Patterns, Places, People: Leveraging the NEON Airborne Observation Platform for scalable observation of Socio-Environmental Systems

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Abstract

During the 21st century, human–environment interactions will increasingly expose both systems to risks, but also yield opportunities for improvement as we gain insight into these complex coupled-systems. Human–environment interactions operate over multiple spatial and temporal scales, requiring large data volumes of multi-resolution information for analysis. Climate change, land-use change, urbanization, and wildfires, for example, can affect regions differently depending on ecological and socioeconomic structures. The relative scarcity of data on both humans and natural systems at the relevant extent can be prohibitive when pursuing inquiries into these complex relationships. We explore the value of multitemporal, high-density, and high-resolution LiDAR, imaging spectroscopy, and digital camera data from the National Ecological Observatory Network's Airborne Observation Platform (NEON AOP) for Socio-Environmental Systems (SES) research. We outline specific applications for addressing SES questions, highlight current challenges, and provide recommendations for the SES research community to improve and expand its use of this platform for SES research. The coordinated, nationwide AOP remote sensing data, collected annually over the next 30 years, offer exciting opportunities for cross-site analyses and comparison, upscaling metrics derived from LiDAR and hyperspectral datasets across larger spatial extents, and addressing questions across diverse scales. Integrating AOP data with other SES datasets will allow researchers to investigate complex systems and provide urgently needed policy recommendations for socio-environmental challenges. We urge the research community to further explore interdisciplinary questions and theories that might leverage NEON AOP data, and present a new Research Coordination Network aimed at supporting these efforts.

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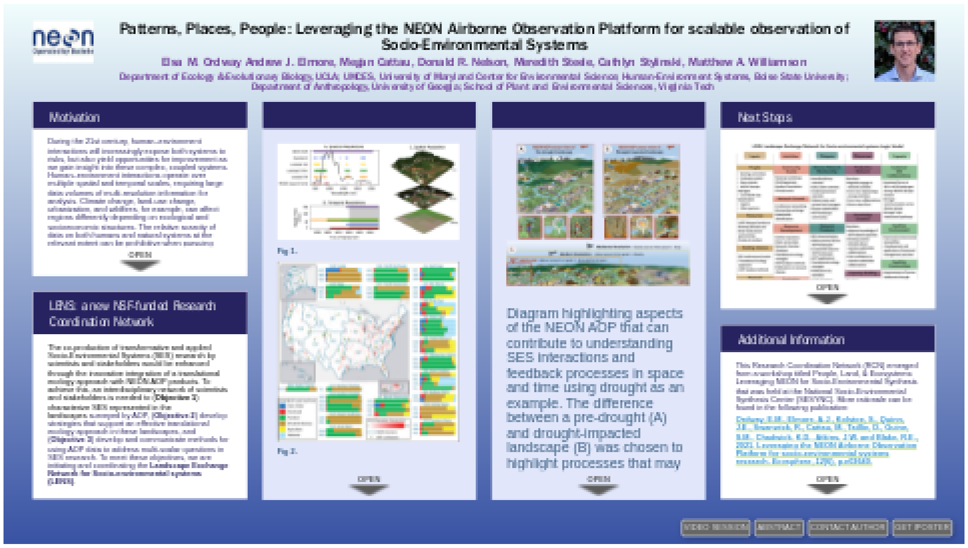

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MOTIVATION

During the 21st century, human–environment interactions will increasingly expose both systems to risks, but also yield opportunities for improvement as we gain insight into these complex, coupled systems. Human–environment interactions operate over multiple spatial and temporal scales, requiring large data volumes of multi-resolution information for analysis. Climate change, land-use change, urbanization, and wildfires, for example, can affect regions differently depending on ecological and socioeconomic structures. The relative scarcity of data on both humans and natural systems at the relevant extent can be prohibitive when pursuing inquiries into these complex relationships. Multitemporal, high-density, and high-resolution LiDAR, imaging spectroscopy, and digital camera data from the National Ecological Observatory Network's Airborne Observation Platform (NEON AOP) offer a valuable opportunity to leverage cutting edge data for Socio-Environmental Systems (SES) research. The coordinated, nationwide AOP remote sensing data, collected annually over the next 30 yr, offer exciting opportunities for cross-site analyses and comparison, upscaling metrics derived from LiDAR and hyperspectral datasets across larger spatial extents, and addressing questions across diverse scales. Integrating AOP data with other SES datasets will allow researchers to investigate complex systems and provide urgently needed policy recommendations for socio-environmental challenges. We urge the SES research community to further explore questions and theories in social and economic disciplines that might leverage NEON AOP data.

LENS: A NEW NSF-FUNDED RESEARCH COORDINATION NETWORK

The co-production of transformative and applied Socio-Environmental Systems (SES) research by scientists and stakeholders would be enhanced through the innovative integration of a translational ecology approach with NEON AOP products. To achieve this, an interdisciplinary network of scientists and stakeholders is needed to (**Objective 1**) characterize SES represented in the landscapes surveyed by AOP, (**Objective 2**) develop strategies that support an effective translational ecology approach in these landscapes, and (**Objective 3**) develop and communicate methods for using AOP data to address multi-scalar questions in SES research. To meet these objectives, we are initiating and coordinating the **Landscape Exchange Network for Socio-environmental systems (LENS)**.

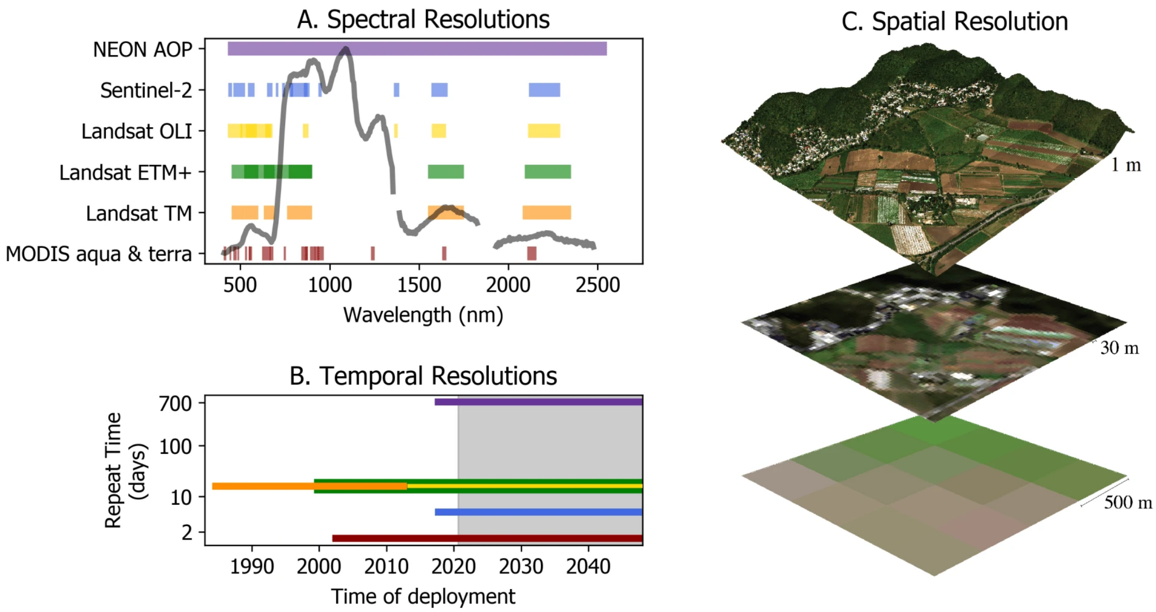
A. Spectral Resolutions
NEON AOP
Sentinel-2
Landsat OLI
Landsat ETM+
Landsat TM
MODIS aqua & terra
500 1000 1500 2000 2500
Wavelength (nm)
B. Temporal Resolutions
Repeat Time (days)
700 100 10 2
1990 2000 2010 2020 2030 2040
Time of deployment
C. Spatial Resolution
1 m
30 m
500 m

Fig 1.

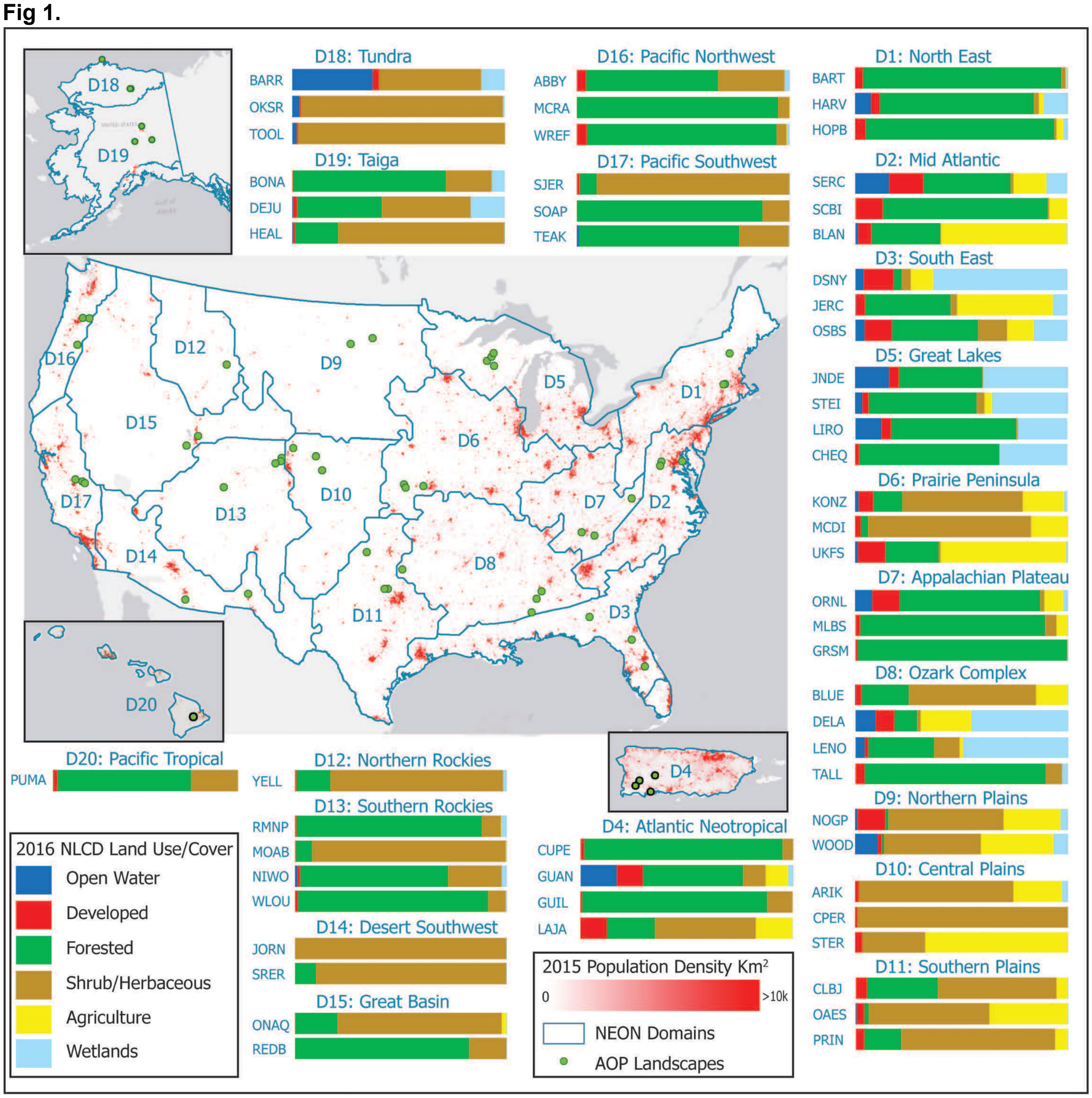
D18: Tundra
BARR
OKSR
TOOL
D19: Taiga
BONA
DEJU
HEAL
D16: Pacific Northwest
ABBY
MCRA
WREF
D17: Pacific Southwest
SJER
SOAP
TEAK
D1: North East
BART
HARV
HOPB
D2: Mid Atlantic
SERC
SCBI
BLAN
D3: South East
DSNY
JERC
OSBS
D5: Great Lakes
JNDE
STEI
LIRO
CHEQ
D6: Prairie Peninsula
KONZ
MCDI
UKFS
D7: Appalachian Plateau
ORNL
MLBS
GRSM
D8: Ozark Complex
BLUE
DELA
LENO
TALL
D9: Northern Plains
NOGP
WOOD
D10: Central Plains
ARIK
CPER
STER
D11: Southern Plains
CLBJ
OAES
PRIN
D20: Pacific Tropical
PUMA
D12: Northern Rockies
YELL
D13: Southern Rockies
RMNP
MOAB
NIWO
WLOU
D14: Desert Southwest
JORN
SRER
D15: Great Basin
ONAQ
REDB
D4: Atlantic Neotropical
CUPE
GUAN
GUIL
LAJA
2016 NLCD Land Use/Cover
Open Water
Developed
Forested
Shrub/Herbaceous
Agriculture
Wetlands
2015 Population Density Km²
0
>10k
NEON Domains
AOP Landscapes

Fig 2.

Figure 1. Spectral (A), temporal (B), and spatial (C) resolution of NEON AOP data relative to other widely used, publicly available remote sensing datasets. (A) Spectral range for different sensors. Note that the NEON AOP is contiguous at 5 nm intervals while other sensors have much larger bandwidths. Overlapping bands are darker in color. The gray line is an example spectra for a vegetated pixel taken from an AOP acquisition to highlight the shape of the reflectance spectrum. (B) Duration of record vs. the repeat time for each sensor (colors designated in A). Future acquisitions are in gray. In (A, B), NEON AOP spectral resolution and temporal resolution are illustrated in purple, Sentinel-2 in orange, Landsat Operational Land Imager (OLI) in yellow, Landsat Enhanced Thematic Mapper Plus (ETM+) in green, Landsat Thematic Mapper (TM) in blue, and MODIS aqua and terra are in red. (C) AOP data at 1 m resolution overlain on LiDAR point cloud data in Guánica, Puerto Rico, compared with 30 m Landsat OLI OLI data and 500 m MODIS (MOD09A1) data at the same location.

Figure 2. Locations and fractional land cover of AOP landscapes with surveys and products available from the NEON website in mid-2020. The landscapes surveyed do not capture any of the major U.S. population centers (red areas on the map), but exhibit considerable land use diversity. While total developed land is less than 1% in about half of the AOP landscapes, 10 of the landscapes are more than 10% developed. Agricultural land ranges from less than 1% to nearly 70%. Data on populations is from the 2015 block-group level census and land cover is from the 2016 National Land Cover Database.

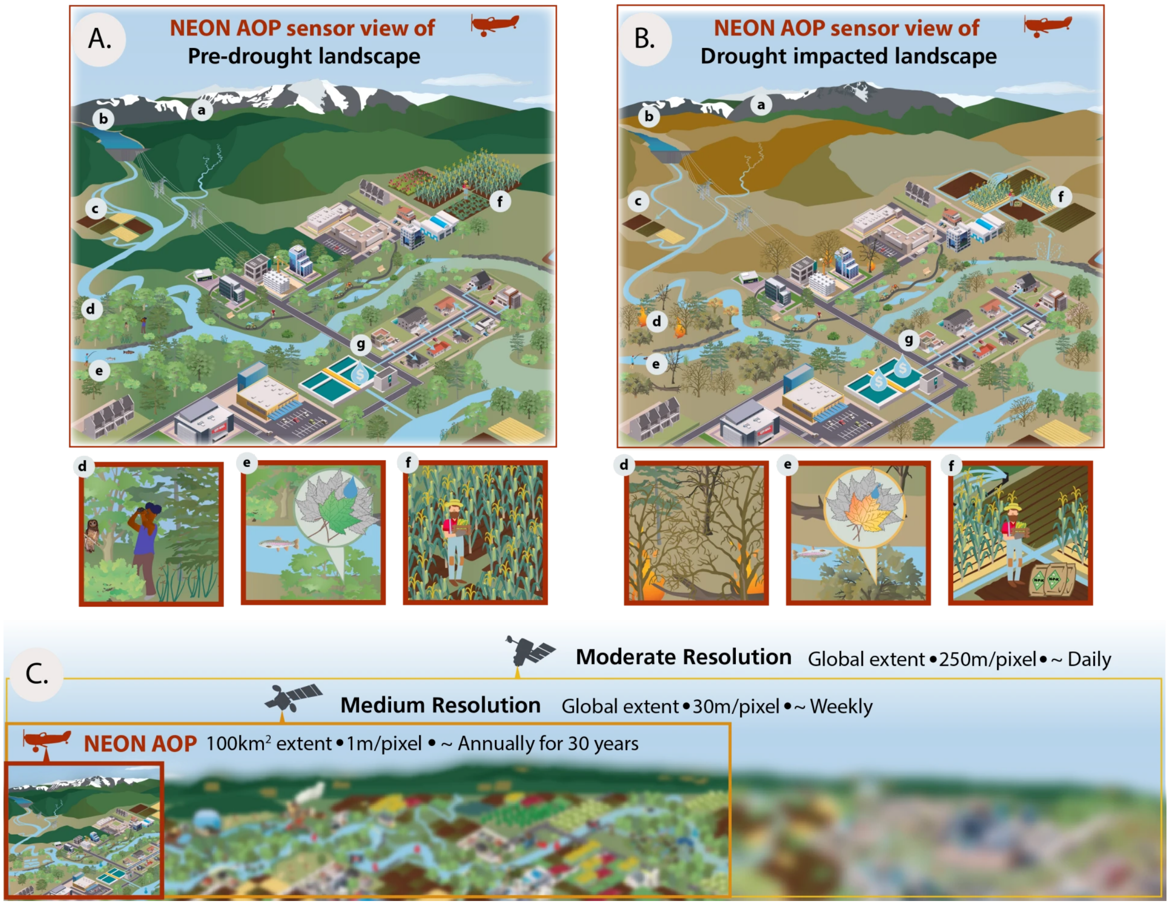

Diagram highlighting aspects of the NEON AOP that can contribute to understanding SES interactions and feedback processes in space and time using drought as an example. The difference between a pre-drought (A) and drought-impacted landscape (B) was chosen to highlight processes that may occur at various scales and in different locations across the landscape (a–g) over the 30-yr planned AOP lifespan. Aspects of socioenvironmental change that can be better understood within an AOP landscape are highlighted in comparisons of (d–f) in panels A and B. For example, fine-scale resolution AOP data will allow researchers to understand drought and related human behavioral impacts on plant species composition and vegetation structure (d), canopy water content (e), and crop yields (f). In addition, AOP data combined with ancillary datasets enables analysis at larger spatial scales (C). The higher temporal resolution of other sensors can also be used to understand change within years at a NEON AOP site (C) and how pressures like reduced snowpack reverberate throughout social, governance, and ecological systems (A a–g → B a–g). Symbols used with permission from UMCES IAN Symbol library (**ian.umces.edu** **(http://ian.umces.edu/)**).

NEXT STEPS

LENS: Landscape Exchange Network for Socio-environmental systems Logic Model

Inputs

People

- Steering committee
- Graduate student
- Data scientist
- NEON Domain Managers
- Core NEON Site Stakeholders
- Experts
- Other partners

Resources

- AOP data and products
- Existing SES data sets
- Inter-institutional partnerships
- Codes of conduct

Existing Science

- SES methods and results
- Translational ecology approach
- AOP analysis methods

Financial

- Previous SESYNC support for first workshop
- NEON assets assigned
- RCN award (this proposal)

Activities

Community Events

- National workshops
- Working groups
- Student Association
- Virtual events

Network Growth

- Conference networking
- Partnership exchange
- Stakeholder identification

Resource Development

- GitHub repository
- Open access data
- Network Member Database
- Translational ecology strategies
- AOP analysis methods
- Publication on network themes

Evaluation

- Membership demographics, attendance and participation
- Annual "pulse checks"
- Post Questionnaire
- Online resource analytics

Outputs

Diverse Network Membership

- Interdisciplinary scientists
- Early career scientists
- Underrepresented scientists
- Federal, state, and private land managers
- Diverse stakeholders
- AOP landscape community

Network Products

- SES characterization
- Define priority SES for AOP landscapes
- Curated SES-data for AOP landscapes
- AOP applications
- Translational ecology strategies
- Publications by members
- Code repository

Communication

- Website with LENS products and findings
- List-serve
- Newsletter
- Research briefs
- Social media
- Virtual events
- Publications on network

Outcomes

Productive Network

Members:

- Regularly engage in network activities
- Form new relationships among members
- Form new collaborations
- Derive value from

Knowledge Creation

Members:

- Advance knowledge of AOP-related capacities
- Develop positive attitudes about scientist-stakeholder collaborations
- Gain confidence in scientist-stakeholder collaborations

Capacity Building

Members:

- Use AOP landscapes and translational ecology strategies for SES research
- Share network opportunities and products with broader community
- Broaden views of participant diversity in research framing

Impacts

Sustained SES Collaborations

- Sustained focus on SES in AOP landscapes during NEON's 30-year horizon
- Stronger communication across diverse groups
- Stronger inter-institutional pathways

Healthier Environment

- Improved environmental stewardship
- Development and application of improved management practices

Healthier Communities

- Improvement of human livelihoods through development of actionable science
- Increased recognition of the importance and impact of co-developed science

ADDITIONAL INFORMATION

This Research Coordination Network (RCN) emerged from a workshop titled People, Land, & Ecosystems: Leveraging NEON for Socio-Environmental Synthesis that was held at the National Socio-Environmental Synthesis Center (SESYNC). More rationale can be found in the following publication:

Ordway, E.M., Elmore, A.J., Kolstoe, S., Quinn, J.E., Swanwick, R., Cattau, M., Taillie, D., Guinn, S.M., Chadwick, K.D., Atkins, J.W. and Blake, R.E., 2021. Leveraging the NEON Airborne Observation Platform for socio-environmental systems research. *Ecosphere*, *12*(6), p.e03640. (https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/ecs2.3640)

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ABSTRACT

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