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〈Report〉

Development of the National Ecological Observatory Network (NEON)

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ABSTRACT: After introducing various aspects of the National Ecological Observatory Network (NEON) being planned and established in the US, the author tries to suggest the future direction for the development of similar activities of the NEON to be carried out in the region of East Asia including Korea. A review was carried out in terms of the challenges, major questions, missions, developmental history, and some other specifics of the NEON design. It was further extended to the discussion of the issues for the regional construction of the Ecological Observatory Network (EON) in East Asia. The author hopes that this review could be used as a preliminary guide in ultimately promoting and advancing research, science and technology in conservation and preservation of ecosystems being degraded due to anthropogenic disturbances in the region of East Asia.

Key words: Ecological Observatory Network (EON), LTER, National Ecological Observatory Network (NEON)

BACKGROUND FOR THE DEVELOPMENT OF THE NEON

Last century can be evaluated as the era for massive destruction of natural environment, which encompasses the conversion of natural lands to agricultural and artificial lands, the decrease of biodiversity, and consequent extinction of numerous species. All of these are due to the exponential growth of human population and subsequent exploitation of natural resources, which additionally resulted in the pollution of environment worldwide. As the trend of environmental deterioration is expected to continue or be accelerated during this century, promoting and advancing research, science and technology in conservation and preservation of ecosystems being degraded due to anthropogenic disturbances will comprise the key challenge for the ecologists in the region as well as the world.

Recently the National Science Foundation (NSF) of the United States proposed to fund the creation of a network of spatially distributed and highly integrated observatories - the NEON, the National Ecological Observatory Network, which is meant to be "a virtual laboratory for comprehensive, synthetic research on biological systems and capable of dealing with phenomena that operate at multiple spatial scales (from microns to continents) and levels of biological organization (from molecules to landscapes)." The goal of the NEON is to help scientists develop a predictive understanding of the nature and pace of biological change. The vision of the NEON is described as "a continental scale research instrument consisting of geographically distributed infrastructure, networked via state-of- the-art communications. ⋯ NEON will transform ecological research by enabling studies on major environmental challenges at regional to continental scales. Scientists and engineers will use NEON to conduct real-time ecological studies spanning all levels of biological organization and temporal and geographical scales. NSF disciplinary and multi-disciplinary programs will support NEON research project and education activities. Data from standard measurements made using NEON will be publicly available" (NRC 2003, http://www.neoninc.org/about).

The NEON was designed from the necessity for the scientific communities in biology and environment to conceive, design, and use large research platforms and facilities, such as particle accelerators, radio telescope arrays, oceanographic research vessels, etc. The concept of the NEON was born in the early 1990s. The ecological research community recognized the need for an integrated, regional- to continental-scale observation system and research platform (Lubchenco et al. 1991). The report from the President's Committee of Advisors on Science and Technology (PCAST 1998) of the US, "Teaming with Life," reemphasized the need for comprehensive research infrastructure to address regional or continental scale ecological questions. In March 1997, the Committee on Environment and Natural Resources, the National Science and Technology Council, presented a report of "Integrating the Nation's Environmental Monitoring and Research Networks and Programs: A Proposed Framework," which links systematic observations and monitoring of ecological systems and resources with predictive modeling and process research (http://www.epa.gov/monitor/Pubs/framewrk.pdf). The linkage was suggested to provide the information needed to improve documentation of status and trends in the ecosystems and natural resources. The integration of the environmental monitoring and research networks was also suggested to

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provide the knowledge base required for selecting management approaches that ensure ecosystem and resource sustainability. Since the middle 1980s, the Long Term Ecological Research (LTER) programs of the US as well as the world have demonstrated the value of long-term, integrated, and site-based research for obtaining a basic understanding of ecological systems (http://www.neoninc.org/documents/LTER20YearReview.pdf, http://ilternet.edu/).

The objectives of this report are to review the challenges, major questions, missions, developmental history and some specifics of the design of the NEON and, consequently, to extend the discussion to the issues for the regional construction of the Ecological Observatory Network (EON) in East Asia including Korea.

CHALLENGES, MAJOR QUESTIONS, AND MISSIONS OF THE NEON

At spatial and temporal scales, the NEON is being designed to cover from organisms to continents and from days to centuries or even to millennia. In the U.S., there are seven important and interacting ecological themes for the scientists to further understanding of ecological processes at small and large scales, which are described as "the challenges" in the environmental sciences that are central to providing the knowledge needed by the next generation to manage the Earth in a sustainable fashion (NRC 2001, 2003), which include:

- biodiversity: "… to improve understanding of the factors affecting biological diversity and ecosystem structure and functioning including the role of human activity"
- biogeochemical cycles: "… to further our understanding of the Earth's biogeochemical cycles; to evaluate how they are being perturbed by human activities; and determine how they might better be stabilized"
- climate change: "… to increase our ability to predict climate variations; to understand the variability; to assess the resulting impacts"
- hydroecology: "… to develop an improved understanding of and ability to predict changes in freshwater resources and the environment"
- infectious disease: "… to understand ecological and evolutionary aspects of infectious diseases; to develop an understanding of the interactions; to make it possible to prevent changes in the infectivity and virulence of organisms"
- invasive species: "… to understand species invasion as an ecological process"
- land use: "… to develop a systematic understanding of changes in land uses and land covers that are critical to ecosystem functioning and services and human welfare."

The NEON is specifically designed to address the major and central scientific questions about the interactions of ecosystems, climate, and land use and about the nature of the world we live in as follows (http://www.neoninc.org/RFI/RFI_v1.0.DOC):

1) How will ecosystems and their components respond to changes in natural- and human-induced forcings such as climate, land use, and invasive species across a range of spatial and temporal scales? And, what is the pace and pattern of the responses?

2) How do the internal responses and feedbacks of biogeochemistry, biodiversity, hydroecology and biotic structure and function interact with changes in climate, land use, and invasive species? And, how do these feedbacks vary with ecological context and spatial and temporal scales?

There are two missions of the NEON in science and education. The NEON science mission is to provide the capacity to forecast future states of ecological systems for the advancement of science and the benefit of society. The NEON's coordinated sensors, experiments, and cyberinfrastructure will collect the ecological data needed to develop the scientific understanding and theory necessary to address the environmental challenges specified above. Meanwhile, the NEON education mission is to enable educators to prepare society, including the scientific community, to use NEON scientific data, information, and forecasts to understand and effectively address critical ecological questions and issues (http://www.neoninc.org/documents/).

THE DEVELOPMENTAL HISTORY OF THE NEON

Initially, the Infrastructure for Biology at Regional to Continental Scales (IBRCS) project at the American Institute of Biological Sciences (AIBS) convened many workshops and meetings aiming at informing the ecological science community and maturing the NEON concept. Afterwards, the Consortium of Regional Ecological Observatories, the organizing body of the group, provided a mechanism for communication among the various groups, the designers, and the NSF and covered the entire country with over 1,800 stakeholders from academic, government, and private sectors. The visions, challenges, questions, and missions of the NEON with the issues of objectives, standard measurements, infrastructure, biological archives, information management, and operational consideration were the products of discussions of many workshops.

The author describes the developmental history of the NEON rather specifically not only because the series of meetings and following reports resulted in a rich set of documents for the readers to refer for further specifics and details on the internet at http://www.neoninc.org/documents/, but because it is important for us to understand that open, careful, and sometimes, long-term process might be needed to ensure the successful designing of such an important project as the NEON at its initial stage.

From September 1998 to August 1999, four Biodiversity Observatory Network (BON) Workshops sponsored by the NSF were held. From 1999 to 2003, the NSF made efforts in defining the role of the foundation for the development of environmental sciences by developing the reports of "Frontiers of Ecology Workshop (December 1999)," "Environmental Science in the 21st Century: The Role of the National Science Foundation (February 2000)," "NEON- Extended Description (2002)," and "Facilities Management and Oversight Guide (2003)," all of which are available on the website. Meanwhile, as described above, the NRC (2001, 2003) made efforts in defining the challenges in the environmental sciences by developing the reports of "Grand Challenges in Environmental Sciences" and "NEON: Addressing the Nation's Environmental Challenges."

From January 2000 to September 2002, six Workshops on the NEON Planning sponsored by the NSF were held, firstly, with focus on formation, organization, and potential roles for NEON; secondly, on technological infrastructure; thirdly, on network management; fourthly, on standard equipment and measurements; fifthly, on biological collections; and finally, on information management.

From 2000 to 2003, efforts were also made in defining the needs of cyberinfrastructure for the development of environmental sciences with the reports of "Research Directions in Biodiversity and Ecosystem Informatics Workshop Report" from an NSF, USGS, NASA Workshop in June 2000; "Scalable Information Networks for the Environment (SINE) Workshop" from an NSF sponsored Workshop held on October 2001; "Environmental Cyberinfrastructure Needs for Distributed Sensor Networks" from a National Science Foundation Sponsored Workshop in 2003.

In March 2003, an IBRCS White Paper, "Rationale, Blueprint, and Expectations for the National Ecological Observatory Network," was developed by the IBRCS Working Group and AIBS and explained the scientific rationale behind the need for the NEON (Holsinger and the IBRCS Working Group 2003) and the results that NEON is expected to produce. In the same year, a report of the conference on the Coordination and Implementation of the NEON was published as an IBRCS White Paper of "A Plan for Developing and Governing the National Ecological Observatory Network (NEON)," which is a synthesis of discussions that took place during the times. It described both an organizational and governance framework for the NEON and a process for implementation (NEON 2003).

In April 2004, the project proposal of "Development of the NEON Coordinating Consortium and Project Office" was submitted to the NSF with the guiding principles that the NEON Design Consortium and NEON Inc. will 1) create a governance structure that is responsive to the NEON user community; 2) ensure diversity at all levels of the NEON Design Consortium; 3) create novel scientific and educational experiences; and 4) adhere to strict financial and accountability principles.

In summer 2004, the AIBS held a series of six workshops from March to September 2004 on the scientific objectives of the NEON project. The NEON Science Workshops were held in series in March on invasive species; in July on ecological aspects of biogeochemical cycles and on biodiversity, species composition, and ecosystem functioning; in August on ecological impacts of climate change and on land use and habitat alteration; and in August - September on ecology and evolution of infectious diseases.

In November 2004, NEON Project manager sought the community input to the NEON design in advance of the first meeting. In January 2005, the first meeting of the NEON Design Consortium was held with the description of key scientific challenges of the NEON. The reports on the interim basis were developed at the meetings from the Committees as follows: Biodiversity and Ecosystem Function, Biogeochemical Cycles, Climate Variability, Consortium Development, Emerging Issues, Higher Education, Hydroecology, Information Technology and Communications, Infectious Disease, Informal Science Education, Invasive Species, K-12, Land Use/Land Change, Research and Infrastructure, and Sensors and Sensor Networks. In March 2005, the second meeting of the NEON Design Consortium was held with the focus on NEON infrastructure needs. The reports were developed at the meetings from the Committees as follows: Abiotic Sub-plenary on hydroecology, biogeochemical cycles, and climate change; Biotic Sub-plenary on biodiversity, invasive species, and infectious disease; Consortium Development; Education; Information Technology and Communications; Land Use; Research and Infrastructure; and Sensors and Sensor Networks.

In June 2005, the third meeting of the NEON Design Consortium was held. In July 2005, a workshop on Modeling in the NEON was held with the resulting publication of Proceedings of the workshop and exploring various ways that modeling could be an explicit part of the NEON.

In August 2005, members of the NEON Senior Management Team and the Advisory Board presented a detailed planning update of the proposed NEON at a special session at the Annual Meeting of the Ecological Society of America held in Montreal, Canada.

In December 2005, the birth of the NEON was official and the NEON Inc. was legally established as a not-for-profit corporation. It will serve as the primary coordinating body of the NEON. In October 2006, the NEON Project Office (NPO) delivered project documents to the NSF panel that will conduct a Conceptual Design Review (CDR), which include the Integrated Science and Education

Plan (ISEP), the Networking and Informatics Baseline Design (NIBD), and the Request for Information (RFI). In November 2006, NPO host a session for Question and Answer (Q&A) to clarify the requirement for the RFI. During November 2006 and January 2007, the RFI was made in order for the interested members of the ecological community to respond to the RFI and contribute ideas that shape the final design of the NEON.

In November 2006, representatives of the NEON presented project details and fielded questions from an NSF's CDR panel for the evaluation of the planning progress for all the aspects of the NEON including science and education, governance, budget and staffing, performance requirements, major system components for science and education, and cyberinfrastructure interfaces. In the same month, the NEON Inc. announced its Chief Executive Officer (CEO).

In 2007, it is expected that an award from the NSF will be made to complete the final Project Execution Plan for the NEON; baseline NEON infrastructure design, cost, and management will be reviewed; NEON fundamental technology unit (BioMesoNet, sensor micronets, and enabling cyberinfrastructure) will be assembled and field-tested; NEON infrastructure deployment plan will be finalized; Environmental Impact Assessment and/or Environmental Impact Statements (EIA/EIS), if appropriate, will be conducted; and additional research and development on environmental sensors and sensor networks and enabling technologies for ecological forecasting will be carried out.

From 2008 to 2011, the construction of NEON research, networking, informatics, and education, training and outreach infrastructure will begin; research and development activities on environmental sensors, networks, cyber tools for the NEON, and interoperability with other networks and observing systems will be continued (http://www.nsf.gov/bio/budget/).

NEON DESIGN CONSORTIUM AND COMMITTEES

Central to the governance and coordination is the NEON corporate entity, which is called "NEON, Inc." Its organization as a corporation is expected to provide a logical and efficient structure for the task of the NEON coordination. This nonprofit corporation is a membership organization governed by a Board of Directors that is elected by the members. The NEON Design Consortium (NDC) consists of the project leadership and the committees and subcommittees and will be assisted by the NPO. To know better about how the NEON is organized and what are the major functions of the NEON, the organization of the NDC and the roles of the project leadership and the committees are described as follows (http://www.neoninc.org/about/neon_design_consortium.html):

Senior Management Team

Senior Management Team is composed of the principal investigators of the project, who serve as the central leadership body of the NEON design effort, and supported by the NEON Advisory Board.

NEON Advisory Board

NEON Advisory Board consists of community leaders with extensive experience in designing observatories and managing large science enterprises, who will support design efforts of the NEON.

National Network Design Committee

National Network Design Committee is charged with synthesizing the plans of all other committees into a final reference design for the NEON and makes the final decisions on prioritizing candidate NEON science missions and observatory functionalities, geographic distribution of observatories, and the scheduling plan for NEON implementation.

Consortium Development Committee

Consortium Development Committee is responsible for establishing the NEON Inc. and has fulfilled its responsibilities to 1) define how various entities, agencies, and institutions will participate in the NEON enterprise; 2) design the structure, membership, operating principles, and governance of NEON, Inc.; 3) design the permanent NEON Project Office and select the location of the NEON, Inc.; 4) and develop the transition plan for phasing out the NDC and phasing in NEON, Inc., according to the project schedule.

Science and Human Dimension Committee

This committee consists of eight interacting subcommittees for identification and refinement of the science questions, which is critical to the works of the other committees. Each subcommittee will 1) refine the scientific questions to continental dimensions and identify the critical measurements and the necessary temporal and spatial resolutions to be achieved; 2) define the critical ecosystems and landscapes that must be part of the observatory design in order to address the adopted scientific questions; 3) determine the synoptic ancillary measurements needed to achieve ecological forecasting; 4) determine the special cyberinfrastructure requirements (data synthesis, fusion, analysis, storage, visualization) and physical voucher requirements (archival and curation) for the observatory; and 5) determine the connections and synergisms with the other subcommittees. Subcommittees and their major research challenges are identified as follows:

1) Biodiversity Subcommittee

How changes in biodiversity affect ecological function and the ecological services valued by humankind

2) Biogeochemical Cycles Subcommittee

The natural and anthropogenic cycling and distribution of biogeochemicals (e.g., carbon, nitrogen, phosphorus), and the resulting effects on ecological function and society

3) Climate Change Subcommittee

Ecosystem responses to climatic variability and climate change, and forecasting climate change effects on biodiversity, ecological function, and society.

4) Emerging Issues Subcommittee

Major emerging research areas and technology challenges, particularly those that cross disciplines and scales of biological organization, and make use of emerging technologies

5) Hydroecology Subcommittee

The natural and anthropogenic cycling, use and distribution of water, and the resulting effects on ecological function and societal values (e.g., fisheries, human health)

6) Infectious Diseases Subcommittee

The spread, dynamics, and control of infectious diseases, particularly those that are vector-borne (e.g., carried by mosquitoes, ticks, etc.) and have significant effects on humans, livestock, and wildlife

7) Invasive Species Subcommittee

The spread, dynamics, and control of invasive species, their impacts on ecosystem function and humankind

8) Land Use Subcommittee

How changing patterns in land use (e.g., converting forest or agricultural lands to residential or industrial, or vice verse) affect ecological and social systems and the ecosystem services of human value.

Education Committee

This committee designs the NEON education plan and considers, in three interacting subcommittees, the unique educational opportunities offered by NEON. Each subcommittee will 1) identify the unique educational opportunities offered by the NEON program and observatories; 2) specify the integration of science and education afforded by NEON; 3) explore educational networking opportunities made possible by NEON's cyberinfrastructure; 4) identify new educational partnerships through connections with the NEON user community; 5) consider web-based assessment and evaluation tools to explore nation-wide understanding of ecological science using NEON's cyberinfrastructure; 6) and identify the infrastructure needed to realize the education plan. Subcommittees and their opportunities are identified as follows:

1) Higher Education Subcommittee

Linkage of NEON science with undergraduate, graduate and post-graduate training

2) K-12 Training Subcommittee

Promotion of scientific ways of thinking and understanding in GK-12 students and encouragement of teaching practices focused on "learning by doing," inquiry instruction, and integration with technology

3) Informal Education Subcommittee

Translation of NEON science into information that is easily accessed and assimilated by the public at large, including the planning for citizen experience sciences.

Facilities and Infrastructure Committee

The committee consists of three interacting subcommittees and will evaluate existing and required technological and facility capacity for supporting NEON, identify availability and/or fabrication time for needed facilities and infrastructure, budgets for the technological and facility capacity for NEON, and assist in developing the reference design for all other NEON infrastructure elements. The committee's three interacting subcommittees will 1) interact continuously with the subcommittees of the Science and Human Dimension Committee to identify science-driven infrastructure needs; 2) assess existing technological and facility capacity for supporting NEON, such as field stations and archive facilities; 3) evaluate needed cyberinfrastructure development including technologies for data management, analysis, fusion, and visualization, as well as tools for control, calibration, and monitoring of heterogeneous, distributed instrumentation; 4) evaluate the availability and/or fabrication time for needed facilities and infrastructure; 5) evaluate emerging technologies (e.g., genomic, visualization, mobile and robotic systems); 6) and budget the technological infrastructure indicated by needs assessment, including staffing. Subcommittees and their major elements to evaluate are identified as follows:

1) Research Infrastructure Subcommittee

Research infrastructure for NEON, especially in relation to laboratory capacity, field stations, and in situ terrestrial and aquatic sampling platforms (e.g., eddy flux towers)

2) Information Technology and Communication Subcommittee

Cyberinfrastructure for support of NEON, including technologies for data management, communication, archives, analysis, and control of distributed instrumentation

3) Sensors and Sensor Networking Subcommittee

Sensing technologies and supporting infrastructure for addressing NEON's science agenda.

SOME MORE SPECIFICS OF THE NEON DESIGN

Besides the issues of the organization of the NEON, those of funding, climate domains or eco-regions, scientific infrastructure, and partners comprise other important parts of the NEON Design (http://www.nsf.gov/bio/budget/, NEON 2006a, 2006b).

Funding and Funding Agencies

The major funding agency for the NEON is the NSF. The NSF estimated that the initial setup will cost about US$ 300 millon and operation will cost about US$ 100 million per year. The initial funding will come from the MREFC (Major Research Equipment and Facilities Construction) program at the NSF, which primarily supports the acquisition, construction, and commissioning of major research facilities and equipment that provide unique capabilities at the frontiers of science and engineering. Currently, MREFC program funds such programs as EarthScope, IceCube, Scientific Ocean Drilling Vessel, South Pole Station, etc.

It is planned to fund and deploy all 20 domains, that will be described below, at the same time. Research funding will be provided as a separate set of "pipelines" from the NSF to the observatories, with various NSF research awards provided to investigators through its proposal peer review process. The NSF intends to generate comparable new funding for biodiversity measurements and research at NEON sites. The NSF would prefer one prospectus per domain and would like to encourage ecologists to work together.

An Inter-Agency Working Group is formed to extend support and interactions with other federal agencies, some of which may supplement funding for NEON activities.

NEON Climate Domains

There are 20 domains (points) which are of approximately equal size and are chosen to represent the continental climatic gradient. Each domain contains one district and each district contains three sites chosen to represent three land use types, i.e., urbanizing, managed, and wild sites. The sites represent the land use gradient at the domain scale. Districts should be no larger than 200 km to minimize logistical problems and variations in climate and geology. Each site should be 1～100 km^2 in size.

In August 2005, the National Network Design Committee members of the NEON defined 20 Climate Domains by using a cluster analysis of climate state variables, combined with airmass seasonality data, to create zones of similar climate. They are Northeast, Mid Atlantic, Southeast, Atlantic Neotropical, Great Lakes, Prairie Peninsula, Appalachians/Cumberland Plateau, Ozarks Complex, Northern Plains, Central Plains, Southern Plains, Northern Rockies, Southern Rockies/Colorado Plateau, Desert Southwest, Great Basin, Pacific Northwest, Pacific Southwest, Tundra, Taiga, and Pacific Neotropical Climate Domains.

Although these domains are subject to further revision, it is interesting to note that the total number of the 20 climate domains increased compared to the initial suggestion of 15 NEON Regions, whose boundaries are divided based on ecoregions represented by the major biomes of the US and Antarctica suggested in July 2004. The map for the NEON Climate Domains is available from the NEON website at www.neoninc.org.

Scientific Infrastructure

As the NEON was designed to address challenging ecological questions at the scale of the continent, the NEON infrastructure is made to support the science needed to achieve continental-scale ecological analysis, synthesis, modeling, and forecasting. The NEON infrastructure comprises sites, a standard set of instruments, outsourced facilities for archiving and curation, outsourced facilities for sample processing, and cyberinfrastructure to integrate and manage the data (NEON 2006a).

The sites can be core sites, gradient sites, sites of opportunity, or experimental sites. Each core site will have a site headquarters with facilities to maintain equipment, process samples, and provide related support. In each climate domain, there are three points along a land cover gradient, i.e., urban, managed, and wildland sites. In each site, there are twelve Land-based Sensor Arrays and one Aquatic Sensor Array, which are the sampling stations. In each sampling station, there are four Clusters of Land-based Sensor Arrays.

In this report, more detailed explanation will be extended to the standard set of instruments and cyberinfrastructure.

1) A Standard Set of Instruments

To effectively collect biological, biophysical, biogeochemical, and land-use and land management data across the continent, the instrumentation is organized into five instrument packages, i.e., a Fundamental Instrument Unit, a Fundamental Sentinel Unit, a Mobile Relocatable Platform, an Airborne Observation Platform, and a Land Use Package.

① A Fundamental Instrument Unit (FIU)

FIU provides monitoring of climate and fluxes between ecosystems and the atmosphere using tower systems and aquatic and terrestrial sensor arrays. Terrestrial tower system comprises the Basic BioMesoNet Tower and the Advanced BioMesoNet Tower. These towers not only track seasonal and long-term climatic patterns and meteorological changes that are important to both ecosystem function and the growth of plants and microbes, but also have additional capacity to provide essential information for research focused on biological responses to land use, water availability, the presence of invasive species or disease, and climate. The Basic BioMesoNet Tower is composed with a canopy height dependent tower equipped with basic BioMesoNet Sensor Package for measurements of 1) air temperature, 2) barometric pressure, 3) relative humidity, 4) wind speed and direction, 5) precipitation, 6) soil moisture, and 7) soil temperature. The Advanced BioMesoNet Tower is composed with a canopy height dependent tower equipped with the advanced BioMesoNet Sensor Package for measurements of 1) soil CO_2 flux, 2) incoming, reflected, total and diffuse solar radiation, 3) sensible and latent heat and CO_2 fluxes, 4) CO_2 concentration, 5) H_2O vapor, 6) stable isotopes of C and O in H_2O and CO_2, 7) CO concentration, 8) NO, NO_2, NO_x concentrations, 9) O_3 concentration, 10) airborne particles, 11) dry deposition of SO_4^{2-}, NO_3^-, NH_4^+, SO_2, and HNO_3, and 11) wet deposition of NH_4^+, NO_3^-, o-PO_4^{3-}, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, K^+, and pH in addition to the basic measurements of the BioMesoNet Sensor Package.

The Terrestrial Sensor Array Measurements consist of two components of arrays, which are the Canopy Microclimate Sensor Array and the Soil Sensor Array. While the Canopy Microclimate Sensor Array monitors 1) total, diffuse, and incident photosynthetically active radiation (PAR), 2) sunshine duration, 3) air temperature, 4) relative humidity, 5) precipitation, 6) leaf wetness, and 7) leaf temperature, the Soil Sensor Array monitors 1) root and mycorrhizae phenology, 2) soil respiration, 3) soil NO_3^- concentration, 4) soil O_2 concentration, 5) soil pH, 6) soil water potential, 7) soil water volume, 8) soil moisture, 9) soil temperature, and 10) biological temperature.

The Aquatic Sensor Array Measurements monitor 1) level of groundwaters, surface waters, and discharging of flowing waters, 2) soil moisture, 3) dissolved organic carbon concentration, 4) dissolved O_2 concentration, 5) nutrient concentrations of NO_3^-, 6) pH, 7) conductivity, 8) temperature, 9) turbidity, 10) chlorophyll, 11) surface PAR and UV, and 12) automated water sample collection for additional chemical profiles and biological (plankton) and isotopic measurements of groundwater and surface waters.

② A Fundamental Sentinel Unit (FSU)

FSU supports measurements of biodiversity and ecosystem responses to climate and environmental change. It supports three types of observations: 1) biodiversity surveys, 2) observations of populations and behavior for animals, plants, and microbes, and 3) observations of biogeochemical processes. The biodiversity sampling plots will include the sampling of 1) plants, 2) soil microbes, 3) ground beetles, 4) fish, 5) algae, and 6) aquatic macroinvertebrates.

FSU measurements are expected to enable researchers to link biological indicators to changes in climate, land use, availability of water, and presence of disease and invasive species.

③ A Mobile Relocatable System (MRS)

MRS provides investigators with flexibility in the deployment of instrumental systems to collect data. The NEON will deploy non-fixed assets known as the Mobile Relocatable Platforms (MRP), which consist of the Relocatable Tower System (RTS) and the Rapid Deployment System (RDS), where the Rapid Deployment System (RDS) will be equipped with the BioMesoNet Sensor Package, Soil Sensor Array, Canopy Microclimatic Sensor Array, and the Aquatic Sensor Array, which is similarly equipped with the arrays of the FIU specified above, where the BioMesoNet Sensor Package can measure 1) soil CO_2 flux, 2) incoming, reflected, total and diffuse solar radiation, 3) O_3 concentration, 4) airborne particles, 5) dry deposition of SO_4^{2-}, NO_3^-, NH_4^+, SO_2, and HNO_3, and 6) wet deposition of NH_4^+, NO_3^-, o-PO_4^{3-}, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, K^+, and pH in addition to the basic measurements of the BioMesoNet Sensor Package of the FIU. The Relocatable Tower System will be equipped with a towing vehicle, trailer to transport and/or house with one or more of the modular units of aquatics, canopy, climate, invasive species, education, soils, and infectious disease, where all modules include network connectivity.

④ An Airborne Observation Platform (AOP)

AOP with remote sensing instruments provides regional information for scaling and extrapolation from sites and monitors canopy properties related to primary production, diversity, invasives, biogeochemistry, and dynamics of land-use change and recovery from disturbance. AOP consists of high-fidelity imaging spectroscopy and wave-form LIDAR, where high-fidelity imaging spectroscopy allows the measurements of vegetation indices, leaf area index, canopy moisture, canopy chemistry in terrestrial and aquatic ecosystems, spectral unmixing of vegetation components, and diversity and canopy pigments of terrestrial and aquatic ecosystems, and wave-form LIDAR allows the measurements of vegetation height, ground topography, height distribution of structural elements, biomass, life form diversity, and Bathymetry.

⑤ A Land Use Package (LUP)

LUP supports assessment and analysis of patterns, changes, and drivers of land use, land cover, and land management.

2) Cyberinfrastructure

Cyber Infrastructure refers to a set of state-of-the-art and advanced information technologies designed to facilitate easy access to distributed resources, including remote instruments, sensor networks, computational and storage platforms, digital data collections, digital libraries, and data archives, visualization capabilities, and collaboration environment. It is interesting to note that, in many areas, science become a team sport, where important scientific questions can only be addressed by bringing together multi-disciplinary groups of scientists in order to solve multi-disciplinary and multi-dimensional scientific problems, where cyberinfrastructure enables scientists to interact easily.

The vision of the NEON cyberinfrastructure encompasses many functions including the rapid communication and secure preservation of high-quality data, timely dissemination of the NEON data and information products, and broad-ranging support for public access and education. Every NEON site will have cyberinfrastructure hardware and software deployed in the field. The Point-of-Presence (PoP), a standalone server, associated with each site will preprocess the data and perform various data cleaning and quality assurance/quality control (QA/QC) protocols. The data will be sent to the NEON Data Center for additional data processing.

The NEON cyberinfrastructure is designed to provide a comprehensive end-to-end digital solution for NEON data, which encompasses the solution from acquisition of data from field-based embedded sensors and remote sensors, through data and information processing and through transfer of NEON data, information and knowledge to scientists, educators, students, and citizens. NEON cyberinfrastructure will be based on proven technologies and built using open systems architecture to support extensibility and easy incorporation of new components. NEON cyberinfrastructure is suggested to include such key software functionality as 1) embedded cyberinfrastructure for distributed instrument control and reliable data transport, 2) data curation and archiving, 3) data analysis, integration, modeling, and visualization, 4) NEON portals, and 5) collaboration environments.

In developing and supporting NEON cyberinfrastructure, they put five overarching principles important in guiding the group and activities, which are 1) provide open access to data and information; 2) employ an open architecture in developing a robust, high performance infrastructure; 3) engage NEON stakeholders in the design and operation of cyberinfrastructure; 4) optimally leverage with partnering organizations; and 5) design for modularity, security, simplicity, and standardization. Readers are referred to the NEON (2006b) for more specifics of the Networking and Informatics Baseline Design.

Partners of the NEON

The NEON requires participation from federal agencies, international agencies, industries, corporations, etc., through partnership, some of which are on the NEON Advisory Board and planning committees. Through the partnership, they can use the facilities, data, and forecasts; extend education, training, and outreach; and promote in the innovation of infrastructure development, deployment, and operation.

Currently, major partners and their contribution to the promotion in the NEON are 1) the US Department of Agriculture Forest Service (USDA FS), whose Experimental Forests occur in many different ecosystem types and are potential sites for NEON infrastructure; 2) the Center for Embedded Networked Sensing (CENS), which carries out researches and develops tools that are integral to the implementation and management of the NEON; 3) AmeriFlux, which is a network of instrumented towers that continuously monitor ecosystem-level exchanges of CO_2, water, energy, and momentum; 4) the US Geological Survey Earth Resources Observation and Science (USGS EROS), which provides a data gateway and visualization technologies for remotely sensed imagery; 5) the National Aeronautics and Space Administration (NASA); 6) the Long Term Ecological Research (LTER) Network, which is the source of long-term ecological data and provides potential sites for NEON infrastructure; 7) the National Center for Ecological Analysis and Synthesis (NCEAS), which develops data analysis and synthesis approaches to advance ecological knowledge through the identification of patterns and principles; 8) the Global Earth Observation System of Systems (GEOSS), which develops the capacity to make global ecological forecasts; and 9) the Heinz Center, which works to improve the scientific and economic foundation for environmental policy in collaboration with industry, government, academia, and environmental organizations.

REGIONAL ISSUES FOR THE CONSTRUCTION OF THE ECOLOGICAL OBSERVATORY NETWORK

From the review above, it should be made clear that the NEON covers the ecological issues ranging from region to continent in space and that the questions to be addressed from the activities of the NEON are in the regional or continental context. Hence, the perspectives for the construction of the Ecological Observatory Network (EON) should be considered in the regional or continental context.

In the region of East Asia, landscapes have been dramatically changed and degraded due to intensive developmental activities and subsequent severe environmental pollution due to anthropogenic disturbances. Consequently, the depletion of resources, the degradation of ecosystem structure and function, climate change, and the loss of biodiversity are the main issues for concern in attaining the sustainability in the future. In this regard, the main challenge for the ecologists in the region is to promote and advance research, science and technology in conservation and preservation of ecosystems being degraded. In addition, it is rather urgent in the necessity for the ecologists to address the fundamental questions on the changes of ecological systems affected by changes in land use, climate and biogeochemistry; the changes in availability and distribution of the water and its effect on ecological systems; the effects of the movement of genes and organisms on biodiversity, ecosystem function; and the spread of infectious diseases and invasive species, all of which the NEON raised to address in the coming years.

In order to meet these pressing environmental challenges, the followings were conceived to be important 1) to apply emerging sciences and technologies; 2) to synthesize the data with standardized facilities from the infrastructure distributed geographically; 3) to carry out study in collaborative environments; and 4) to move toward a predictive science, all of which will work as the basic principles for guiding the activities in establishing the EON in the region as well as in the world (Arzberger, personal communications).

Although scientists have realized the importance of studying long-term phenomena in ecology over a longer period of time for better understanding and sustainable management of biotic and abiotic components of ecosystems, major advancement in long-term ecological research has not yet been made in many parts of the world (Kim 2006*)*. It is appreciated that the current infrastructure for the International Long Term Ecological Research (ILTER) Network available for research and science has limitations in the synthesis required to address the environmental challenges the region faces.

Recently, the Chinese Academy of Sciences (CAS) announced that they would build scientific observatory networks to boost science throughout the country, to stimulate research innovation, and to collect data on the Earth and its ecological systems. Although, in 1988, the CAS started to build the Chinese Ecosystem Research Network (CERN), the Chinese LTER Network, with uniform operations and standardized equipment, this new initiative is hoped to bring about scientific breakthroughs in China by seemingly rivaling the development of the NEON of the US, in scope as well as in budget. These scientific observatories are suggested to be vitally important for the scientific community to carry out research on ecological restoration, environmental protection, agricultural development, disaster reduction, and sustained exploitation of natural resources in the country (http://english.people.com.cn/200506/09/eng20050609_189233.html). Currently, only the US and China are the countries that are currently constructing the EON in the boundaries of their countries.

Another example of the observatory network at a global scale is the network of lakes from the world, which is called as "Global Lake Ecological Observatory Network (GLEON)." The GLEON is a grassroots network of people of lake scientists, engineers, information technology experts; institutions including universities, national laboratories, agencies; programs of PRAGMA, US-LTER, TERN, EcoGrid, etc.; instruments; and data (www.gleon.org). It is linked by a common purpose and cyberinfrastructure with a goal of understanding lake dynamics at local, regional, continental, and global scales. Currently, the participating countries are Australia, Canada, China, Finland, New Zealand, Israel, Korea, Taiwan, United Kingdom, and the US. It was made possible by the development of the e-science, the merging of science and information technology, for the observations and understanding, which were previously unobtainable (Arzberger, personal communications; Porter, et al. 2005).

In this review, various aspects were introduced in the design of the NEON, which include funding, climate domains or eco-regions, scientific infrastructure, as well as the organization of design consortium and various committees. In designing the EON in the region of East Asia, full attentions should be paid to all theses aspects including clear identification of the challenges to meet, questions to address, and missions to accomplish.

The author evaluates that it is high time for the governments, funding agencies, and ecologists of the region to devise the mechanism to make agreements, to provide supports, and to carry out research and science in cooperatively designing the plans for the EON of the region, which is a multi-scale research network that combines experimentation and observation replicated at numerous sites across the region. In this regard, the author hopes that this review could be used as a preliminary guide in ultimately promoting and advancing the development of research, science and technology in conservation and preservation of ecosystems being degraded due to anthropogenic disturbances in the region of East Asia. Finally, as was described above, the author wants to reemphasize that it is important for us to understand that open, careful, and sometimes, long-term process might be needed to ensure the successful designing of such an important project as the EON at the initial stage.

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