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Current status of Korea Long-Term Ecological Research (KLTER) Network activities compared with the framework activities of the Long-Term Ecological Research (LTER) Networks of the United States and China

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Abstract

Since the initiation of national Long-Term Ecological Research (LTER) Network activities in the US and China from 1980 and 1988, respectively, and that of the International LTER (ILTER) Network activities from 1993, there are currently more than 40 national/territorial LTER networks developed globally. The developmental stage of each national/territorial LTER network can be evaluated as a fully active network, a consolidating network, or an inactive network. In order for the Korea LTER Network to be promoted from a consolidating network to a fully active network, the categories and criteria for evaluating the stage of the Networks were suggested by stage, current status was evaluated, and further directions were suggested for each category. In this review, the developmental histories of the fully active LTER networks of the US and China were reviewed, and best practices were introduced. In order for the Korea LTER Network to be promoted from a consolidating network to a fully active network, the criteria to be further promoted include: establishing bylaws and organizational entities specified in the bylaws; making strategic plans in science, monitoring, and research; and finding the core mechanism to serve societies in education and outreach. The highest priority is to develop a strategic plan to promote the Korea LTER Network.

Key words: Chinese Ecosystem Research Network (CERN), Korea LTER Network, Korea National Long-Term Ecological Research (KNLTER) Program, Long-Term Ecological Research (LTER), LTER Governance, LTER Strategic Plans, US LTER Network

INTRODUCTION

Since the International Long-Term Ecological Research (ILTER) Network was formed in 1993, the importance of long-term research for assessing and resolving such complex environmental issues as climate change and biodiversity conservation has increased significantly at local, regional, and international levels. The vision of the ILTER Network is "a world in which long-term science helps prevent and solve environmental and socio-economic problems," and the mission of the ILTER Network is "to improve understanding of global ecosystems and inform solutions to current and future environmental problems." The ILTER Network consists of networks of scientists engaged in long-term, site-based ecosystem and socio-ecological observation and research (International Long-Term Ecological Research Network 2006).

In April 1995, two Korean ecologists including the se-

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nior author were invited to join the ILTER Asia-Pacific Regional Network, which was formed to establish a foundation for communication and collaboration among long-term ecosystem researchers in the region. In 1998, the Korea LTER Network officially joined the ILTER Network at the Sixth ILTER Annual Meeting held in Florence, Italy, in which three sites managed by the Korea Forest Research Institute were recognized as official LTER sites in Korea. Since the successful hosting of the Third ILTER East Asia-Pacific (ILTER-EAP) Regional Conference in 1999 and the Eighth INTECOL International Congress of Ecology in 2002 in Korea, the Ministry of Environment of Korea endorsed the initiation of the Korea National Long-Term Ecological Research (KNLTER) Program sponsored by the Ministry of Environment of Korea. Since then, the number of sites in the Korea LTER Network has increased significantly to over 20.

While the issues of biodiversity conservation, ecosystem services, and monitoring and assessing the effects of climate change and consequential ecosystem changes at local, regional, and global scales have become the core areas of the ILTER Network activities, Kim (2000, 2006) reviewed the development, potentials, and challenges of the ILTER Network and the Korea LTER Network. The ILTER Network is the network which aims at increasing the understanding of global environmental phenomena and extending the influence, strength, and relevance of national/territorial and regional networks by collaborating, cooperating, and data sharing among the network scientists. In the near future, the ILTER Network is expected to provide a basis for increased utilization of ecosystem data to solve human problems and transfer knowledge among members by the shared approaches and methods and standardized data collecting mechanisms with improved ILTER infrastructure to support long-term, cross site-based research (International Long-Term Ecological Research Network 2006).

As it is already 15 years since the Korea LTER Network initiated its activities, it is time for the scientists of the Korea LTER Network to review activities and strategies in comparison with the framework activities of the international LTER networks in order to make sure of the establishment of right framework, governance, and direction in monitoring, research, and science. Currently, the status of the activities of each international LTER network is evaluated as a fully active network, a consolidating network, or an inactive network. Among more than 40 international LTER networks, some are inactive and many are consolidating networks. We assumed that the status of the activities of the LTER networks of the US and China can be evaluated as fully active networks in most aspects and that of the Korea LTER Network can be evaluated as a consolidating one. To promote the Korea LTER Network to a fully active network, we need to diagnose the current status of the Korea LTER Network and find ways to promote the Korea LTER Network to accomplish its vision, mission, and goals commonly shared by the international LTER networks.

This article reviews the history of the framework activities of the LTER networks of the US and China, to create categories and criteria for evaluating the activities of LTER member networks, to evaluate the current status of the Korea LTER Network, to find ways to promote the Korea LTER Network, and to define the challenge and opportunity issues for the promotion of the Korea LTER Network in the future.

MATERIALS AND METHODS

This review was prepared using a literature review of the major documents on LTER and ILTER activities, which include the papers and documents made by Chinese Ecosystem Research Network (1993), Fu et al. (2010), the ILTER Network (2006), Kim (2000, 2006), Mirtl et al. (2009), Müller et al. (2010), and the US LTER Network (1993, 1998, 2007). In 2006, the ILTER Network published a strategic plan in developing the vision, mission, goals, and strategies to guide its work over the next 10 years and also an operation plan to follow up in laying out objectives, action items, and estimated budgets. This review of the major LTER activity developments from fully active networks was made from the cases of the LTER activities of the US and China. We adopted categories and criteria for evaluating ILTER Member Networks by examining the case studies suggested in the US LTER Decadal Plan (US Long Term Ecological Research Network 2007) and the ILTER Strategic Plan (International Long-Term Ecological Research Network 2006). Using these categories and criteria, we evaluated the current status of the Korea LTER Network and suggested ways to promote the Korea LTER Network to a fully active network.

RESULTS AND DISCUSSION

Categories and criteria for the evaluation of the stage of the LTER Networks

The bylaws of the ILTER Network and LTER-Europe

Network specify criteria for joining the ILTER Network as an ILTER member: 1) recognition by a governmental/territorial body or other institutional entity at the national/territorial level; 2) existence of a national/territorial committee or other management structure; 3) a set of sites or proposed sites with criteria for the selection of new sites; 4) a statement of collective purpose that might include defined research or monitoring themes; 5) a data management and accessibility policy including a commitment to share and exchange data and knowledge with other members of the ILTER Network; 6) assurance of the long-term nature of the national/territorial network; 7) a commitment to supply information about its sites and procedures as may be reasonably requested by the ILTER Committee or its officers; and 8) a commitment to meet eventual LTER network criteria as defined by the ILTER Coordinating Committee. In addition, in order for a national/territorial LTER network to meet the objectives of ILTER as a major element of the ILTER research infrastructure, the criteria required to meet are 1) participation in the annual ILTER Coordinating Committee meeting; 2) provision of information on national/territorial network structure; 3) communication and responsiveness; 4) organization of annual national/territorial LTER network meeting; 5) nomination of contact persons; 6) regular update of information on national/territorial LTER facilities (sites and platforms) at the ILTER regional meetings; 7) annual status/progress report of national/territorial network to ILTER; and 8) a data management and accessibility policy including a commitment to begin the process of sharing and exchanging data and knowledge with other members of ILTER (unpublished ILTER Network bylaws and LTER-Europe bylaws).

We categorized these criteria into three groups: 1) governance and infrastructure to secure long-term funding, facilities and equipments, and site security; 2) sustainability of current and future directions in research, monitoring, and science; and 3) the core mechanism to serve societies. While the criteria related to establishing bylaws and the organizational entities specified in the bylaws belong to the governance structure category, the criteria related to strategic plans including the missions, vision, and goals in science, monitoring, and research belong to the strategic and action plan category. The criteria related to the core mechanism to serve societies include the criteria for education and outreach. Considering the three categories and the criteria for evaluating network activities, the activities of the Korea LTER Network are comparatively evaluated with those of the US and China for the promotion of the network.

Development and strategies of the US LTER Network

Developmental history

In 1980, the US National Science Foundation (NSF) initiated LTER Network activities with an initial set of six sites selected, i.e., North Temperate Lakes, H. J. Andrews Experimental Forest, Coweeta Hydrological Laboratory, Konza Prairie, North Inlet Marsh, and Niwot Ridge to carry out long-term ecological research projects towards question/hypothesis formulation and resolution over long time and broad spatial scales. In 1993, an International LTER Summit was held at Estes Park, Colorado, USA with the third US All Scientists Meeting, where the ILTER Network was officially initiated, whence the long-term ecosystem research programs have expanded rapidly on the globe. Until 2004, the US LTER Network Office sponsored by NSF solely supported the ILTER Network activities in finance and governance. The main characteristics of the US LTER Network activities include 1) site-based ecosystems studies; 2) networks of sites at local, regional, and global levels; 3) long-term research and monitoring; 4) data sharing and archiving as key activities; 5) standardization for providing comparability of results; 6) addressing environmental problems for decision makers; and 7) ecological data for future generations (US Long Term Ecological Research Network 1993, 1998). As of December 2010, there are 26 sites in the US LTER Network. The sites represent a wide geographic distribution ranging from Alaska to Antarctica and from the Caribbean to French Polynesia and cover a diverse array of ecosystems over broad ranges of environmental and human conditions. The vision of the US LTER Network includes “a society in which exemplary science contributes to the advancement of the health, productivity, and welfare of the global environment that, in turn, advances the health, prosperity, welfare, and security of the nation.” The mission of the US LTER Network is “to provide the scientific community, policy makers, and society with the knowledge and predictive understanding necessary to conserve, protect, and manage the nation’s ecosystems, their biodiversity, and the services they provide.” The US LTER Network’s goals are advancing and promoting 1) understanding; 2) synthesis; 3) outreach; 4) education; 5) information; and 6) legacies. Major developments, achievements and future directions are well introduced and documented on the US LTER Network website at http://www.lternet.edu/. Readers are referred to the website for further details.

Science and integration

In the US LTER Network, each site develops individual research programs in five core areas, which include 1) pattern and control of primary production; 2) spatial and temporal distribution of populations selected to represent trophic structure; 3) pattern and control of organic matter accumulation in surface layers and sediments; 4) patterns of inorganic inputs and movements of nutrients through soils, groundwater and surface waters; and 5) patterns and frequency of site disturbances. Besides these core research areas, site-specific research is carried out based upon the site specific needs in research, monitoring, and science (US Long Term Ecological Research Network 1993, 1998). In October 2007, the US LTER Network published a report, "The Decadal Plan for LTER: Integrative Science for Society and the Environment (ISSE)," which describes a unifying framework to map out the US LTER Network's science agenda for the next 10 years to understand 1) how humans perceive the critical services provided by ecosystems at multiple human scales; 2) how these perceptions change behavior and institutions; and 3) how these changes feed back to affect ecosystem structure and function and the ability of ecosystems to continue to deliver services over the long term. The ISSE suggested crucial, long-term, and social-ecological questions for the LTER scientists to address in three thematic areas such as 1) land and water use changes; 2) climate change, variability, and extreme events; and 3) nutrient mobilization and species introductions (US Long Term Ecological Research Network 2007). To increase the society's awareness of environmental problems and its ability to develop solutions, ISSE recommended a goal for the LTER scientists to expand spatial and temporal scales of understanding, which requires efforts and actions 1) to enhance and expand collaborative research opportunities; 2) to expand opportunities for transdisciplinary collaboration; 3) to expand opportunities for long-term research; 4) to expand opportunities for synthesis; and 5) to create a network-based, long-term, multi-site transdisciplinary research program.

Cyberinfrastructure

Cyberinfrastructure is the term coined by a US NSF Blue-Ribbon Committee to describe new research environments "that support advanced data acquisition, data storage, data management, data integration, data mining, data visualization, and other computing and information processing services over the Internet. In scientific usage, cyberinfrastructure is a technological solution to the problem of efficiently connecting data, computers, and people with the goal of enabling derivation of novel scientific theories and knowledge (Atkins et al. 2003)." ISSE recommended a goal for the LTER network and scientists to develop cyberinfrastructure for integration and collaboration, which requires efforts and actions for the advance of the science 1) to support for the deployment, integration, and interoperability of cyberinfrastructure, standards, and people across environmental networks; 2) to support curated repositories for data and models to expand the knowledge base for synthetic research; 3) to invest in programs for technology transfer and training of information specialists and domain scientists; 4) to support key technology developments in the area of socio-ecological informatics; and 5) to enhance data collection and information management systems relevant to socio-ecological research (US Long Term Ecological Research Network 2007).

Education and outreach

ISSE also recommended that LTER networks and scientists build intellectual capacity for integration and public engagement for future scientists and the public to understand the complexity, nature, and limitations of the common resources, which requires efforts and actions 1) to support environmental education research focusing on learning progression, curriculum development, and pedagogy that facilitates science literacy; 2) to support network-level efforts to engage broad participation representing the diverse society; 3) to engage college graduate-level students in inquiry-based science education that integrates socio-ecological disciplines and focuses on working with data; and 4) to provide opportunities for graduate students to conduct transdisciplinary research within the context of long temporal and broad spatial scales (US Long Term Ecological Research Network 2007).

Governance

In 2006, the US LTER Network adopted a governance structure, which was designed to promote network-level science while supporting the ability of sites to meet site-level science needs. The basic governance structure was identified in the network bylaws, which clearly define membership, meetings of membership, Science Council, Standing Committees, Executive Board, Network Office, Officers, etc. It is important to notice that the bylaws state that the network should have periodic LTER All Scientists Meetings at approximately 3-year intervals. The US LTER Network bylaws clarify the purpose of the US LTER Network, which is to promote the advancement and application of long-term domestic and international ecological research. This is accomplished through communication

and coordination of research, education, and information management activities, and through synthesis activities across sites and ecosystems and among other related national/territorial and international research programs.

Challenges

As people witness dramatic changes in ecosystems at local, regional, and global levels, it is needed to adopt new, transdisciplinary, and integrative sciences to address important questions. The challenge areas that the US LTER Networks have conceived are 1) global climate change, variability, and related risk; 2) altered hydrologic cycles; 3) altered biogeochemical cycles; 4) altered biotic structure; 5) dynamics of land use, land management, and land cover; 6) altered ecosystem function and ecosystem services; and 7) changes in human health, well-being, and security. The ISSE framework is expected to significantly increase the capacity of the research community to detect, understand, and respond to the known and anticipated changes in socio-ecological systems and outreach the information to the key stakeholders and user groups. Here, ISSE might conceive of opportunistic areas for LTER scientists to contribute to the society by 1) upgrading the level of science and education; 2) increasing the capacity of educators and society to respond to these challenges; 3) encompassing the diversity of socio-ecological science; 4) generating scientific and cyberinfrastructure tools; and 5) establishing educational programs for the next generation (US Long Term Ecological Research Network 2007).

Comprehensive evaluation

Considering the activities of the US LTER Network by category, the US LTER Network has been evaluated as the most fully active and leading LTER network in the world.

Development and strategies of the Chinese Ecosystem Research Network (CERN)

Developmental history

CERN initiated its activities in 1988 with 29 field stations, five sub-centers, and one synthesis research center founded as a national key project supported by the Chinese Government and a loan from the World Bank. Until 2002, capacity and leadership building in LTER were the major missions, in which the latter focused on the development of a steering committee, scientific committee, and advisory committee. In 2008, CERN celebrated its 20th anniversary and continues to promote leading activities in LTER domestically and internationally by establishing an LTER sub-committee under the Ecological Society of China and by opening the Secretariat for the ILTER-EAP region, respectively (Chinese Ecosystem Research Network 1993, Fu et al. 2010).

Governance, site, and research infrastructure

The Chinese government, majorly the Chinese Academy of Sciences (CAS), is the sponsoring agency for CERN activities. The steering committee together with the science advisory committee and science committee coordinate the major affairs of CERN. Currently, CERN has 40 field stations, which consist of 16 agricultural ecosystems, 11 forest ecosystems, six aquatic ecosystems, three desert ecosystems, three grassland ecosystems, and one urban ecosystem. CERN also has one synthesis research center and five sub-centers, which consist of five disciplines including hydrology (water), soil, meteorology (atmosphere), biology, and aquatic ecosystems (http://www.cern.ac.cn). CERN is a network of more than 1,000 scientists and graduate students from 20 institutes in the fields of ecology, natural resources, and environment under CAS. Considering the size of land area of China, which is about 96 times larger than that of South Korea, the number of sites may not be too many compared with that of Korea.

Strategy

The vision of CERN is "to improve ecosystem management, to ensure the rational utilization of natural resources and sustainable socio-economic development, and to advance ecological study through network observation and experiments with remote sensing, GIS, and mathematical modeling and by achieving long-term and comprehensive ecological monitoring and research in China." The major mission items include "monitoring, research, demonstration, consultation, and public education." To be more specific about the major mission items of CERN, the mission on monitoring is carried out by 1) engaging in monitoring of the water, soil, atmosphere, and biological elements of major ecosystems; 2) important ecological processes such as energy and matter flow; and 3) land use and land cover changes in the surrounding areas of the field stations using standardized methods. The current emphasis is on monitoring such issues as 1) routine long-term ecological and environmental monitoring; 2) terrestrial ecosystem flux observation; 3) terrestrial transect investigations; and 4) controlling experiments and monitoring. The mission on research is carried out by conducting research on the

structure, function, and dynamics of the major ecosystems in China and by using approaches and methods for sustainable ecosystem management. The core research areas include 1) horizontal, vertical, and trophic structures of ecosystems; 2) cycling of carbon, nitrogen, water, and other key elements of life-supporting system; 3) ecosystem energy flow; 4) ecosystem productivity; 5) ecosystem dynamics; 6) restoration and rehabilitation of degraded ecosystems; 7) impacts of human activities on ecosystems; 8) sustainable management of ecosystems; 9) biodiversity conservation and sustainable use; and 10) interactions between climate change and ecosystems. The current emphasis is placed on research for such issues as 1) the carbon cycle; 2) ecosystem structure and function; and 3) ecosystem restoration and management. The mission on demonstration is carried out by providing sustainable ecosystem management models for the surrounding areas of the field stations. CERN has stated that dynamic analyses of monitored data and public service are the most important means to enhance the social influence and vitality of CERN. CERN thinks that it is important to serve society by playing roles such as 1) providing support for their policy-making; 2) providing publicity material to improve public awareness on environmental protection; and 3) providing information services to promote the national and local socioeconomic development and environmental conditions in China by updating central and local governments with the latest information on ecosystem changes (Fu et al. 2010).

Science and synthesis

To understand fundamental ecological processes under different environmental conditions, CERN undertakes synthesis research in such core thematic areas as 1) coupling carbon, nitrogen, and water cycling processes; 2) response and adaptation of ecosystems to global climate change; 3) biodiversity conservation and biological resources exploitation; 4) ecosystem restoration and sustainability; 5) the impact of human activities on ecosystem structure and function; and 6) ecological monitoring, modeling, and eco-informatics applications (Fu et al. 2010).

Cyberinfrastructure

Since the establishment of CERN in 1988, the CERN Synthesis Research Center has collected a wide array of monitored and observed data through its field research stations and has established databases, while standardized techniques and methods for data collection, transfer, archiving, analysis, and synthesis were applied to all CERN stations. Datasets are currently available for the public on the CERN website (http://www.cern.ac.cn), which provides the scientific community with the opportunity to conduct cross-site synthetic research on ecological processes and global change issues in various ecosystems across China (Fu et al. 2010).

The strategic plan

In 2006, the Scientific Committee of CERN drafted the Strategic Plan of CERN to 2020. After a vigorous internal discussion, it was finalized in 2008, with the following provisions: 1) to highlight the key directions of the intermediate-term development of CERN; 2) to promote capacity-building for monitoring, research, and demonstration; and 3) to propose an overall goal and objectives for CERN at different stages by 2020. In the Strategic Plan, the overall goals of CERN were redefined as 1) a series of original findings on fundamental ecological study should be achieved by 2020, with breakthroughs made in some areas by producing significant impacts on the international community; 2) some key ecological issues that are critical for the country will be resolved on ecology development, environmental protection, and sustainable agricultural development; and 3) CERN will develop into a national science and technology innovation base and a long-term ecological research facility in Asia in terms of long-term ecosystem monitoring, research, and demonstration (Fu et al. 2010). We evaluated CERN as a model case for other international LTER networks.

A comprehensive evaluation

Considering all of these categories of activities, we evaluated CERN as a fully active LTER network and also as a leading international LTER network for the future.

Evaluation of current status of the Korea LTER Network activities and defining the gaps to bridge

Evaluation of the Korea LTER Network activities by category and criteria

Site security: The Korea LTER Network includes two Programs; the Korea Forest LTER Program, sponsored by the Korea Forest Research Institute, initiated in 1997 and the KNLTER Program, sponsored by the Ministry of Environment of Korea, initiated in 2004. Currently, there are five sites under the Korea Forest LTER Program and 18 sites under the KNLTER Program. As the sites under the Korea Forest LTER Program are managed by the Korea Forest Research Institute and the land owners of the sites are mainly the central government, the sites are secured.

Meanwhile, sites under the KNLTER Program are managed by a group of volunteer researchers, and the land owners of the sites are not necessarily the central or local government. Therefore, the sites are either loosely secured or not secured at all. Thus, we urgently need to evaluate the security of each site and find ways to establish permanent security. In this regard, the roles of Korea National Park, where some sites under the KNLTER Program are located, should be reconsidered not only as actively managing the sites but also as co-leading the LTER activities within their boundaries with their staff researchers.

Governance, research infrastructure, and science for integration: The two Korea LTER Network Programs managed independently have limitations in research infrastructures and science programs. First, full participation of scientists to conduct a wide array of LTER activities is limited due to insufficient understanding of the potential of LTER network activities. This has occurred due to the consequential failure of established governance to ensure open management systems of the programs. Therefore, we need to establish governance, which will be discussed in the following section. Second, systematic approaches assuring the functionalities of the programs were not developed due to the lack of a strategic plan and subsequent action plans to follow-up. To assure systematic approaches, we must develop a strategic plan for the Korea LTER Network as a whole after reviewing the strategic plans and the characteristics of other international LTER networks discussed above. Third, scientific approaches are not being developed because no scientifically significant questions have been formulated and shared with all the Korea LTER Network scientists as the foci of science approaches. Fourth, no effort is currently being made to integrate various aspects of sociological sciences with ecological sciences. Fifth, the basic infrastructure for research including equipments and facilities for monitoring and observing ecosystem changes

Table 1. Categories and criteria for evaluating the status of LTER Networks

Category	Criteria by developmental stage	
	Developmental stages	Criteria
Governance and infrastructure	1st stage	Recognition by a government body or institutional entity at national level
		Sites and security
		Long-term funding
		Facilities and equipments
		LTER Network office
	2nd stage	Bylaws
		National/territorial committee authorized to make commitments for the members and sub-committees
	3rd stage	Evaluation and planning of Strategy and Action Plans for the Development of Governance and Infrastructure
Sustainability of research, monitoring, and science	1st stage	Monitoring protocol and activities
		Research protocol and activities
		Ecological Information Management protocol and activities
	2nd stage	Science protocol and activities
		Cyberinfrastructure protocol and activities
	3rd stage	Evaluation and planning of Strategy and Action Plans for the Development of Science and Integration
Service to society by communication, cooperation, and outreach	1st stage	LTER All Scientists Meeting
		Website building, update, and newsletter
		International cooperation, coordination, and participation
	2nd stage	Communication, demonstration, and extension
		Education, outreach, and capacity building
	3rd stage	Evaluation and planning of Strategy and Action Plans for the Service to Society

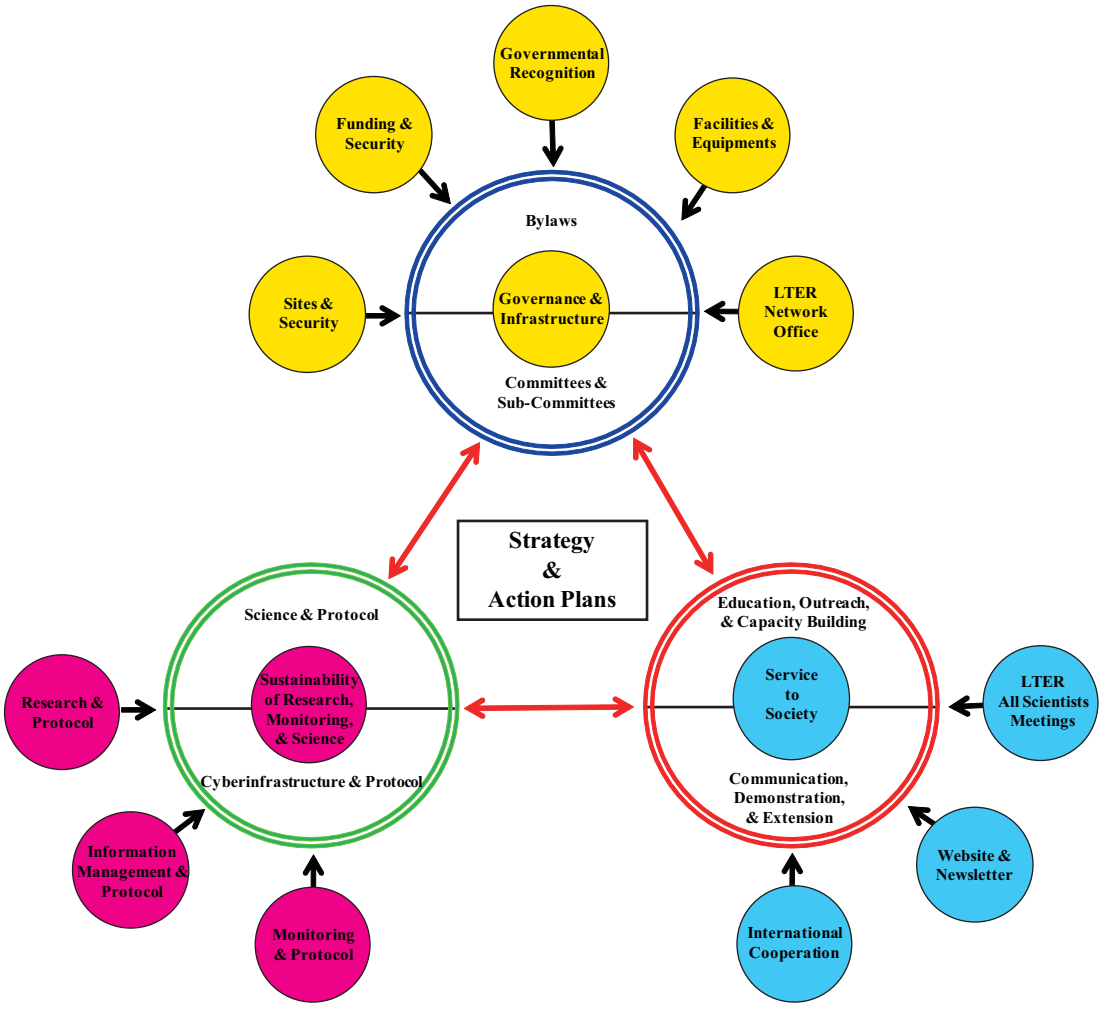

Fig. 1. A diagram for considering a strategic plan for the Korea Long-Term Ecological Research Network.

has not been installed at all Korea LTER Network sites, where assuring the comparability of data standardized across the sites by temporal dimension is the key mission of local, regional, and international LTER networks. Here, the need for making a strategic plan to establish sound infrastructure for conducting leading research and science from the Korea LTER Network is emphasized.

Cyberinfrastructure, education, and outreach: Currently, the capacity of cyberinfrastructure in advanced data acquisition, data storage, data management, data integration, data mining, data visualization, and other computing and information processing services at sites is not fully incorporated with ecological data and information management activities, and no efforts for synthesis and integration are being made at local, regional, or global level. Significant efforts to incorporate Korea LTER Network activities with education and outreach to students and the general public were not made.

A comprehensive evaluation of the current status of activities of the Korea LTER Network: Considering all of the major categories related to Korea LTER Network activities, the Korea LTER Network is considered to be in a consolidating stage on the way toward a fully active stage. Here, the most pressing priority to promote the Korea LTER Network is to create a strategic plan for developing and overcoming challenge issues and taking advantage of the opportunities given under the ever-dynamic national situation of Korea (Table 1 and Fig. 1).

Suggestions to promote the Korea LTER Network to a fully active LTER Network

Strategies

Vision, missions, and goals: In order for any organiza-

tion to be developed, a strategy must be in place to develop structure and promote functionality with a road map and time frame. Thus, it is strongly requested for the Korea LTER Network to develop a strategic plan. In this review, cases of strategic plans were introduced from different international LTER Networks including ILTER (International Long-Term Ecological Research Network 2006), US LTER (US Long Term Ecological Research Network 2007), LTER-Europe (Mirtl et al. 2009), and CERN (Fu et al. 2010). By examining the strengths, weaknesses, opportunities, and threats of the Network, missions and goals should be suggested to implement the vision commonly shared with the participants of network activities. Strategy items are suggested below as a conclusion to this review.

Governance: The governance of the Korea LTER Network should be considered first by making a strategic plan, which includes establishing bylaws, identifying funding agencies, an advisory board, a Network office, an executive board, committees, science council, sites, and facilities and equipments.

Site security: Compared to the sites of the Korea Forest LTER Program established on the national forests, the security of sites of the KNLTER Program is a key issue of concern, because some KNLTER sites were not established on national land, so the long-term management of the sites could not be secured. Furthermore, the links between researchers and Korea National Park were not well established at some KNLTER sites in Korea National Park, so tighter relationships between the researchers and Korea National Park should be established. We think it is important for managers of Korea National Park to consider hosting and fostering Korea LTER Network activities in Korea National Park and provide institutional support for managing, protecting, and monitoring the sites, sharing the outputs and outcomes, planning strategies and further actions plans, and constructing infrastructure.

Science and integration: Current Korea LTER activities are mainly focused on monitoring ecosystem changes affected by climate and environmental changes at the local level. As was discussed in the cases from other international LTER Networks above, more rigorous scientific quests must be promoted and more syntheses as well as analyses of data, information, and knowledge are further sought. Here, it is very important to consider carrying out science with scientifically significant questions. More importantly, studies on natural aspects should be integrated with studies on sociological aspects, which are the sources of complexities exhibited in the natural phenomena monitored long-term.

Cyberinfrastructure: Creating and sharing ecological data and information under standardized protocols at local, regional, and international levels are some of the most important activities of the LTER network, which include data creation by measuring and sensing, data transfer and modification, and data utilizing and archiving, where strong cyberinfrastructure becomes the key components in the data processes. As Korea is a country with strong information technologies (IT), it is quite important for the Korea LTER Network managers to invite IT scientists to manage ecological data and information for research, science, education, outreach, and communication over different temporal and spatial dimensions.

Education and outreach: While long-term benefits of the LTER network activities are the legacy of a future generation with well documented ecological data and information, short-term benefits are the information and knowledge produced from network activities. The processes and outputs of LTER activities at the local level should be shared with education systems at various levels including the general public and decision makers so that the network activities are sustained and supported by tax money paid by the public. Various activities using websites, data archives, mass media, and field schools should be openly promoted to link LTER activities with various stakeholders.

Research infrastructure: In order to make good outputs and outcomes from the LTER Network activities, special attention should be paid to establish effective infrastructure for research, which includes scientists, research plans, equipments, facilities, and funds. Generally, the levels of infrastructure for the Korea LTER Network are far below those of other major leading LTER Networks such as the US LTER and CERN. Thus, sponsoring agencies are requested to share a futuristic vision that the Korea LTER Network is being developed into a leading international LTER Network in the world.

Challenges and opportunities

Domestic challenges and opportunities: In 1995, the Korea LTER Network participated in the First International Conference of the East Asia-Pacific Regional Network of the ILTER Network held in Taipei, Taiwan. The first domestic challenge is to advance the Korea LTER Network activities from a consolidating stage to a fully active stage with criteria for establishing site security, advancing science and integration, converging with IT on cyberinfrastructure, extending to education and outreach, and constructing a state-of-the-art research infrastructure. The second challenge is to link Korea LTER

Network activities with the activities of biodiversity conservation, ecosystem services, ecosystem restoration, and integration with social sciences, in which many opportunities exist for these long-term ecological research activities. Currently, economic development in Korea is mainly contributed from the economic sectors including global scale industries. The Korean economy continues to stay in the black by balancing exports and imports. These economic surpluses are being made on the deficits for ecology or ecosystems at local, regional, and global levels. Considering these ecological deficits, it is a real challenge for the society as a whole to monitor, assess, and predict the change in the status of drivers, impacts, status, and pressure and to identify ways to respond to short-, intermediate-, and long-term goals.

Green Growth is a key national policy issue under the current Korean Government, and we consider that it is a sustainable economic development in concept in a large sense. If the current government is actually considering Green Growth as the top national policy issue, establishing an excellent LTER network consisting of world class super LTER sites is a real challenge for the Korea LTER Network scientists and the Korean governmental bodies. The governmental policy of Green Growth also renders good opportunities for Korea LTER Network scientists to explore and take advantage of this opportunity to construct a leading LTER network in the world. However, carrying out the strategy becomes a real challenge.

International challenges: Since 1995, the Korea LTER Network has continued to cooperate with international LTER networks at regional and global levels. The first challenge at the international level is to contribute to developing international LTER network activities by advancing Korea LTER Network activities and, consequently, showing leadership in certain areas of science and integration; developing high-tech observation technologies by converging with cyberinfrastructure; showing the sample cases with links to education and outreach; and constructing and managing state-of-the-art research infrastructures. Among these, developing high-tech ecological observation technologies by converging with cyberinfrastructure, which is a strength factor of Korea, can be an area for the Korea LTER Network to lead international LTER network activities (Kim 2007). Strategic approaches are needed for further development.

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