Developing the Environmental Long-Term Observatories Network of Southern Africa (ELTOSA)

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LONG-TERM ECOLOGICAL RESEARCH (LTER) facilitates the understanding of long-term environmental processes and episodic changes at local to global scales. The Environmental Long-Term Observatories Network of Southern Africa (ELTOSA) is a regional LTER network of country Environmental Observatories Networks (EON) encompassing the natural environments and their socio-economic context. EON involves the documentation, analysis and information dissemination concerning long-term (decades to centuries), large-scale (ecosystem, biome, continental, global) ecological and socio-economic processes. These are elucidated through multidisciplinary research and monitoring over a network of institutionally operated field observation sites. Basic functions concern fieldwork, data management and sharing, analyses and interpretation, and information dissemination, all operated in such a way as to benefit most from cooperation among professionals and with resource managers at all levels. Requirements for continuity include programmatic tenure and funding, data archiving, data sharing, training, and networking. EON involves networking at four scales. First, the level of the EON centre inter-connects specific study plots over time and space, and facilitates collaboration between researchers and students using the centre. Second, the country network level inter-connects several institutions and programmes with common goals and activities. Third, the regional network level, such as ELTOSA, promotes subcontinental programmes, synergy, and complementarity. Fourth, the global network (ILTER, International Long-Term Ecological Research Network) facilitates planning and information exchange concerning such programmes across the world. This position paper describes the current status and character of ELTOSA, sets out to solicit programmatic support from funders and policy-makers, and intends to serve as a discussion focus for its further dynamic development.

Introduction

Background

In May 2001, we, scientists from six countries in southern Africa, formed the Environmental Long-Term Observatories Network of Southern Africa (ELTOSA). Further development was made at the ELTOSA conference on Inhaca Island, Mozambique, during July 2002. ELTOSA connects country Environmental Observatories Networks (EON), the African adaptation of LTER (long-term ecological research). The International Long-Term Ecological Research Network (ILTER) has accepted ELTOSA as a regional member, and currently three ELTOSA country members have individual ILTER membership (Namibia in 1999, Zambia in 2001, South Africa in 2002) and others are working towards membership.

This position paper describes the development of a vision for EON in southern Africa. We outline the importance of developing EON and list the opportunities this offers for the natural and social sciences. Finally, we focus on some challenges that accompany the development of EON in the region, with suggestions on how to meet them.

EON

LTER is a well-established concept involving ecology,[1,2] and its broader application in Africa in the ecological as well as socio-economic context is termed Environmental Observatories Network. While the word 'observatories' expresses the idea of monitoring at multiple fixed sites that is fundamental to this kind of long-term data acquisition, 'network' expresses the interdisciplinary, multi-institutional synergy and large-scale ('big science') scope of EON. Finally, EON also expresses the long-term scope and the challenge of elucidating events across landscapes, species assemblages and aeons.

EON, in its generic sense, is a research platform and information management system for multidisciplinary, multi-institutional and participatory ecosystem studies with strong local, national, sub-continental and global linkages. EON tackles the formidable task of improving understanding of ecosystem function and change, as well as agents of change, to promote wise use and management of ecosystem goods and services through policies, strategies, public awareness and environmental education. Although environments are complex and dynamic with many interacting factors that vary at different scales, EON can provide a mechanism for effective early-warning systems and for the prediction of deleterious environmental change.

Data keepers

Good time-series data are necessary to address some of our most important questions concerning the environment. Obtaining these requires strategies to capture past data electronically, make new observations, and incorporate them into accessible, understandable and shared data archives that build up a legacy of information that is independent of the whereabouts and welfare of the contributors. This, in turn, makes it possible to obtain data that no single individual, or institution or generation can accumulate, while it simultaneously minimizes data loss and redundancy. These strategies towards national and regional environmental information systems must be non-profit orientated and require synergy and good coordination among many scientists and institutions.[3] EON therefore concerns monitoring, data archiving, data accessibility and sharing, and ensuring continuity of such programmes.

Scale

Long-term and large-scale phenomena require long-term and large-scale monitoring programmes. Data obtained at different times and different sites can be compared across space and time. Typically, the time scale of EON monitoring extends from several years to centuries (with predictions extending into millennium-scale probabilities). However, they do also capture episodic events,

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environmental phenomena that may be short, rare and unpredictable, but extremely important (for example, extraordinary rainfalls or droughts, heat-waves or deep frosts, freak storms or extensive hot fires). Spatial scales typically extend from the size of a plot or patch (for example, 1 m^2, 1 ha, 1 km^2), across landscapes to biomes. Networking stretches the scale across subcontinents, continents and the globe. EON endeavours to provide baseline data and information on changes, including how changes affect and are affected by people.

Over time, environmental sciences have become more holistic in their outlook, combining natural and socio-economic environments into one field. This cross-sectoral approach addresses issues relating to sustainable development, but also provides scientific strength by being more inclusive, although it remains an academic challenge to master and to evaluate. The key is synergy, where co-operation produces greater products than the sum of the outputs by individual participants working alone.

Box 1. Typical kinds of parameters measured at EON sites (not necessarily all at each site).

- **Climate**: precipitation, temperature, humidity, wind, solar radiation, ocean currents
- **Episodic events**: high rainfall, long drought, high flood, heavy storm, deep frost, extensive hot fire, landslide, volcanic eruption, algal bloom/red tide, tornado/cyclone, political strife, pandemic, economic depression/boom, disastrous pollution
- **Primary productivity**: Nett primary productivity (NPP), leaf area index, forest biomass, NDVI, phytoplankton
- **Ground truthing**: for remote sensing, for example, NDVI, biomass, precipitation
- **Long-term population dynamics**: local and spatial changes in abundance and demography of wild and domestic plants and animals
- **Growth**: especially of long-lived individuals (for example, whales, *Welwitschia*, yellow-wood trees, lichens)
- **Phenology**: seasonality, development patterns, reproductive output
- **Biodiversity**: species richness, alpha and beta diversity, biogeography, status of threatened species
- **Community composition**: ecosystem changes, alien invaders, bush encroachment
- **Decomposition**: rate of consumption of standard substrates, amount of detritus and dead wood
- **Weathering**: erosion, corrosion, dune movements
- **Water levels**: runoff volume, dam level, groundwater depth, water quality
- **Greenhouse and ozone-depleting gases**: background level, local volume
- **Carbon stocks (gains and losses)**: standing crop, combustion of fossil fuel, fire prevalence
- **Soil nutrients**: organic carbon, nitrogen and phosphorus, light fraction
- **Natural resource use**: water abstraction, grazing, type and intensity of land use, water, firewood and timber, yield of harvest of marine and terrestrial plants and animals
- **State of Environment Indices**: consumption, emissions, waste production, income from particular natural resources, poverty index, welfare, health, education levels, marketing of natural products, employment rate, bio-indicators
- **Human demography**: density over time and space, age structure, life expectancy, birth rate, emigration and immigration, economic and educational status
- **Application of appropriate technology**: conservation farming techniques, genetically modified crops, unleaded petrol, clean production technologies
- **Implementation of environmental policies**: environmental impact assessments, water management, pollution and waste, invasive alien control

Multidisciplinary research

Basic research provides first-hand knowledge that can be translated into relevant information and applied to relevant target groups. Such research is necessary for coming up with novel insights that were not predicted initially. Knowledge, and its application, can in this way advance in quantum leaps. Basic research is thus fundamental for adaptive applied research. The distinction between applied and basic research, however, is not always clear with biodiversity conservation and primary productivity. Basic research in the context of its application is especially important for effective capacity building, because the ability to conceptualize is as important for research as is the acquisition of skills.

While EON is currently conducted by ecologists rather than social scientists or economists, the human element is one of its core components and it calls for multidisciplinary approaches (Box 1). Boundaries of disciplines should be indistinct in order to address complex environmental problems, however, ecologists also need to delve into history, religion, philosophy, geography, economics, and political science.[1] Sustainable natural resource management inextricably links the natural environment and the socio-economic environment, as has been the case for many millennia in Africa. Changing conditions in natural environments that support larger and more demanding human populations in developing countries make natural and socio-economic sustainability and their indicators important issues. Furthermore, such research is very closely linked with the need to raise awareness and to transfer relevant knowledge to resource managers and incorporate it into policy. African environmental scientists are gaining experience in using multidisciplinary and simultaneous basic–applied approaches and can therefore be influential in the growth of this approach in other regions of the world. EON is an important platform for these aspects and it is therefore essential to promote it in southern Africa.

Environmental conventions

In the aftermath of the 2002 World Summit for Sustainable Development, it is important to stress that EON and its related programmes (including LTER and the Global Terrestrial Observation System, GTOS) are crucial to nations and the international community meeting the goals of Agenda 21. EON represents a network of programmes and field stations that monitor environments and can provide data on baseline conditions, changes and trends, or a lack of changes. This provides input of time-series data and reflection on the conditions in which the Conventions operate, including their successes and failures. Such monitoring is an important element in the implementation of the UN Convention on Biological Diversity (CBD), the UN Convention to Combat Desertification (CCD), the UN Frame Convention for Climate Change (FCCC), the Ramsar Convention on Wetlands, the Convention on International Trade in Endangered Species (CITES), as well as numerous other global programmes, such as the International Geosphere–Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP), and DIVERSITAS.

EON therefore promotes the development of the interest, understanding, and political will in African countries to incorporate the environment into informed development planning. EON focuses on parameters that are good indicators. Are efforts to improve water/soil/atmosphere,

or to improve the basic living conditions of people or biota working or not? At which scale? How can we make predictions? What chronic changes may affect people and the environment in the future and how can one obtain early warnings? Most reliable answers can be gained by examining well-documented lessons extending over time, space and ecosystems, lessons learnt from quantitative data obtained through monitoring and synergy among compatible institutions and data archives. EON can provide this.

Box 2. Objectives of the International Long Term Ecological Research Network (ILTER).[10]

The ILTER Network was founded in 1993 with the purpose to

- Promote and enhance the understanding of long-term ecological phenomena across national and regional boundaries.
- Promote comparative analysis and synthesis across sites.
- Facilitate interaction among participating scientists across disciplines and sites.
- Promote comparability of observation and experiments, and integration of research and monitoring.
- Encourage data exchange.
- Provide training and education in comparative long-term ecological research and its relevant technologies.
- Contribute to the scientific basis for ecosystem management.
- Facilitate international collaboration among comprehensive, site-based, long-term ecological research programmes.
- Facilitate development of such programmes in regions where they currently do not exist.

Development of EON in Africa

Recently, Africa has been involved in the international developments of LTER. Namibia was represented at the founding of ILTER in 1993, when the ILTER network office was established in Albuquerque, New Mexico (Box 2). A visit by ILTER to South Africa in 1996[5] and the subsequent visit by a South African group to ILTER[6] caught the attention of several African countries and initiated planning towards network formation. This led to the ILTER membership of Namibia in August 1999, based on the formation of a country network in Namibia (now called Environmental Observatories Network of Namibia, EONN). The first official EON centre in Africa was the Gobabeb Training and Research Centre in the Namib Desert; several additional potential EONN centres were also identified in Namibia.

The South African LTER movement organized an International LTER Symposium and a National LTER Workshop in 1999, in Skukuza, South Africa. This was a landmark occasion in which the international ILTER representatives and four African countries participated. Zambia gained ILTER membership in July 2001, followed by South Africa in April 2002. The South African government granted funding to the National Research Foundation (NRF) to form the South African Environmental Observatories Network (SAEON) and charged it with selecting the first South African flagship EON centre and identifying further candidate centres, as well as spearheading the EON process (programme and infrastructure development) in South Africa.

Discussions towards a regional EON network were initiated at the August 1999 meeting in Skukuza (four African countries), and followed up at the August 2000 meeting in Snowbird, U.S.A. (five countries). A tour of American LTER sites and a meeting in Washington, D.C., by representatives from Botswana, Mozambique, Namibia, South Africa and Tanzania during May 2001, culminated in the formation of ELTOSA. Soon Kenya, Zambia and Zimbabwe joined the discussion forum, and there are now eight countries involved, although they differ in status (Table 1). During July 2002 on Inhaca Island, Mozambique, the first ELTOSA annual general meeting began formulating the modus operandi and business plan of the ELTOSA network.

EON/LTER networks at local, country, regional and global levels

Benefits of EON increase through its functional networking at many levels. Synergy and coordination of many scientists, institutions and other stakeholders, adds context and continuity, and provides EON programmes with a broad, dynamic and adaptive outlook.

While research programmes conducted at individual sites and centres form the basic ingredients, they are nested at various levels (Table 2). ILTER promotes the idea that countries are appropriate levels for institutions to coordinate local LTER programmes.[1,2] Countries form networks, endorsed by their own governments, and this facilitates their effectiveness and durability. Country networks are members of regional networks, continents, subcontinents, or groups of nations with common interests. Country and regional networks, in turn, are affiliated to ILTER, which provides guidance through mutual consensus.

Local networks

An EON centre is a local network where fieldwork is conducted (Box 3), for example Gobabeb (Box 4). An effective EON centre requires networking and agenda setting by local EON programme managers to make their centre known and its data accessible and useful, to attract expertise from elsewhere, and to promote information exchange between professionals and local resource managers. Its functions are coordination of research and monitoring at specific places; managing, archiving and analysing data; disseminating information, and education and outreach programmes. An EON centre operates permanent field sites that serve as nodes for affiliated sites which may be either external to the core EON area, or based on temporary projects. EON centres are typically associated with field stations operated by national (rather than foreign) institutions that can give permanence and relevance to a succession of research and monitoring programmes

Table 1. Current status of ELTOSA members in December 2002 indicating whether or not (Y/N) they are ILTER members, have government commitment for funding, are actively developing a country network, and have declared EON centres.

Country	ILTER member	Own government funding	Developing country EON	EON centres
Botswana	N	N	Y	Y
Kenya	N	N	N	Y
Mozambique	N	N	Y	Y
Namibia	Y	N	Y	Y
South Africa	Y	Y	Y	N
Tanzania	N	N	Y	Y
Zambia	Y	N	Y	N
Zimbabwe	N	N	N	N

Table 2. Networking of African EON at four scales.

Aspect/scale	Site or centre	Country	Region	Global
Network	EON centre (e.g. Gobabeb)	EONN, ZamEON, SAEON	ELTOSA	ILTER
Operated by	Local resident institutions (e.g. Desert Research Foundation of Namibia)	National committee with lead institution	ELTOSA committee (and office?)	ILTER members and office
Networking	Among researchers and trainers	Among centres and country collaborators	Between countries and regional collaborators	Between countries and regions
Most important functions	Monitor and conduct field research, collect and archive data, provide data and information, conduct training and outreach	Facilitate continuity and operation of centres, define and review common goals, coordinate site activities, data sharing, policy relevance	Facilitate country networks, define common vision, coordination of country activities, maximize regional complement of sites, researcher exchanges, ILTER relations	International collaborative programmes, guide and facilitate country and regional networks, international profiling
Fieldwork	Conduct research and training, interpret, publish	Enhance standardisation and quality verification, cross-centre activities	Enhance standardisation, facilitate training, transboundary activities	Enhance standardization, facilitate training, global programmes
Data management	Data archive, centre metadata	Country metadata connecting centre metadata	Information via common connection of information communications technology	Guide data management
Data sharing policy	Centre-specific, guided by country policy	Country-specific to guide centres	Guide countries	Guide countries and regions
Researchers	Core of local resident researchers, foreign collaborators, training of young scientists	Training of young scientists from country, collaboration among national and foreign researchers	Training of young scientists from region, regional and international collaboration	International collaboration
Training	Fieldwork and data management, researchers and technicians	Promote training at centres and identify appropriate candidates, facilitate availability of future practitioners	Conduct training in data management, exchange students between countries	Facilitate regional training programmes, particularly in data management
Funding required for	Core monitoring, data management, research projects, training, information dissemination	Communications, metadata, information dissemination	Communications, workshops, information dissemination	Communications, conferences, AGM
Current principal funders	International collaboration, fund-raising not through research, government and industry	Donor and government-funded networks	ILTER, South African government	ILTER
Planning for future potential funders	Donors, local programme funds (national science foundations)	National science foundations, National EON offices	Regional programmes via SADC, ILTER	ILTER
Institutional capacity building	Strategy for future human capacity and organizational development	Identify and promote institutions, guide provision of national support, national training workshops	Synergy between institutions in the region, researcher exchanges	International collaboration that promotes institutional capacity, visiting researchers

and can also house the data archives. EON centres and programmes have non-terminal time horizons ('no sunset clause', J. Gosz pers. comm.). A strong likelihood of permanence is important for planning new EON centres.

Through their connection to the EON centre, partner institutions increase capacity, support the data archive, and gain access to previous data and information, which enhances synergy and relevance. Well-funded projects from foreign institutions, particularly industrial nations, can (and are often necessary to) supplement EON sites in return for guidance and access to the data archives of their hosts. It is the role of local institutions to coordinate foreign–local collaborations and to ensure that data and information are archived at the EON centre.

EON centres can be diverse in nature. For instance, in Namibia, the Etosha Ecological Institute is operated by a government institution in a national park, and the agricultural stations Gellap-Ost, Sonop and Mile-46 are government institutions on state land. Gobabeb is also situated in a park and is operated through a joint venture between government (Ministry of Environment and Tourism) and an NGO (Desert Research Foundation of Namibia). Erongo Mountain is a freehold conservancy affiliated to Gobabeb. Walvis–Sandwich-Lagoon are under joint management of municipality and government, also affiliated to Gobabeb.

Country networks

EON centres exchange information with each other to form a national network. It is at the country level that EON meta-databases really come into play; the information contained in several data archives of EON centres is combined and strengthens the data policy of the institutions managing these sites. This gives practitioners access to information on who is managing which data and what the data access conditions are. Metadata provide context and effectiveness to networking by EON on national and international levels.

It is at the level of country networks that the commitment for EON is most crucial for programmes to be effective, as the kinds of institutions associated with EON

operate most effectively within the context of national objectives and are affected by the commitment of national decision-makers. In other words, without country networks to bind inter-institutional connectivity through objectives and common vision, EON would not be assured of the compatibility and continuity that characterizes LTER. Country networks can either operate with a national office, as in South Africa, or have a lead centre in their network that coordinates country activities, as in Namibia.

Institutional and human capacity building are the most challenging factors for the development of EON in southern Africa. It is a priority for each country EON programme to promote capacity building and to give recommendations for best practices in this regard. EON can only have a future with good recruitment from within countries. Students, starting at school level, should be trained to become practitioners and leaders to continue EON into the future. Governments and the public should be made aware of the valuable contribution EON is making to natural resource management policies and in facilitating the incremental accumulation of knowledge.

Regional networks

Country networks are members of regional networks, encompassing geographic groups of nations; there are regional LTER networks in North America, South America, Asia and Pacific, the Middle East, central Europe, western Europe, and southern Africa.

All ELTOSA members are countries that are practising or interested in EON. Countries are represented by EON leaders — ecologists from within a country, attached to either a national network office or an institution operating a (potential) EON centre. ELTOSA members do not need to have functional country networks yet, but should be developing such networks to become ILTER members. ELTOSA can facilitate the establishment of EON centres and country networks where requested.

Proposed roles of ELTOSA include improving connectivity between country networks and to coordinate regional planning of EON, in particular making best use of multi-national programmes, for example, concerning transboundary parks/ecosystems, river basins, and the atmosphere. ELTOSA should facilitate collaboration, high-quality research, and standardization of methods where possible and appropriate. Such regional collaboration is the best way for EON centres to complement, rather than duplicate each other; data sharing and dissemination of information are fundamental to EON, and ensuring this is an important role of ELTOSA. ELTOSA should increase the visibility of EON programmes both within southern Africa and globally, assist with advising funders, facilitate the distri-

Box 3. EON centre characteristics.

- Locally responsible environmental research institution that coordinates research and training at study sites under its jurisdiction.
- Scope of long-term tenure of site (decades to centuries).
- Member of national EON network.
- overall goals, and research and monitoring projects serving these goals.
- A core set of monitoring activities with commitment to continue these.
- Updated detailed documentation of all field and data procedures.
- Management of shareable data archives and metadata housed within the local institution based on documented data policy and procedures.
- Long time horizon of monitoring and research goals/outputs based at specific study sites.
- A legacy of data and data-derived products at the centre, with good growth potential.
- Strategy and scope for long-term funding security.
- Training strategies and activities for capacity building, primarily targeting national and regional future professionals, and secondarily globally.
- Strategy and activities towards ongoing institutional capacity building.
- National and international collaboration.
- Appropriate information exchange with scientists and students, policy-makers and local communities.

Box 4. Gobabeb Training and Research Centre.

- The first African EON centre is Gobabeb in Namibia.[7] Gobabeb was started in 1962 as a field research station in the Central Namib Desert to host researchers and students. A range of environmental training opportunities and programmes were developed. In 1998, the Gobabeb Training and Research Centre became a non-governmental organization under a joint venture between government, represented by the Ministry of Environment and Tourism, and an NGO, the Desert Research Foundation of Namibia.[8] In 1999, Gobabeb EON became the lead centre at the founding of EONN and the Namibian membership of ILTER.
- Data and detailed records of methods and study sites of resident and visiting scientists have accumulated at Gobabeb. Continued monitoring by Gobabeb staff follows some projects that were originally conceived with short-term goals. The monitoring programme includes climate; renewable energy; surface and ground water availability and use; dynamics of dunes, inselbergs and desert pavement; weathering; effects and geomorphology of anthropogenic disturbance; productivity, growth, population dynamics and diversity of trees, shrubs and grasses, riparian forest, and several vertebrate and invertebrate populations; dynamics and management of natural resources for people.
- Besides the core programme, Gobabeb EON also feeds past data into new research. Not only research is conducted, but data and understanding gained from EON also form the basis for field courses, in-service training, environmental education programmes, and are used for policy-making through projects such as Parliamentary Environmental Updates and Decision-Makers' Guides. Today, the 40-year old Gobabeb Training and Research Centre represents an extensive network of researchers and students. Training opportunities include in-service experience and courses concerning a range of disciplines. In this respect, Gobabeb is geared towards training potential future EON practitioners for EONN and ELTOSA.
- Sites of the Gobabeb EON centre are situated across the Namib Desert and adjacent areas; satellite EON sites are the developing research facilities of Walvis–Sandwich Lagoon and Erongo Mountain Conservancy. Gobabeb EON sites cross an extremely steep rainfall gradient (10–300 mm per annum over a distance of 300 km), ideal for monitoring and addressing questions concerning biodiversity, desertification and climate change. Data and research findings are being incorporated into an electronic data archive, while the extension of physical facilities enables Gobabeb to increase services to research and training clients and partners. Indeed, most of the research needs to be conducted by visiting scientists, as there are only a few resident researchers.
- The Gobabeb EON programme is largely funded through income from professional services and project overheads. Training programmes, as well as enhancement of institutional capacity, rely on donors. Gobabeb is striving to become financially self-sufficient eventually to be supported mostly by projects and service provision for training and research. This challenge faces many field stations in southern Africa without the prospect for government funding for EON programmes.

Box 5. Benefits of countries and regions affiliating with ILTER.

- **Designation as a participating network**: in many cases, this will strengthen the justification for continuing measurements at the site(s). It will also provide a natural focus for coordinated, multidisciplinary measurements and programmes.
- **Enhanced collaboration**: by being included in a global network, the opportunities for coordinated observations and scientific collaboration will be much improved. Individual networks will learn from the experiences of other networks for science operation and data management.
- **Contribution to global environmental conventions**: for climate, biodiversity, desertification, wetlands and endangered species, among others. The participating networks will make an important contribution to meeting the political and scientific objectives of these conventions and the responsibility taken on by their respective countries.
- **Enhancement of the network's impact**: in most cases, the effectiveness of a network's operation will be enhanced if others use the collected data. Also, a network's programme will benefit by having structured access to data from other similar networks.
- **Facilitation of data access**: The availability of comparative data from a wider range of sites will improve the interpretation of a particular site's data.
- **Increased visibility**: nationally and internationally, through participating in the networks and various initiatives.
- **Opportunities for additional funding and benefits**: although the networks will be largely self-financed, it is expected that supplemental funding will be sought for special initiatives, for pilot projects, and to fill gaps in observations. The leverage provided by ILTER will be helpful in making the case for new funds.

bution of funds, as well as assist with feedback and review processes to funders.

ELTOSA members are English- and Portuguese-speaking countries from Africa south of the Equator. Countries in this subcontinent are already connected through social, economic and environmental networks, giving ELTOSA a good starting point. While pan-African political networks are beginning to connect all 53 African countries at government level [and ELTOSA is set to make a significant contribution to the New Plan for Africa's Development (NEPAD)], the networking capacity among research and training institutions across Africa is still limited. It is also important for ELTOSA to stimulate LTER network formation in both West and North Africa.

Global network

There are many benefits for country EON networks and the regional ELTOSA network to affiliate with ILTER (Box 5), which provides guidance through mutual consensus. ILTER currently has 25 country members and several regional members.[9,10] ILTER provides information and advice, and also facilitates coordination of global programmes. It specifically avoids being prescriptive, avoids the design and use of standard templates for fieldwork methods, but does encourage standardization where possible. ILTER emphasizes that projects be designed for local conditions to provide effective indicators. ILTER collaborates closely with other global networks such as GTOS, IBOY, DIVERSITAS, and IGBP. Metadata management is a major focus of ILTER,[11] and it can help countries to develop this capacity. The ILTER-funded ELTOSA workshop and ILTER-metadata course in Mozambique from 21 to 26 July 2002 was a good example of such support.

Conditions for EON in Africa

EON is developing according to African needs and capabilities. Few African countries have national research councils or science and technology ministries mandated to fund or otherwise directly support research institutions, even government research departments operate in conditions of serious financial shortage. Where fully-fledged councils do not exist (this applies to all southern African countries except South Africa), networks tend to be based on associations between institutions.

Furthermore, because there are so few African researchers, collaboration and innovation are crucial to achieving the challenging goals set by the agenda. Government does support research, but this is largely by recognition and endorsement. Government also plays an important role in planning and outsourcing commitments resulting from the ratification of environmental conventions, largely donor-funded. The focus of such funding is on furthering sustainable development directly; the fundamental role of EON lies in monitoring the effects of such support.

The great need to meet basic human requirements, especially food security, is given top priority in Africa and research needs to support this priority. This requirement for relevance and applicability does not diminish the need for African research to be academically sound, based on sound data and scientific analyses. Dependence on natural resources in rural areas is not only a challenge for resource management, but also provides opportunities for resource users to participate directly in research, including recording data and assisting with its interpretation. Participation at the grass-roots level provides learning opportunities and can greatly facilitate the fulfilment of recommendations resulting from research endeavours. Users of natural resources, including some of the poorest people, become directly involved in monitoring and interpretation processes. At the same time, top-level decision-makers need to be informed and become involved. The relatively small government departments and short hierarchies make this goal fairly easy for research institutions to achieve.

Currently human and institutional capacities in environmental research in Africa are still low compared to many other areas of the world. This can be overcome through proactive training programmes that focus on skills for African environmental researchers and environmental awareness for resource managers and decision-makers. While institutional capacity growth will require more concrete support from government and funding agencies, institutions will ultimately become more self-sufficient when more highly skilled research and training staff increase the income-generating capabilities of institutions through professional service provision and large projects.

Opportunities and challenges for EON in southern Africa

There are many opportunities for environmental scientists to work in the field in southern Africa. In the global context, southern Africa represents a unique geographic location: there is a great diversity of habitats and people, including extremes represented in several deserts and rainforests, escarpments and mountains, woodland savannas and inselbergs, perennial and ephemeral rivers, swamps, lagoons and lakes, warm coral reefs and cold upwelling currents, and oceanic islands ranging from tropical to uninhabited sub-antarctic. The region includes four global biodiversity hotspots[12] and

several WWF areas of high conservation priority. Many of the largest river catchments and lakes are shared between countries, providing opportunities for transboundary research programmes. Southern Africa contains many large and famous national parks, game reserves, or other kinds of wilderness areas, harbouring not only fauna and flora, but also entire ecosystems and human settlements. World-class institutions that have been or should be developed into EON centres in southern Africa include institutions at Serengeti, Lake Malawi, Inhaca, Marion Island, Kruger–Gorongosa, Okavango, Cape Floral Kingdom, Maputaland, and Gobabeb (to name a few, without implying that these are the only ones or that these should necessarily all become EON centres).

There are also many opportunities for EON centres to cover diverse habitats across the region in a complementary fashion. There is a need to monitor the same kinds of habitats and parameters at different sites in order to fully understand the spatial dimensions of ecosystems drivers and response mechanisms, or to replicate observations. While EON monitors spatial shifts in biomes, vegetation types and productivity, it will be important to relate these to the dominant issues of climate change, water sources, use and needs, as well as land tenure, land transformation and land use.

Southern Africa has particular water, land and atmospheric conditions that invite study and require monitoring to detect patterns of change. Fresh water is the most important resource of all, and its pathways, sources, requirements, uses, abuses and conservation need to be monitored and studied intensively, as it is fundamental to human and ecosystem health. Current land transformation and land-use changes are opportunities to understand the environmental implications of changing land-use patterns. Climate change will affect both water and land conditions. It is therefore important to monitor continuously climate, as, indeed, all EON sites do. In addition, the particular atmospheric conditions in southern Africa facilitate calibration of large-scale processes, invaluable for predictions at global scale, for example, the origin and pathway of smoke and other atmospheric components traced by SAFARI 2000.[18,19]

Rural people in southern Africa depend on natural resources, and many of these people are poor and in dire need of improved livelihood security. They are subject to the vagaries of an already harsh environment, the shortage of resources and education that they have to cope with renders them even more vulnerable in the face of potentially extreme events caused by climate change. Socio-economic–ecological research is required to address this situation; indeed, participatory monitoring and research in poor rural communities, coupled with awareness and information exchange, are a good way of promoting sustainable development.[13] EON captures the main factors involved in natural resource management, provides objective data on changes, increases the ability to learn from the past, and improves prediction of environmental developments. This should benefit the livelihoods of rural communities through education and improved environmental quality resulting from either mitigation or preparation for chronic change.

The SAEON research framework[14] encapsulates these opportunities and priorities in its tabulation of four stressors — climate change, land transformation, nutrient loading, and episodic events — against four response measures — biodiversity, primary and secondary production, disturbance regimes, and nutrient fluxes. Human welfare and the impact of technological advances should be added as these affect the environment in many different ways. The multi-sectoral approach to research and training (combining socio-economic and biogeophysical aspects) has a good track record in southern Africa and can have heuristic value for researchers from further afield.

Southern Africa has considerable existing institutional infrastructure in environmental fields that can host, facilitate, or become environmental observatories — field stations, long-term programmes by universities, and donor- or government-funded institutions. While the location of these established programmes need not dictate the planning of new EON centres, it is pragmatic to build on existing infrastructure and expertise. Considering current financial conditions, and given the very many environmental issues that require study, it should be a priority to base EON networks on local institutions with good track records.

The main challenges facing EON in southern Africa are of the organizational kind. It is especially important to maintain local leadership of foreign-funded, long-term environmental research programmes on the subcontinent. Potential contributions by foreign-funded programmes are appreciated, but these programmes are sometimes insensitive towards local traditions and sensitivities, and intellectual property rights and systems, placing additional demands on the already limited capacities of southern African countries.

In summary, southern Africa has many challenging environmental subjects and high-quality environmental institutions, providing opportunities for EON to make a significant impact on local environmental policies, and to develop the capacity to conduct research of good quality and quantity. EON also provides a local framework to facilitate and coordinate international research collaboration in the field.

Continuity

EON centres require continuity to be effective in providing long-term data with reflective and predictive capabilities. This requires security of tenure and commitment to keep monitoring programmes going and to keep them relevant. To ensure success of EON, yesterday's and today's data and information should be available and understood in future. Skilled practitioners must be recruited to ensure the succession and growth of EON in southern Africa. EON requires several levels of networking to continue to be operational and adaptive. Improved prospects of funding for research and training in southern Africa will be required for field stations to continue collecting, archiving, sharing, and interpreting data and disseminating information.

Data archiving and sharing

EON banks on data. EON centres require physical and technical facilities and expertise to give data a future. Good data management mechanisms need to ensure the availability and correct interpretation of data beyond the professional life-span of individual EON practitioners. For data to be useful for analyses and interpretation, the location and method of collection must be known and the data must be accessible, as documented in metadata. EON centres should archive original field data books and manage electronic data and metadata. LTER sites elsewhere in the world have extensive experience and software for these functions,[11] which can either be adopted or guide local adaptation. Mechanisms must be in place to facilitate access and understanding by persons and projects other than those collecting data, so that data can serve several purposes for different users now and in future (for example, comparison over space and time). Data-sharing policies must be in place to guide access by multiple users (see Box 6).

Box 6. Example of benefit of data sharing, SAFARI 2000.

SAFARI 2000's data policy is based on open data sharing, cooperation, and synergism.[20]

All SAFARI 2000 data are made available to all SAFARI 2000 participants through open online storage or submission to the Regional Data Centre. Access to some of the data at the Regional Data Centre will be limited to registered SAFARI 2000 participants for a period of 18 months after completion of the project. SAFARI 2000 data are placed in the public domain, except for commercially restricted or copyrighted data. Originators may specify appropriate restrictions to data sets deposited at the Regional Data Centre. Any scientist wishing to participate and benefit from SAFARI 2000 must register with the Regional Data Centre and be approved as a participant by the Science Steering Committee. Registration requires an explicit declaration by the registrant to abide by the SAFARI 2000 Data Policy.

After registration as a SAFARI 2000 participant, investigators using data generated by other investigators should request permission from the data originator and offer co-authorship. Given that collaboration signifies the spirit of SAFARI 2000, joint publications between in-region and out-of-region scientists are especially encouraged.

SAFARI 2000 participants participate actively in data sharing. First, they inform SAFARI 2000 of their primary and derived data holdings through the registration of *metadata* as soon as possible after collecting or procuring a data set. Second, when primary data reduction and quality checking procedures are complete, or secondary data products are stabilized, participants make such data sets available to other participants. The meta-database facilitates the rapid sharing of information between participants by assembling descriptive summaries of all research activities in a searchable index. Such information allows for the identification of potential gaps and overlaps in the SAFARI 2000 data archive and may aid in the avoidance of redundant field efforts. The metadata entries can be made publicly searchable, even though the data sets themselves may be copyright restricted or restricted to SAFARI 2000 participants.

Training

Technical and professional staff is required to operate EON centres. Although there are some potential EON centres in southern Africa, several require further personnel development to reach the capacity needed to become fully-fledged EON centres. The staff of an EON centre would typically consist of a director, resident researcher(s) and students, data manager, field and data assistants, and educators. A regional pool of future practitioners needs to be developed on an ongoing basis. Training courses and programmes of in-service training should be developed and held at formal training institutions (universities, polytechnicons, colleges) and at existing EON centres, and can involve experienced foreign practitioners (for example, through ILTER). Various training initiatives in the region should develop partnerships and coordinate with each other. Training should focus on field techniques, data management, analyses and interpretation, and application (see Box 7 for some suggestions on course contents). Such training should be directed at postgraduate students, as well as existing EON centre staff. Multidisciplinary courses would further the broad experience required by EON. Principal investigators will in future continue to be recruited from master's or doctoral graduates, some of whom may have done their thesis work at EON centres as part of programmes coordinated expressly for that purpose. The success of EON programmes should help to provide job opportunities and to attract good students, but recruitment can also be improved through bursaries, good publicity through environmental education, and the professional advantages of gaining multidisciplinary experience through EON.

Box 7. Some suggestions for EON training.

- **Training approaches**
  - **A**: courses focusing on EON-related knowledge and skills.
  - **B**: in-service training and internships.
- **EON field technicians:** the A–Z of field data, climate, NPP, plant growth, tree and shrub phenology, animal abundance, population structure, community composition, diversity indices, water availability, soil condition, geomorphological processes, atmospheric composition, experiments, planning new data sets, instruments and their care.
- **EON data management:** data book management, metadata management, data computerization, quality assessment and control, electronic data archiving, data sharing policy, internet publication management, managing computer hardware and software upgrades.
- **Environmental Indicators:** what to indicate, choosing good indicators, monitoring over time and space, determining thresholds, detecting change of state, spatial data analyses, trend detection over time, data display, publications, information dissemination.
- **EON applications for natural resource management:** introduction to multiple disciplines, linking science and local communities, techniques of information exchange, identifying limiting resources, monitoring natural resource use and availability, participatory research, information dissemination.

Network coordination

The basic building blocks of EON are EON centres, local networks of sites, researchers and information technology. However, centres are strongly dependent on funding for actual activities and cannot secure the pathways for obtaining funds themselves; networks at country and regional levels are required to achieve this and to guide the overall direction. Country networks define the characteristics of EON in their country and have a powerful influence on the ability of EON centres to operate in the long term. Members can affect the character of country networks, but the regional and global networks can also affect the country character. As countries, rather than institutions, are the smallest units of EON, this is the first node that needs to be considered. For small countries, it may not be affordable to have separate EON country offices, and it would be more cost-effective to conduct these functions through EON centres, as is the case in Namibia. ELTOSA would ultimately benefit from a regional network office, either residing at an EON centre or country office in the region, or at a larger office, such as SADC-ELMS (Environment and Land Management Sector, or at its successor in the Food, Agriculture and Natural Resources Sector). EON practitioners, however, must remain key players in the development of ELTOSA for it to be effective. In other words, funders should first be guided through the current bottom-up discussions in order to strengthen EON in the region, although some funding for regional networking will also be required.

Funding

Based on actual experience, to operate the programmes of an EON centre such as Gobabeb, Inhaca, Okavango or Serengeti, requires in the order of US$100 000 per annum. This estimate is substantiated by experience in several countries in southern Africa and also in other continents. This amount is sufficient for small programmes with a small staff (see above), field transport, equipment maintenance, data management, and commu-

nication for the EON programme, and does not cover major new acquisitions for establishing EON programmes, or establishing and maintaining infrastructure of the field station itself (which requires many times this amount). Satellite sites operate with less funding, but these sites do incur additional managerial costs to their parent institutions; funding at such sites depends on many factors, but US$25 000 would be a reasonable estimate. Funding is also required for country networking activities, which includes communication, transport, and attendance or convening of meetings. Given the chronic shortage of funding for research in southern Africa, funding can in some cases come through training programmes linked to EON. Also, much of the funding needs to come from international sources. Active collaboration with foreign scientists can help to sustain EON projects. Furthermore, it is possible to obtain donor funding based on the important function EON has for improving the global knowledge base, as well as the critical ability to evaluate and predict factors affecting sustainable development. Strategic planning is required by ELTOSA and its member countries to develop a core of EON centres with sufficient funding.

EON for Africa

The Environmental Observatories Network represents a new approach in Africa, but it incorporates and integrates a legacy of environmental programmes and previous initiatives in this direction.[15] In its field, EON is currently the Renaissance in Africa.[16] It is based on improving the theoretical understanding of the environment and simultaneously improving the application of this knowledge for sustainable development, making best use of two powerful scientific approaches — basic and applied research. This greatly promotes informed policy-making and wise environmental management.

Although ELTOSA is still embryonic, and most member countries do not yet have formal networks (Table 1),[17] there is already sufficient momentum among all ELTOSA members to proceed with a regional network that will facilitate the further development of EON centres and country networks. Fundamental challenges at the outset are obtaining commitment, political will, and funding from governments and regional bodies such as SADC to promote EON as an environmental programme that represents a collective of institutions that will provide invaluable information for policy decisions. For ELTOSA to achieve this, it should form a core group that develops strategies and promotes country-specific and regionally relevant programmes through field stations with current and potential environmental monitoring sites, with the capacity to archive data and support training and research. This core group will require dedicated resources to carry out these functions and to guide prospective programme supporters in the region even if the professional members of the core team are themselves EON practitioners based at individual field stations in the area.

ELTOSA's basic role is to facilitate the ability of countries and field stations to develop EON capacity in a coordinated and complementary fashion and to focus on environmental indicators required for identifying and predicting critical changes, and for future planning and review of sustainable development.

Networks — local, national, regional, and global — are the best way forward, as they promote coordination of resources and infrastructure, greatly facilitate synergy, and maximize the legacy of data. At the beginning of the 21st century, EON puts southern African environmental research on a higher platform.

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