The National Ecological Observatory Network: Science strategy, data collection and products

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*USDA Forest Service, Former Chief of Science, NEON Inc.
The overarching goal of NEON is to enable understanding and forecasting of the impacts of climate change, land use change, and invasive species on continental-scale ecology *by providing infrastructure* to support research in these areas.

- **Information infrastructure**: Consistent, continental, long-term, multi-scaled data-sets and data products that serve as a context for research and education.

- **Physical Infrastructure**: A research platform for investigator-initiated sensors, observations, and experiments providing physical infrastructure, cyberinfrastructure, human resources, and expertise, and program management and coordination.
NEON’s Scientific Approach

Forcing

Interactions

Feedbacks

Responses

Climate Change
Land-Use Change
Invasive Spp.

Spp. Composition
Phenology
Physiology
Stoichiometry

Biodiversity
Biogeochemistry
Ecohydrology
Infectious Disease
GRAND CHALLENGES

Forcing
Climate, Land Use, Invasives

Interactions, Feedbacks
Productivity, Functional Diversity, Soil Moisture, Habitat Structure, etc.

Responses
Biodiversity, Biogeochemical, Disease, Ecohydrology

Lead to focused questions that NEON can address on continental scales...

What implications do breeding bird phenological shifts have for West Nile Virus disease risk?

How does the changing pattern of land use affect terrestrial productivity at the continental scale?

What is the aquatic biological response to sustained increases in nutrients?

How are the rates of geographic spread and population growth of invasive species affected by land use and climate change?

That require specific data products to answer the questions...

Bird diversity; West Nile Virus prevalence in mosquitoes

Benthic macro-invertebrate diversity and abundance; Stream metabolism

Land cover classification; Ecosystem exchange of carbon

Invasive species risk maps; Historical Climate Data

And NEON’s infrastructure supports science packages that provide the measurements required to produce the data products

FSU Science Reqs Tech/Ops Reqs
FIU Science Reqs Tech/Ops Reqs
AOP Science Reqs Tech/Ops Reqs
LUAP Science Reqs Tech/Ops Reqs
STREON Science Reqs Tech/Ops Reqs

+ ...
A National Observatory: 20 Eco-climatic Domains

NEON Domains

- 1 Northeast
- 2 Mid Atlantic
- 3 Southeast
- 4 Atlantic Neotropical
- 5 Great Lakes
- 6 Prairie Peninsula
- 7 Appalachians/Cumberland Plateau
- 8 Ozarks Complex
- 9 Northern Plains
- 10 Central Plains
- 11 Southern Plains
- 12 Northern Rockies
- 13 Southern Rockies/Colorado Plateau
- 14 Desert Southwest
- 15 Great Basin
- 16 Pacific Northwest
- 17 Pacific Southwest
- 18 Tundra
- 19 Taiga
- 20 Pacific Tropical
An example relocatable deployment
NEON Deployment

- Headquarters (incl. CI, labs, etc.) - Boulder
- 20 Domains
  - 20 Core sites (wildland)
  - 40 Relocatable sites (land-use sites)
- 10 Mobile laboratories (AK, HI, CONUS+PR)
- 3 Airborne Observation Platforms
- Land Use Analysis Package
- STREON Experiment
<table>
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<tr>
<th><strong>FSU</strong></th>
<th><strong>Fundamental Sentinel Unit</strong></th>
<th><strong>Human Observers/Samplers</strong></th>
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<tr>
<td><strong>FIU</strong></td>
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<td><strong>AOP</strong></td>
<td><strong>Airborne Observation Package</strong></td>
<td><strong>Aircraft Remote Sensing</strong></td>
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<td><strong>LUAP</strong></td>
<td><strong>Land Use Analysis Package</strong></td>
<td><strong>Satellite Remote Sensing +</strong></td>
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Fundamental Sentinel Unit

- Biodiversity
- Population Dynamics
- Productivity
- Phenology
- Infectious Disease
- Biogeochemistry
- Microbial Diversity and Function
- Ecohydrology
Fundamental Instrument Unit

- Physical and chemical climate forcing
- Ecosystem responses
- Stand/plot level sampling
- Automated instrumentation
- Micrometeorological scalars and fluxes
- Soil array
- Aquatic array
- Over 2000 measurements per core site at frequencies of ~0.1 to 20 Hz
Airborne Remote Sensing (AOP)

- **Spectroscopy**
  - Vegetation biochemical & biophysical properties
  - Cover type & fraction

- **LiDAR altimetry**
  - Vegetation Structure
  - Sub-canopy topography
  - Biomass

- **High resolution imagery**
  - Land use & land cover
Notional Flight Plan for Standard Observations of NEON Core and Relocatable Sites

Assumes 2 payloads in operation from roughly April to Sept

Notional flight plan for payload 1 (blue dots) and payload 2 (orange diamonds). The location of the vicarious ground site is indicated by the *. This flight plan has been optimized to survey each domain at its period of peak greenness and when cloud cover is expected to be minimal.
Land Use Analysis Package

- Continental coverage
- Land cover
- Land use
- Vegetation biophysical properties
- Geographic data including census data
- User interface to facilitate geographic analysis by the non-specialist
STREON Experiment

NEON control reach

Instrument station, water sampling site

Experimental units (baskets

Consumer exclosure (electrified barriers

Nutrient addition station

STREON treatment reach

Basket incubation (e.g. streamside flume or in situ recirculation chamber)
Spatial Scaling Strategy

LUAP

AOP

FIU

Mobile Labs

FSU+ AQS

Ecological Forecast models
Cascade of multi-scaled information from observations through analyses to users

Web portal:
Information for science, education and management

Observations:
- Field observations and instruments
- Airborne remote sensing
- Satellites, statistical data

Models

Organisms, genomes

Communities, ecosystems, landscapes

Climate patterns, transport of material and organisms

Small Spatial scale Large
Low and High Level Data Products

**Level 1-3 Products**
- Winds, CO$_2$ concentration, H$_2$O vapor concentration
- Minirhizotron Images
- Small mammal species ID, small mammal age, small mammal gender

**Level 4 Products**
- Carbon and water fluxes and parameters: GPP, $R_A$, $R_H$, WUE, $A_{max}$
- Root phenology
- Population parameters: abundance, survival, recruitment, fecundity

**Flux assimilation model**
**Image analysis calibration**
**Mark-recapture model**

539 L1 products + 35 L2-L3 products
118 L4 products
Key NEON Data

• Bioclimate Suite
  – Temperature, precipitation, humidity, radiation

• Biodiversity Suite (includes invasive spp.)
  – Abundance and diversity (mosquitoes, aquatic invertebrates, beetles, fish, birds, plants, …)
  – Phenology (mosquitoes, beetles, plants)
  – Microbial function and diversity (functional genes, metagenomes)
  – Bioarchive (all taxa, substrates)

• Biogeochemistry Suite
  – Carbon stocks, fluxes, isotopes
  – Nutrient stocks, fluxes, isotopes
  – Chemical climate (N-deposition, Ozone)
Key NEON Data

- **Ecohydrology Suite**
  - Water balance components (storage and flows)

- **Infectious Disease Suite**
  - Disease prevalence (Dengue, Hanta virus, Lyme disease, West Nile Virus)

- **Land Use and Land Cover Suite**
  - Remote sensing data (vegetation performance and structure)
  - Geographic data (topography, historical climate, etc.)
  - Statistical data (human geography)
NEON Level 1 Data Products

Remote Sensing and Geographic: 8%
Instrument: 15%
Field: 22%
Lab: 55%
Chemical: 54%
Taxonomic: 9%
Isotopic: 18%
Genetic: 16%
Disease: 4%

Lab Breakdown
Information Processing

539 Primary Observations:
- In Situ
- Airborne
- Experimental GIS

100 Summary Variables:
- Statistical Genomics
- GIS

18 Model Outputs:
- Continental Gridded Estimates and Forecasts
The overarching goal of NEON is to enable understanding and *forecasting* of climate change, land use change, and invasive species on continental-scale ecology by providing infrastructure to support research in these areas.

**Ecological Forecasting**

- What is the most likely future state of an ecological system?
- What-if: what is the most likely future state of a system given a decision today?
Improvements in forecasts come from repeated comparison between data and forecasts
**Question:** How will climate change affect the spread of mosquito-borne diseases? The specific case of dengue fever.

**Approach:** Climate envelope model for *Aedes aegypti* (vector for dengue fever)

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Integration of NEON data to produce analyses and forecasts

Potential NEON Invasive Species Analysis and Forecast

Mapped Forecasts of Invasion and Invasibility

Ecological Niche Model

Site-Based Data
- Biomass and NPP of Natives and Invasives
- Diversity

Spatial and Remote Observations
- AOP Biomass
- AOP Habitat Structure
- NISIC
- Climate

Distribution and Abundance of Invasive Species

Organism Scale Processes
- Physiology Reproduction

Stand to Landscape Processes
- Disturbance Fragmentation Corridors

Regional Scale Processes
- Proximity to Gateways Transport Vectors Climate
Science Case 1 – Infectious Disease

County habitat suitability for Aedes aegypti

Average test AUC: 96.2
Average of 25 replicate models
71 presence locations, 30% for testing
Hashes: currently reported

Created with: Maxent v 3.2.19

Greatest variable contribution (avg):
Annual mean temperature (54.2%)
Urban area (14%)
Mean temperature of wettest quarter (10.9%)
Mean temperature of coldest quarter (10.7%)

T. Stohlgren, unpublished
**Science Case 2 - Biogeochemistry**

**Question:** How will climate change affect US ecosystem carbon uptake?  
**Approach:** Carbon data-assimilation model

**Level 4 Data Products (examples)**
- **Bioclimat_e_001**: Summary weather statistics  
- **Biogeochemistry_017**: Ecosystem exchange, tower  
- **Biogeochemistry_019**: Ecosystem exchange of carbon, NEON Realm  
- **Biogeochemistry_020**: Net Primary Productivity  
- **Land_Use_007**: Land cover classification  
- **Land_Use_008**: Land cover classification, AOP  
- **Land_Use_024**: Historical Climate Data

**Level 1 Data Products (examples)**
- **FIU.1.0003**: Air temperature WMO  
- **FIU.1.0006**: Bulk precipitation  
- **FIU.1.0010**: CO₂ concentration  
- **FIU.1.0011**: CO₂ profile  
- **FSU.1.0112**: DBH live trees  
- **FSU.1.0116**: Litter traps, leaves  
- **FSU.1.0125**: Coarse root live biomass  
- **FSU.1.0142**: Coarse downed woody debris  
- **LUAP.1.0015**: MRLC National Land Cover Database  
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Integration of NEON data to produce analyses and forecasts

Potential Spatial Analysis of US Carbon Budget using NEON and North American Carbon Program Infrastructure
Results from NOAA Carbon Tracker (displayed) present estimates of carbon uptake by ecosystems based only on atmospheric data. NEON will complement this with a data-assimilation model based on terrestrial measurements.
Opportunities for Scientists and Educators

• Deployments:
  – Mobile Deployment Platform (10 mobile labs)
  – Airborne Observing Platform (1 of 3 platforms)

• Data Products
  – 539 Level 1 and 118 Level 4 data products.
  – New data products developed based on community inputs

• Bioarchive
  – ~130,000 samples per year (species and substrates)

• Experiments
  – Externally funded experiments using NEON sites and infrastructure
NEON Status

• The National Ecological Observatory Network (NEON), completed its Final Design Review in November 2009 -- a major milestone in the design and execution of the project.

• Pres. Obama made a request in the 2011 budget

• National Science Board (NSB), governing body of the National Science Foundation (NSF), has authorized the NSF Director, at his discretion, to make an award for construction of NEON.

• If all goes well … construction starts in FY 2011
The Human Dimension

• The ecological scientific and educational community forms a network (or many networks) of interacting autonomous peer groups collaborating on issues of mutual interest.

• NEON is a continental observatory and a facility for the scientific, educational and environmental management community to use…

• While the NEON staff must envision how NEON might be used to advance the field, NEON staff will not be the ones doing this…

• NEON’s success or failure of NEON will be determined by how it is used by investigators and educators (by you) in hundreds of future research and education projects, in the field, in the lab, in classrooms, offices, in public, etc….
NEON Advisory Structure

- **STEAC** – Science, Technology, and Education Advisory Committee (strategic advice)
- **DSECC** – Domain Science & Education Coordination Committee (input on domain level)
- **TWG** – Technical Working Group (input on specialized area to Product Team Lead or Project Scientist)
The National Ecological Observatory Network is a project sponsored by the National Science Foundation and managed under cooperative agreement by NEON Inc.

www.neoninc.org

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