 NEON data downloads in the past 2 years. To further expand these explorations, the first NEON Science Summit was hosted by Earth Lab at the University of Colorado (CU)–Boulder in October 2019 (https://bit.ly/2u8ah5W). The Summit brought together 168 scientists for an "unconference" (a loosely structured, participant-driven meeting) that prompted more than 70 ideas on how to use NEON data, from integrating vertical remote-sensing data to answering questions about disturbance, resilience, and tipping points. While there is already substantial momentum around NEON, the Summit identified two emergent Grand Challenges that are critical if NEON is to reach its full potential: building open data skills for all ecologists and linking NEON to the larger environmental data constellation.

Across environmental sciences there is a widespread lack of capacity in the data and computing skills needed to leverage large, heterogenous data (Hampton *et al.* 2017; *BioScience* **67**: 546–57), including, we argue, the full suite of NEON data. The first Grand Challenge, and arguably the foundation for advancing NEON-generated knowledge, is building the core skills necessary for open, data-intensive ecology. NEON's commitment to open data at the outset is one of its most transformational elements, potentially enabling access and discovery across a diversity of backgrounds, career stages, and institutions. Required skills include: (1) best practices for developing and sharing data, code, software, and entire scientific workflows; (2) analysis of vast quantities of data on distributed cyberinfrastructure or the cloud; and (3) collaboration skills in an open science framework that facilitate large-team science. New educational efforts in Earth analytics at CU–Boulder (www.earthdatascience.org) and environmental data science at NCEAS (www.nceas.ucsb.edu/Learning-Hub) are early examples of the data-centered curricula that are increasingly essential for undergraduate, graduate, and professional ecologists.

NEON has become fully operational in the era of big data. The second Grand Challenge is to link NEON to major environmental datasets. Alone it is powerful; combined with other data sources we believe NEON will be transformational. There are at least four major sources of environmental data that should be harmonized with NEON output in the coming decade: existing observatory networks (eg LTER and CZO); emergent observing sensors and platforms (eg UAVs and microsensors); key satellite and space-borne assets (eg Landsat, ECOSTRESS, and GEDI); and climate and land-use data and models (eg GRIDMET and CMIP6). These data harmonization efforts will enable testing of global change ecology questions at continental scales and across the past several decades. NEON should be a central node that links many sources of environmental data, leading efforts to build data-, cyber-, and knowledge-infrastructure. Furthermore, the heterogeneity of NEON data is unique among large-scale instrument investments, and, we believe, will encourage interdisciplinary research. These efforts will expand the NEON community by engaging experts in data science, remote sensing, computer science, and other allied fields.

NEON is radical. We believe the network's growing pains may reflect the fact that many current and future ecologists have yet to fully adopt NEON because of these two Grand Challenges. We envision that NEON will be a cornerstone of our science for the next three decades, but the next 5 years are critical. We need our research community to promote a new ecology, embracing new data skills, data-driven inquiry and analytical approaches, coordinated and large-team science, and a commitment to open science. Otherwise, ecology will be left behind by other disciplines, like physics and biotechnology, that are rapidly advancing new approaches to science. Our vision is that, through environmental data skills and links to a diversity of environmental data, a NEON community of thousands will address the continental-scale ecology questions that the observatory was designed to answer. A big shout-out to the 168 NEON Science Summit participants who are helping to lead the way. We are just getting started.