Chapter 14
Earth Stewardship, Socioecosystems, the Need for a Transdisciplinary Approach and the Role of the International Long Term Ecological Research Network (ILTER)

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Abstract The way we see ourselves and understand the world we live in guides and determines the types of solutions we are designing and implementing to deal with our global change problems. System thinking is helping us to recognize humanity as complex, self-organized, multi-level, and highly integrated socio-bio-physical entities that we refer to as socioecosystems. This new ontological paradigm requires new epistemological tools, and transdisciplinary research is inducing changes in different aspects of our scientific endeavor, including: the philosophical approach we use to observe our world; the level of commitment we put in our scientific work; the extent and scope we envision in our research goals; the geographical scale and context in which we focus our case-studies; the type of collaboration we engage in with other scientists; and the institutional arrangements we construct to accomplish our research efforts. The International Long Term Ecological Research Network (ILTER) includes national-level networks of scientists engaged and committed to conducting long-term and site-based ecological and socio-economic research and monitoring, with a strong interest in capacity building. ILTER members have expertise in the collection, management, and analysis of long-term environmental data and, together, they are responsible for creating and maintaining a large number of unique long-term datasets. ILTER has been a natural partner for global initiatives dealing with environmental issues, and many members of its community have been participating in these international programs. We should not underestimate the urgency, nor the level of commitment, required to foster worldwide socioecosystem research with a transdisciplinary approach, which are essential for the success of the sustainable Earth Stewardship initiative.

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14.1 Introduction

The extent of our current environmental crises has reached planetary proportions, clearly shown in a variety of challenges collectively known as "global change" (Vitousek 1992; Steffen et al. 2004). It includes not only climate change, loss of biodiversity, soil erosion of arable land, and stratospheric ozone depletion, but other problems less mentioned in the mass media, but equally important, such as ocean acidification and disruption of the global N and P biogeochemical cycling (Rockström et al. 2010). All of these are interconnected in various ways. Among these earth-scale environmental problems, land use change particularly is relevant since it is not only the main cause of biodiversity loss, it also embodies the transformation of natural ecosystems and thus the processes eroding earth's life support system (Ehrlich and Ehrlich 1991).

Society's development highly depends on the benefits it obtains from nature (Daily et al. 1997). In order to get these ecological services, humans interact and transform their local ecosystems. These local transformations became regional with human expansion currently, and have reached global proportions (Kates and Paris 2003). Sustainability has been proposed as the goal of societal development in response to this severe environmental crisis (ICSU 2010; Spangenberg 2011). Global-level problems require global-level solutions, an idea that is embedded in the Earth Stewardship concept (Chapin et al. 2011). As Power and Chapin (2009) state:

> Planetary stewardship requires that decision makers and stakeholders be well-informed about how global change is likely to affect households, resources, livelihoods, and quality of life. They must also learn how local actions and reactions to change could feed back to influence the trajectory of planetary change. To provide this information, ecologists must redouble their efforts to understand and forecast ecosystem changes across multiple scales.

An important initiative within the global research arena is the International Long Term Ecological Research Network, known by its acronym ILTER (www.ilternet.com). Since its creation, ILTER has grown at an average rate of two countries and 30 sites per year, reaching now 37 national networks and embracing nearly 600 academic groups anchored in specific sites over the five continents and committed to conducting scientific research spanning decades (Gosz 1996; Parr 2013).

In the following lines we will describe the type of changes that are already occurring in the scientific sector to deal with this global-scale environmental crisis. Also we will identify changes that we need to foster and speed up in order to advance towards an earth-level stewardship process, and will lift up the role of ILTER in this endeavor.

14.2 The Complex Nature of Socioecosystem: A New Ontological Paradigm

Global change not only refers to changes at global scales, but changes associated with human activities. The extent of the human impact on earth has been so deep that some authors are calling the current times the Anthropocene as a new geologic era (Crutzen and Stoermer 2000). We know that humans are not the only organisms capable of transforming their environment at global scales. The appearance of photosynthetic cyanobacteria transformed the oxygen-free atmosphere into an oxidizing one, which dramatically changed the composition of life forms on Earth billions of years ago. However, humans are the only species that has been conscious about its global effect on the environment, and with technological means to do it in a much faster manner.

Being conscious and able to generate technology is generating ecological drawbacks, but these human characteristics are also our best tools to deal with those environmental problems. In fact, most organisms do not think about their environmental problems. They just react to them using their natural arsenal encoded in their genes, and, through a Darwinian evolutionary process, the best momentary solutions are selected in each generation and transmitted to their descendants. Humans, instead, have the capability of thinking about their environmental problems. Through knowledge generation and technological development humans make a conscious attempt to deal with those challenges, and this is what Earth Stewardship is all about. Our best solutions are incorporated into our cultural legacy and transmitted not only from one generation to the following, but also to other humans of the same generation in other places in a more horizontal fashion. As Callicott (2007) has pointed out, this conscious and horizontal evolution in humans, somewhat of a Lamarckian type, is many times faster than Darwinian evolution, giving to humans a peculiar character that differentiates us from the rest of living organisms. This more conscious evolution of humans highly depends on the way we see and understand the world, and guides and determines the types of solutions we design and implement to deal with our environmental problems. Therefore, the way we see the world is critical for the solution of our environmental problems.

System thinking has produced a profound change in the way we appreciate and understand our world (Ackoff 1999; ICSU 2010). The ecosystem concept brought fresh air to our perception and comprehension of life phenomena at levels higher than individual species (Golley 1993; Maass and Martínez-Yrízar 1990; Kaya et al. 1999). What remains controversial, though, is the conceptual place of humans in nature.

Physicists state that life is just another type of organized star dust. Although it is true that all living organisms are made of atoms following the laws of nature, biologists have show that life, in comparison to most entities in the universe, has the particularity of being able to store information in genes. This ability of store and reproduce genetically encoded information, generates new and different entities, built from already existing ones, without the need to start from zero every time it deteriorates as a result of interaction with other components of the system or just thermodynamic decay. This biological evolution is a much faster process than physical-chemical evolution.

Likewise, some biologists believe that humans can be conceptualized as just another type of biological species. Although it is also true that humans are biological entities that store, reproduce, and transfer genetic information, they also store and encode information in the form of a symbolic language with a highly complex syntactic structure (Maass 2012). This ability of humans to store and share cultural information allows them to generate knowledge and develop technology in a progressive way without precedence in the history of life on our planet (Ehrlich 2002).

In the same way as living nature is a biological-physical-chemical phenomenon, human nature is a socio-cultural-biological-physical-chemical phenomenon (Maass 2012). And in the same way living organisms cannot exist without their physical-chemical matrix, humans cannot live without their ecosystem matrix (O'Neill 2001). From a system perspective an ecosystem is the result of living and non-living entities interacting in time and space at different hierarchical scales (Odum 1953, 1969). Ecosystems are as small as a drop of water (or even smaller as a group of bacteria interacting in a corner of a cell wall), or as large as the entire planet. From the same system perspective, a **socioecosystem** is the result of humans and ecosystems interacting in time and space at different hierarchical scales. Socioecosystems are as small as a farmer with his family interacting with his agricultural piece of land, and as large as the entire planet (and beyond, if we consider the satellites, the International Space Station, and other human made space crafts visiting the Moon, Mars, and other planets).

We see humans as embedded in socioecosystems, recognizing their sociocultural-biological-physical nature. The recognition of this complex, multi-level and highly integrated socio-bio-physical entities, require new epistemological frameworks to properly study and deal with them.

14.3 The Epistemological Paradigm of Transdisciplinary Research: A Must for the Study of Socioecosystems Required for an Earth Stewardship Initiative

Scientific research has evolved in its attempt to deal with this new ontological paradigm, which implies the study of these highly coupled socio-ecological systems, or "socioecosystems", as we like to call them. Changes occurred as early as the middle of the last century when the systems approach appeared in the scientific arena (Bertalanffy 1950). However, these changes have gained important momentum in the last 20 years. This shift in the way we do science has happened in different aspects of our scientific endeavor, including: the philosophical approach we use to observe our world; the level of commitment we put in our scientific work; the extent and scope we envision in our research goals; the geographical scale and context in which we focus our case-studies; the type of collaboration we engage in with other

Table 14.1 Aspects in the way science is changing ("*from…*" to "*a more*…") in order to deal with **socioecosystem** research and in its quest for earth stewardship towards sustainability

CURRENT PARADIGM	→	+ NEW TRANSDISCIPLINARY PARADIGM
Change in philosophical approach		
Reductionist	→	+ Holistic
Analysis	→	+ Synthesis
Rational (Cartesian)	→	+ Empirical (phenomenology)
Change in commitment		
Current generation concern	→	+ Future generation concern
Curiosity driven	→	+ Result based research
Understanding	→	+ Managing ecosystems
Change in scope		
Disciplinary	→	+ Interdisciplinary
Process oriented	→	+ System oriented
Short term	→	+ Long term
Change in geographical scale of focus		
Local	→	+ Global
National	→	+ International
North-north	→	+ North-south
Indoors	→	+ Outdoors
Change in type of collaboration		
Competition	→	+ Cooperation
Individual	→	+ Collective
Teamwork	→	+ Network
Disciplinary	→	+ Transdisciplinary
Change in institutional arrangements		
Peer review	→	+ Society review
Vertical governance	→	+ Horizontal
Institute	→	+ Meta-institute

scientists; and the institutional arrangements we develop to accomplish our research efforts (Table 14.1). We will describe briefly all these changes that constitute a whole new epistemological paradigm of science for the study of socioecosystems.

14.3.1 Philosophical Approach

System thinking is a relatively new philosophical approach to observe nature. This approach has been able to comprehend the hierarchical character of nature, show the limitations of the analytical approach to studying its complexity, and demonstrates the importance of stepping back to ponder the whole and to identify the emerging properties of that whole, which is "more than the sum of its parts". With a more phenomenological approach, we can recognize a world in which reality expresses itself, in contrast to a strict Cartesian view, which starts from doubting the existence of reality itself. As Sokolowski (2012) explains:

> Phenomenology is the study of human experience and of the ways things present themselves to us in and through such experience. (…) Phenomenology is a significant philosophical movement because it deals so well with the problem of appearances. (…) [I] n its classical form, [it] insists that parts are only understood against the background of appropriate wholes, that manifolds of appearance harbor identities, and that absences make no sense except as played off against the presences that can be achieved through them.

Moreover, phenomenology, since its inception by Husserl (1913), has opened what can be named a correlational view, in which any kind of reality or "world" (a "noema" in phenomenological terms) can only be understood in its mutual relationship with subjective lived processes ("noesis" in phenomenological terms) in which it is given or experienced. Thus, humans can only be understood against the proper (socioeco)system in which they live, and correlatively, this socioecosystem should be understood as a correlate of human life and intentions (Hopkins 2010).

14.3.2 Commitment

Sustainability originally was stated as a trans-generational issue, i.e., *"how can we develop, as a society, without putting at risk the development of future generations?"* Therefore sustainability science has incorporated a commitment to future generations. However, on the face of the magnitude of the problem and the urgency of scientists to supply the solutions society is demanding to deal with global change, science also is moving from just a "curiosity driven approach", to a more "problem oriented" and a more "result based" research. Still driven by curiosity; however, it recognizes that curiosity alone is not enough to understand how the world works. It is also necessary to promote the incorporation of this understanding into public policy (Vaughan et al. 2007). And furthermore, it is important for policies we design to be implementable and functional. This requires evaluating whether or not the socioecosystem is really going in the direction it was expected and that damage to the environmental life support system is being avoided. Frequently this can be done following an "adaptive management" approach, when suitable options are available (Holling 1978), but there are cases when it is not possible given that there are no management options available that prevent serious damage to the environmental life support system.

14.3.3 Scope

In our efforts to study and understand how socioecosystems are structured and work, the extent and scope of our research approach has increased. Within the reductionist approach, scientists interested in functional aspects tend to specialize on particular process, and by studying the same processes under different settings or contexts, a better understanding of the process is achieved. Within a system approach, the strategy shifts to a focus on a particular system and examines different processes within it, developing an understanding of the whole. Under this system approach, there is a need for multi and interdisciplinary efforts in which several disciplines interact to understand the complexity of socioecosystems. In the same way as "problem oriented" science does not kill "curiosity driven" science, interdisciplinary approaches do not replace disciplinary efforts. The difference between *multi*-disciplinary research and *inter*-disciplinary research is the level of interactions among the disciplinary efforts. In the latter, the interdisciplinary group identifies and defines the problems, and the level of interaction among disciplines demands common conceptual frameworks and stronger communication skills (García 1994).

14.3.4 Scale of Focus

A major shift in science as a result of incorporating the system approach, is the recognition of needing multiple level of analysis to cope with the hierarchical nature of systems. The study of socioecosystems is not the exception. The need for long-term research has been identified since the last century, and there are very good examples of studies conducted for decades long before formal research programs were established to foster long-term endeavors (Swank and Crossley 1988). As we mentioned, and we will further discuss below, the establishment of the United States LTER network in the 1980s (Gosz et al. 2010) and the International LTER network 10 years later (Gosz 1996), have been important advances to this change of research scope in science (Parr 2013). Socioecosystems research not only requires a shift in time scale, but also implies a shift in spatial scales. Socio-ecological processes take place in multiple spatial scales and the shift from strictly local research to a more regional and global scope is crucial for an earth stewardship undertaking. Cultural diversity in a particular region is aligned with the local biodiversity (Toledo 1995, 2001). Therefore, the great ecosystem diversity found on earth has produced a large diversity of socioecosystems, as well as an enormous variation in the ways humans see, interact with, and transform their natural environment. It is very important to recognize and consider all these variations in human expressions to truly understand their impact in the earth socioecosystem. However, it is essential to recognize the deep contrast in the amount of economic resources allocated to science between north and south. In order to overcome these gaps in multiescalar research and geographical representativeness, research has become more international. However a stronger effort should be placed on moving from dominant north-north collaboration, to more north–south and south-south collaborations.

14.3.5 Collaboration

The complexity of socioecosystems is forcing scientist to engage in collaborative work. As we suggested above, interdisciplinary research does not mean converting ourselves into generalists. What it means is the need of collaboration with scientists from other disciplines (social scientists and natural scientists working together on a common problem). And because of the regional and global scope, these collective efforts have transcended our traditional local disciplinary institutions, inducing the creation of networks of teams at different scales. Even more, the socioecosystem paradigm is stimulating the development of a truly transdisciplinary approach, in which the intelligence behind the understanding of our world cannot come only from the scientific research (Spangenberg 2011), but also from knowledge acquired in a more empirical way, sometimes over hundreds of generations (Toledo 1995; Rozzi et al. 2008; Rozzi 2010). Following this new approach, research is conducted in collaboration with other sectors of society directly involved in the particular problem that is the object of study. Research tools and approaches like "co-design", "participatory monitoring" and "citizen science" have been developed to incorporate local and traditional knowledge into the research process (Burgos et al. 2013).

14.3.6 Institutional Arrangements

All of the above are pressuring scientific institutions interested in transdisciplinary research to find new and creative arrangements to accomplish the task. A difficult aspect is how research performance should be evaluated. Peer review is very important to assure the rigor of the research, but it is not enough if we accept the commitment to cross the line from "curiosity driven" research all the way to "solution base" research. Under these new conditions, other sector of society involved in the enquiry subject should participate in the evaluation process to assure the *pertinence of the study*, since they are experts in the matter (Spangenberg 2011). Another complicated aspect of collaborative research, in which many groups and institutions are involved, are "author's rights" and "governance" issues. Sharing data protocols and multi-authored documents are becoming important aspects within socioecosystem research. Polycentric governance approach in which multiple governing bodies interact to make and enforce rules within a specific arena or location, have been suggested to deal with this multi-level and nested institutions (Simonsen et al. 2014). Most academic institutions are big and old, with enormous inertia. It has been very difficult to move them toward new administrative arrangements. One way to overcome the need for interaction between scientists of different disciplines and sectors without dramatically changing the current administrative arrangement has been the creation of meta-institutes. They consist in a particular arrangement, in which the associated researchers, belonging to different institutions and thematically and geographically separated, collaborate on a regular basis with the help of new information technologies and communication protocols.

14.4 The Role of ILTER in the Earth Stewardship Initiative

Moving from the current dominant disciplinary science to a more interdisciplinary approach is a requirement for the study of global change and its consequences for society. Seeking ways to deal with this challenge has been present in the admonitions and efforts of several international research organizations endeavoring to effectively prevent environmental deterioration on Earth. Such are the cases of the International Geosphere and Biosphere Program (IGBP) and its social counterpart, the International Human Dimensions of Global Environmental Change (IHDP) Program. They have documented the magnitude of the problem, the urgency of taking actions, and the need of long-term research and monitoring to understand the causes and consequences of global change. Other initiatives focused on more specific aspects such as the Millennium Ecosystem Assessment (MA) launched to evaluate the state of ecosystem services at regional and global scales, and their importance for the human wellbeing. This initiative not only documented the fragility of our life support system, but also the severity of knowledge fragmentation and the difficulties of the world scientific system to conduct interdisciplinary research (Norgaard 2008). As we will describe next, the International Long Term Ecological Research Network (ILTER) is also engage in this effort to conduct socioecosystem research for a sustainable earth stewardship (Maass and Equihua 2014).

14.4.1 Vision and Mission

ILTER envisions a world in which science helps to prevent and to solve environmental and socio-ecological problems. ILTER contributes to solving international ecological and socio-economic problems through question and problem-driven research, with a unique ability to design collaborative, site-based projects, compare data from a global network of sites, and detect global trends (www.ilternet.edu). Most ILTER members are national or regional networks of scientists engaged in long-term, site-based ecological research and monitoring. They have expertise in the collection, management, and analysis of long-term environmental data. Together they are responsible for creating and maintaining a large number of unique long-term datasets (Parr 2013). ILTER is a natural partner to global initiatives, and many members of its community have been participating in these international programs.

14.4.2 From LTER to LTSER

There has been a natural evolution of scientific groups of ecologists interested in long-term research to move from strictly ecological research (LTER) to a more socio-ecological research (LTSER; Fig. 14.1). One of the main objectives of LTER, 30 years ago, was to fill up the knowledge gap created by the established scientific

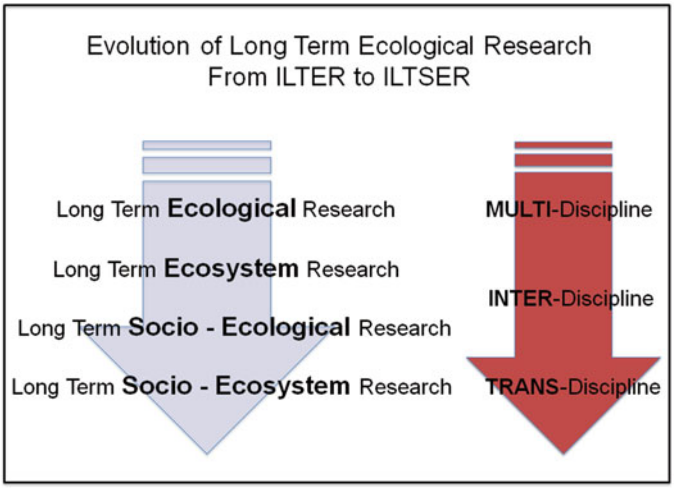

Fig. 14.1 Evolution, during the last 30 years, of the focus and epistemic tools of long-term research, within the international scientific community interested in global environmental problems

funding system which promoted either small scale studies (e.g. a few species in a few m^2 for a 1–2 years) or large scale studies but conducted in short time (e.g. 2–3 years study of the ice or sediment cores thousands of year old). Initially, most LTER groups were working on natural reserves, looking to extend their understanding of ecological processes for longer periods of time (decades) and at larger scales (hectares and km^2) in a "secure" environment. The ecosystem approach followed naturally when scientists from different disciplines started to work on the same place for many years (site based research concept), accumulating the necessary knowledge to deal with the complexity of ecological systems. The socio-ecological research came later in order to understand the human drivers behind the transformation of natural ecosystems and with an interest in supplying scientific information for proper ecosystem management. However, the need for a transdisciplinary research has emerged with the new socioecosystem paradigm, in which humans are not just another species taking advantage of ecosystem services, but a complex human-biological-physical entity that evolves into a tight integration of biophysical and cultural components, living and non-living, at different scales. *Socioecosystem research* requires a shift from viewing humans as external drivers of natural systems to that of agents acting within socio-ecological systems (Grimm et al. 2000; Redman et al. 2004; Haberl et al. 2006). On these grounds, a new initiative within the LTER community has been launched as a strategic research initiative called "Integrative Science for Society and the Environment" (ISSE), proposed to elevate environmental science to a new level of integration, collaboration, and synthesis necessary for addressing current and emerging environmental research challenges (Collins et al. 2007).

14.4.3 The Importance of Site-Based Research

Most ILTER members are country-level networks of academic groups committed to maintain their research efforts on a particular site during many years. This “site-based research” character of ILTER is one of its most important assets. It not only allows for the accumulation of knowledge through time, as was stated before, but also is the only way to develop the necessary trust between the academic community and the local stakeholders that require a transdisciplinary research approach. Capacity building is another advantage of site-based research since working with complex systems requires the recognition of uncertainty and, therefore, the need for a strong and long-lasting learning process. Teaching and tutoring students in socioecosystem research requires identifying a particular aspect to focus during a short time, without loosing the long-term and large-scale context of their thesis research theme. This is crucial and is easier to accomplish within a long-term and site-based research group.

14.4.4 Partnerships Approach

ILTER is not alone in this quest for global change, socio-ecological, and earth stewardship research. Its international scope, its flexible research agenda, and its commitment for long-term and site-based research, makes ILTER a natural partner for many global initiatives (Parr 2013). As stated above, members of ILTER actively participate in local, national, regional, and international initiatives. One of the main objectives at ILTER meetings is to engage in collaborative research activities and to foster partnerships with international players such as the Group on Earth Observations Biodiversity Observation Network (GEO BON); the Global Land Project (GLP); UNESCO International Hydrological Program (UNESCO IHP); etc. We are currently designing a multi-site level project to participate in the new Program for Ecosystem Change and Society (PECS-ICSU) which has a strong socioecosystem and transdisciplinary approach (Carpenter et al. 2012).

14.4.5 ILTER Heterogeneity and North–South Inequalities

ILTER comprises nearly 600 research sites located in a wide array of ecosystems. Of course not all ILTER sites have the same experience and capabilities. Of the ILTER groups that do ecosystem research, many are involved in socio-ecologic studies while a minority conducts socioecosystem and transdisciplinary research. However the interest among the groups to do transdisciplinary research has increased in recent years. As we said before, we are currently building a collaborative strategy for the PECS Program, which certainly will stimulate further socioecosystem and transdisciplinary research in the network. Forest biome dominates ILTER sites (40 % of the sites), but aquatic sites are also well represented: fresh water (25 %), costal (7 %) and marine sites (5 %). There are also mountain sites (10 %), deserts (6 %), and grasslands (6 %). We even have a few urban LTER sites (less than 2 %). On top of this ecosystems diversity, there are also diverse socio-economic conditions, bringing important heterogeneity of socioecosystems types and arrangements, which makes ILTER a very profitable platform for earth stewardship and sustainability research. However, it is also important to recognize that ILTER does not differ from other International Programs in which there is an important unbalance of North/South research effort. Rozzi et al. (2012) have pointed out the Northern hemispheric research dominance, and highlighted a particularly notorious gap of ILTER research sites in the temperate and sub-Antarctic regions of South America (between 40° and 60° south). In fact, only 3 % of the current ILTER's research sites, listed on its webpage, are located on the southern hemisphere and only 8 % of the sites belong to the inter-tropical zone (between 23°N and 23°S). A similar gap has been detected in the Northern Africa and Middle East region, as well as in the North of Asia. It does not necessarily mean that no one is working in these regions, but the fact is that there are very few groups associated with ILTER there. However, ILTER is taking actions to revert this situation, fostering the participation of new partners though a new type of membership called "associated sites". Under this admission category, a research group from a country without a formal ILTER national-level network will be able to join ILTER through an affiliation process with an already accepted member. The associated sites will have the commitment to participate in building their national-level network. With this mechanism, ILTER is expecting to incorporate good research groups, which are already making individual efforts to conduct LTER research in developing countries.

14.4.6 The Bottom Up Approach

In very large organizations like ILTER, with a highly heterogeneous membership, it is difficult to coordinate research activities in which all members participate. Our approach has been to standardize methods (to facilitate data sharing and comparison), foster diversity (to increase collective intelligence), identify common interest (to induce collaboration), facilitate the communication between groups (to generate opportunities), and allow for self-organization of activities through what we call "bottom up" initiatives. By scooping from the bottom, ILTER not only increase the possibility of getting new and exciting ideas, but also is facilitating the integration process within the network. Since "bottom up" initiatives can come from any network group, the member's participation is encouraged, the commitment is self-imposed, the sense of community is amplified, and the effort of running the network is distributed. "Bottom up" initiatives are very good for dealing with local limitations and identifying good opportunities for collaboration. They may also promote redundancy and bring stability to the network (Csermely 2006; Ahn et al. 2010).

14.5 Some Precisions About Socioecosystem Research

As we have asserted here, socioecosystem research for a sustainable earth stewardship urges significant changes in the way we do science. We should not underestimate its urgency, nor the level of commitment required. Thus, it is important to make some comments about the speed and magnitude of these changes, because there is a tendency to overstate the roll of scientists, increasing the already heavy load on the research community. Firstly, it is important to point out that we recognize that what it is needed to stroll along the sustainability path is a socio-economic *development model* blended in a socioecosystems framework (integral, nested multi-level, non-linear, complex, self-organized, human-biological-physical system). However, what we have been discussing here is just the need for a change to a more transdisciplinary scientific *research model* that will feed into this new approach for earth stewardship. There is an important difference between a *transversal approach* (working with different sectors of society) and a *transdisciplinary approach (*working with different sources of knowledge). The former is a *development tool*; the latter is an *epistemological stance*. We need both. However, scientists do not necessarily need to become producers, policy makers, business people or developers but, in order to conduct research in a truly transdisciplinary fashion, they have to participate in real development situations, as another stakeholder embedded in the collective. Participating in transversal work is the only way to learn about this "other knowledge" requirement in real transdisciplinary research. A good analogy is a university hospital in which scientific research on health is conducted with real patients. However, rather than working as a health service unit for the local community, the university hospital selects particular cases for treatment based on their research interests. Transdisciplinary research is conducted in real case studies, and that is why "site based research" is so important.

Another aspect that requires awareness by scientists interested in socioecosystem research for a sustainable earth stewardship is the recognition of our working under conditions of high uncertainty. We are not only confronted with highly complex systems, but the climate change scenario is increasing even more this uncertainty. Adaptive management is a conceptual tool developed to deal with this uncertainty, provided that suitable management options are at hand and reversibility of very dangerous environmental impacts is possible (Holling 1978). We no longer expect to have a complete understanding of the process for making management decisions. Rather, managers decide based on the best available knowledge, but keep a monitoring program to feed back into their decision-making process. If the system is performing as expected, the decision is maintained; if on the contrary it is not, the decision is tuned or changed accordingly. Scientists are not managers, but they should also recognize their limitations as knowledge providers under these highly uncertain conditions. An *adaptive learning* approach has to be followed, but the only way to do it, is working on real situations where *adaptive management* is conducted.

The multi-level character of the socioecosystems is another heavy load for scientists interested in sustainability research for earth stewardship. We not only need to incorporate the social, biological, and physical aspects in our research, but also, to consider the multiple spatial-temporal strata in which socioecosystems operates. How to tackle such a complex system? The environmentalist slogan "think globally and act locally", conveying some systems thinking perspective, may help. However, between the global and local tier, there are plenty of other levels to consider (municipal, state, national, regional, continental, hemispheric, etc.). In order to deal with such complexity, it is recommended to choose one particular tier to focus our research, and concentrate on the interactions between that particular level of interest with the immediate upper (or supra) and lower (or sub) ranking. One can be aware of further upper and lower layers (beyond the immediate supra and sub ranks), but only as observers, reducing the level of observations as the scales get farther away from the focus of interest. In this way, one will be able to understand the immediate context's factors, which are inducing the behavior of our socioecosystem (at the focus of interest) and also the local and particular conditions that our chosen scale of focus is directly influencing, without loosing the whole perspective. Sometimes, it is also necessary consider a particular levels of the hierarchy that most strongly influence your level of interest. For example, the critical level above the national level might be global (rather than regional) because of globalization of trade and climate.

Finally, we cannot leave this discussion without talking about the role of technology. Although it is true that in many respects technology brought us into an environmental conflict of global proportions, there is no way we can deal with the problem and walk a sustainable earth stewardship course without the aid of technology. However, technological development should also be aligned with this socioecosystem paradigm. Human nature is technological because it is the blend of knowledge and conscious intent prompted by environmental interactions, and thus it is the way humans live with their surroundings. Our environmental awareness should encourage a technology design shift conscious that humans do need their ecosystems, not only because they depend on them, but truly because with them we constitute socioecosystems. The idea of Jordan (1998) encouraging "working with nature" suggests that an understanding of the many interactions and processes that occur in nature, should enlighten us to embed them in our technological design. We need to align our technological quest with our socioecosystem character.

Rozzi (2012) has pointed out that a particular *habitat* induces in living things *habits* that eventually match to astonishing perfection that particular *habitat*. It is a fact of life. Species appear, adapt, and extinguish following this interactive rational, and if something changes, ecosystems self-organize following through this dynamic systemic imperative. With the help of technology we have created artificial habitats, giving us the impression that we do not need our original environment any more. And we have developed habits that obviously do not match with our original habitat. With the advancement of technology we have come to think that we are separated from the rest of the species, and we dream of traveling in an aseptic spacecraft (just humans and machines) conquering other worlds: it is a false impression (Margulis 1998). Even when we have visited the moon several times and even set technological foot in

Mars, currently we are not contemplating the idea of establishing a colony there, because there are no ecosystems on the moon nor apparently on Mars. Everybody can have an artificial climate in cars, but only a few can afford to have it in houses. We can imagine an artificial climate in a small city, but it is highly impractical. It is certainly beyond our current skills and knowledge at regional or global scales. The current environmental crisis is not only evidencing the always incomplete adaptive nature of technology, but also is disclosing our socioecosystem nature and demonstrating our dependence on ecosystems to maintain us. The challenge is to learn how to fulfill human needs through coevolution with nature, rather than aiming to subdue it (Jordan 1998).

14.6 Final Remarks

We have to recognize that the changes we describe in the way we do science in order to align with the socioecosystem nature of human enterprise, have already been taking place very slowly (for decades), and some of them in a serial fashion (one after the other). Some of the changes are now very well established in the scientific community and many others still need to gain recognition by it (see for example Carmel et al. 2013). In any event these changes do not mean a substitution of one type of research for another. Rather, a complementarity of approaches for better understanding our world is what is emerging. However, we are convinced that the epistemological paradigm we have described, is a reaction to some of the limitations the current scientific paradigm has in identifying and dealing with the severe global-scale environmental crisis that we are facing. The level of implementation of these necessary changes varies highly between countries and academic communities, as is also the level of opposition from them to explore alternative approaches. However, the process is gaining momentum and it is a matter of time before we see this new approach fully flourishing. The sooner the better, since time it is not precisely our ally in the face of the currently high-speed planet's degradation process.

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References

Ackoff RL (1999) Ackoff's best: his classic writings on management. Wiley, New York

Ahn YY, Bagrow JP, Lehmann S (2010) Link communities reveal multiscale complexity in networks. Nature 466(7307):761–764

Bertalanffy L (1950) An outline of general system theory. Br J Philos Sci 1:134–165

Burgos A, Páez R, Carmona E et al (2013) A systems approach to modeling community-based environmental monitoring: a case of participatory water quality monitoring in rural Mexico. Environ Monit Assess 185(12):10297–10316

Callicott JB (2007) Lamarck Redux: temporal scale as the key to the boundary between the human and natural worlds. In: Brown CS, Toadvine T (eds) Nature's edge: boundary explorations in ecological theory and practice. State University of New York Press, Albany, pp 19–34

Carmel Y, Kent R, Bar-Massada A et al (2013) Trends in ecological research during the last three decades – a systematic review. PLoS ONE 8(4):1–8

Carpenter SR, Folke C, Norstrom A et al (2012) Program on ecosystem change and society: an international research strategy for integrated social–ecological systems. Curr Opin Environ Sustain 4:1–5

Chapin FS III, Power ME, Pickett STA et al (2011) Earth stewardship: Science for action to sustain the human–Earth system. Ecosphere 2(8):Art. 89. doi:10.1890/ES11-00166.1

Collins SL, Swinton SM, Anderson CW et al (2007) Integrative science for society and environment: a strategic research initiative. National Science Foundation, p 35. http://www.lternet.edu/decadalplan/

Crutzen PJ, Stoermer EF (2000) The Anthropocene. Glob Chang Newsl 41:12–13

Csermely P (2006) Weak links: the universal key to the stability of networks and complex systems. Science 126:2827. doi:10.1007/978-3-540-31157-7

Daily GC, Alexander S, Ehrlich P et al (1997) Ecosystem services: benefits supplied to human societies by natural ecosystems. Issues Ecol 2:1–16

Ehrlich PR (2002) Human natures: genes, cultures and the human prospect. Penguin Books, Rutherford

Ehrlich PR, Ehrlich AH (1991) Healing the planet: strategies for resolving the environmental crisis. Addison Wesley, Reading

García R (1994) Interdisciplinariedad y Sistemas Complejos. In: Leff E (ed) Ciencias Sociales y Formación Ambiental. Ed. Gedisa/UNAM, Barcelona, pp 45–71

Golley FB (1993) A history of the ecosystem concept in ecology. Yale University Press, London

Gosz JR (1996) International long-term ecological research: priorities and opportunities. Trends Ecol Evol 11(10):444

Gosz JR, Waide R, Magnuson J (2010) Twenty-eight years of the US-LTER program: experience, results, and research questions. In: Muller F, Schubert H, Klotz S (eds) Long term ecological research: between theory and application. Springer, Dordrecht, pp 54–75

Grimm NB, Grove JM, Pickett STA et al (2000) Integrated approaches to long-term studies of urban ecological systems. Bioscience 50(7):571–584

Haberl H, Winiwarter V, Andersson K et al (2006) From LTER to LTSER: conceptualizing the socioeconomic dimension of long-term socioecological research. Ecol Soc 11(2):13. http://www.ecologyandsociety.org/vol11/iss2/art13/

Holling CS (ed) (1978) Adaptive environmental assessment and management. Wiley, London

Hopkins BC (2010) The philosophy of Husserl. McGill-Queen's University Press, Montreal/Kingston, pp 90–132

Husserl E (1913) Ideen zu einer reinen Phänomenologie und phänomenologischen Philosophie. Erstes Buch: Allgemeine Einführung in die reine Phänomenologie. Max Niemeyer Verlag, Halle

ICSU (International Council for Science) (2010) Grand challenges in global sustainability research: a systems approach to research priorities for the decade. International Council for Science, Paris

Jordan CF (1998) Working with nature: resource management for sustainability. Taylor & Francis, Amsterdam

Kates R, Parris TM (2003) Long-term trends and a sustainability transition. PNAS 100(14):8062–8067

Kaya JJ, Regierb HA, Boylec M et al (1999) An ecosystem approach for sustainability: addressing the challenge of complexity. Futures 31:721–742

Maass JM (2012) El manejo sustentable de socio-ecosistemas. In: Calva JL (ed) Cambio climático y políticas de desarrollo sustentable, Tomo 14 de la colección Análisis Estratégico para el Desarrollo. Juan Pablos Editor-Consejo Nacional de Universitarios, México, pp 89–99
Maass JM, Equihua M (2014) La Red Internacional de Investigación Ecológica a Largo Plazo a 20 años de su creación: sus avances y retos. Bosque 35(3):415–419
Maass JM, Martínez-Yrízar A (1990) Los ecosistemas: definición, origen e importancia del concepto. Ciencias Núm Especial 4:10–20
Margulis L (1998) Symbiotic planet: a new look at evolution. Basic Books, New York
Norgaard RB (2008) Finding hope in the millennium ecosystem assessment: an essay. Conserv Biol 22(4):862–869
O'Neill RV (2001) Is it time to bury the ecosystem concept? Ecology 82(12):3275–3284
Odum EP (1953) Fundamentals of ecology. W.B. Saunders, Philadelphia
Odum EP (1969) The strategy of ecosystem development. Science 164:262–270
Parr T (2013) The international long-term ecological research network and its role in global research and policy. In: Tabarelli M, Duarte da Rocha CF, Romanowski HP et al (eds) PELD – CNPq: dez anos do Programa de Pesquisas Ecológicas de Longa Duração do Brasil : achados, lições e perspectivas. Ed. Universitária da UFPE, Recife, p 446
Power ME, Chapin FS III (2009) Planetary stewardship. Front Ecol Environ 7(8):399–399
Redman CL, Grove JM, Kuby LH (2004) Integrating social science into the Long-Term Ecological Research (LTER) network: social dimensions of ecological change and ecological dimensions of social change. Ecosystems 7(2):161–171
Rockström J, Steffen W, Noone K et al (2010) A safe operating space for humanity. Nature 46:472–475
Rozzi R (2010) Field environmental philosophy. Dialogue Universalism 20(11/12):85–109
Rozzi R (2012) Biocultural ethics: recovering the vital links between the inhabitants, their habits, and habitats. Environ Ethics 34(1):27–50
Rozzi R, Arango X, Massardo F et al (2008) Field environmental philosophy and biocultural conservation: The Omora Ethnobotanical Park Educational Program. Environ Ethics 30(3):325–336
Rozzi R, Armesto JJ, Gutiérrez JR et al (2012) Integrating ecology and environmental ethics: earth stewardship in the southern end of the Americas. Bioscience 62:226–236
Simonsen SH, Biggs R, Schlüter M et al (2014) Applying resilience thinking: seven principles for building resilience in social-ecological systems. Stockholm University, Stockholm
Sokolowski R (2012) Introducción a la Fenomenología. (trans: Marín Ávila E), 1st edition in Spanish. Círculo Latinoamericano de Fenomenología (Coord. Zirión A et al) Jitanjáfora Morelia Editoral, México
Spangenberg JH (2011) Sustainability science: a review, an analysis and some empirical lessons. Environ Conserv 38(3):275–287
Steffen W, Sanderson A, Tyson PD et al (2004) Global change and the earth system: a planet under pressure. Springer, Berlin/Heidelberg/New York
Swank WT, Crossley DA Jr (eds) (1988) Forest hydrology and ecology at Coweeta. Springer, New York
Toledo VM (1995) Peasantry, agroindustriality, sustainibility: the ecological and historical grounds of rural development. Interamerican Council on Sustainable Agriculture. Working Papers 3:1–27
Toledo VM (2001) Biodiversity and indigenous peoples. Encycl Biodivers 3:451–463
Vaughan H, Waide RB, Maass JM et al (2007) Developing and delivering scientific information in response to emerging needs. Front Ecol Environ 5(4):W8–W11
Vitousek PM (1992) Global environmental change: an introduction. Annu Rev Ecol Syst 23:1–14