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PERSPECTIVES

Addressing the interplay of poverty and the ecology of landscapes: a Grand Challenge Topic for landscape ecologists?

Bryan C. Pijanowski · Louis R. Iverson · C. Ashton Drew · Henry N. N. Bulley · Jeanine M. Rhemtulla · Michael C. Wimberly · Annett Bartsch · Jian Peng

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Abstract We argue for the landscape ecology community to adopt the study of poverty and the ecology of landscapes as a Grand Challenge Topic. We present five areas of possible research foci that we believe that landscape ecologists can join with other social and environmental scientists to increase scientific understanding of this pressing issue: (1) scale and poverty; (2) landscape structure and human well-being; (3) social and ecological processes linked to spatial patterns in landscapes; (4) conservation and poverty, and (5) applying the landscape ecologist's toolkit. A brief set of recommendations for landscape ecologists is also presented. These include the need to utilize broad frameworks that integrate social and ecological variables, build capacity to do this kind of work through the development of strong collaborations of researchers in developed and developing

B. C. Pijanowski (✉)
Human-Environment Modeling and Analysis (HEMA) Laboratory, Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN 47906, USA
e-mail: bpijanow@purdue.edu

L. R. Iverson
United States Department of Agriculture, Forest Service, Northern Research Station, 359 Main Road, Delaware, OH 43015, USA
e-mail: liverson@fs.fed.us

C. A. Drew
Biodiversity and Spatial Information Center (BaSIC), Department of Biology, North Carolina State University, Raleigh, NC 27695-7617, USA
e-mail: cadrew@ncsu.edu

H. N. N. Bulley
Department of International Development, Community and Environment/Graduate School of Geography, Clark University, 950 Main Street, Worcester, MA 01610-1477, USA
e-mail: hbulley@clarku.edu

J. M. Rhemtulla
Department of Geography, McGill University, 805 Sherbrooke St. West, Montreal, QC H3A 2K6, Canada
e-mail: jeanine.rhemtulla@mcgill.ca

M. C. Wimberly
Geographic Information Science Center of Excellence, South Dakota State University, Brookings, SD 57007, USA
e-mail: michael.wimberly@sdstate.edu

A. Bartsch
Institute of Photogrammetry and Remote Sensing, Vienna University of Technology, Gusshausstrasse 27-29 A, 1040 Vienna, Austria

J. Peng
College of Urban and Environmental Sciences, Peking University, 100871 Beijing, People's Republic of China
e-mail: jianpeng@urban.pku.edu.cn

countries, create databases in international locations where extreme poverty exists, and create a new generation of researchers capable of addressing this pressing social and environmental issue.

Keywords Poverty · Millennium Development Goals · Grand Challenge Topic · Scale · Biological conservation · Human well-being

Introduction

The International Association of Landscape Ecology (IALE) recently celebrated its 25 year anniversary (Wu 2007, Wu and Hobbs 2007). Over this time, landscape ecologists have developed or enhanced new tools, databases, and theories to address a myriad of ecological problems relevant to policy and management in human-dominated landscapes (Antrop 2007). For example, we have conducted numerous empirical studies that link spatial variability in landscapes to a variety of ecological processes all over the world. Most of these studies have emphasized human–environment interactions, particularly the influences of human activities on habitat fragmentation and the resulting ecological effects. Yet, surprisingly little research in landscape ecology has focused on one of society's most difficult challenges—poverty. Poverty is both a human and an environmental crisis (Iverson 2007). The purpose of this perspectives paper[1] is to suggest to the IALE community the opportunity and responsibility for landscape ecologists to contribute their expertise to enhancing the understanding of the interaction between poverty and landscapes. In doing so, we would like to strongly encourage the IALE community, and indeed all that can be even loosely defined as landscape ecologists, to embrace *the study of the interactions of poverty and ecosystem services inherent in landscapes as a "Grand Challenge Topic"*. This call parallels similar efforts by groups, such as the National Research Council (e.g., National Research Council 2001), who issue grand challenge research topics of high societal need. Our call is consistent with the IALE mission, which emphasizes the merger of science and action:

> IALE encourages landscape ecologists to transcend boundaries and to work together building theory and developing knowledge of landscape pattern and process, developing integrative tools, making them applicable to real landscape situations, and applying them to solve problems. Throughout the world, landscapes are being altered more rapidly, more extensively, and more profoundly than at any point in human history. Comprehensive land-use planning and sound land-use policy are still the exception, but should become the rule. Members of IALE have a critical role to play. Applying landscape ecology stimulates the integration of various disciplines. Therefore, landscape ecologists should always look for opportunities for action and always strive to improve the applicability and accuracy of their tools. (IALE website, www.landscape-ecology.org)

We hope that recognizing poverty and the ecology of landscapes as a Grand Challenge Topic will raise the awareness that landscape ecologists can contribute valuable knowledge to understanding and solving this important problem. Our call also amplifies the appeal by others to be more holistic (e.g., Naveh 2000) and to infuse more social science (e.g., Antrop 2001) into our research. Here, we 1) provide justification for our suggestion that this become a Grand Challenge Topic by highlighting the immediacy of the topic; 2) briefly describe five areas where landscape ecologists can make significant contributions to our knowledge about poverty and the environment; and, 3) suggest directions that landscape ecologists can take in addressing this very important social and ecological issue.

Immediacy of the topic of poverty

We recognize that many topics could merit a claim to be a Grand Challenge Topic. However, poverty is an increasingly urgent topic that affects millions, even billions, of humans and we wish to encourage more

[1] This paper grew out of special sessions on Poverty and Landscape Ecology at the US IALE meetings held in Madison, Wisconsin on April 25, 2008 and Snowbird, Utah on April 17, 2009. The co-authors represent a mixture of session presenters and attendees from the audience of the first session and several presenters of the second session.

landscape ecologists to get involved. The United Nations Development Program (UNDP) has outlined a set of time-bound goals for achieving measurable improvements in the lives of the world's poorest people by 2015. These Millennium Development Goals (MDG), agreed upon by 191 nations in 2000 and monitored by UNDP, include: (1) eradicate extreme poverty and hunger; (2) achieve universal primary education; (3) promote gender equality and empower women; (4) reduce child mortality; (5) improve maternal health; (6) combat HIV/AIDS, malaria, and other diseases; (7) ensure environmental sustainability; and (8) develop a global partnership for development (www.undp.org/mdg). There are also 12 targets consisting of 60 measurable indicators to strive for by 2015. For example, two targets comprising the first goal call for, between 1990 and 2015, a reduction by half the number of people living in extreme poverty (less than a dollar a day) and the number of underweight children under age five. Target 10 of goal 7 (ensure environmental sustainability) calls for reducing by half the number of people with inadequate water and sanitation over the same period.

There has been measurable progress towards achieving the MDG targets. At the time of the Global Monitoring Report of April 2008 (World Bank 2008), the authors projected that the goal of halving extreme poverty by 2015 would likely be met on a global level due to the rapid economic growth (especially in China) over the past decade. Since then, however, the global economic and food crises have threatened the progress towards meeting these goals (www.undp.org). During the period 1990–2005, the proportion of people in developing countries living in extreme poverty fell from 31.6 to 19.2%, for a total reduction of 270 million people (i.e., from 1.25 billion to 980 million), though in sub-Saharan Africa the proportion was still 41.1% in 2004 (United Nations 2008). The proportion of children under five who were underweight only shrank from 33 to 27% between 1990 and 2005, so accelerated progress is needed to reach the one-half goal by 2015 for this indicator. The proportion of people in developing countries with access to improved sanitation rose from 35 to 50%, with the goal of 68% by 2015 (United Nations 2008). Yet despite the progress made, over 1 billion people still lack access to clean water and 2.5 billion lack access to basic sanitation. Ten million children under five died in 2006 from mostly preventable diseases such as diarrhea, malaria, pneumonia, measles, and AIDS (United Nations 2008). Of additional concern is the projected impact of climate change, especially on sub-Saharan Africa, a region that is most seriously behind in reaching the MDGs (IPCC 2007; Watkins et al. 2007). Help is needed from all sectors to accelerate progress toward the targets to meet the 2015 deadline.

A need for effective, sustainable management of natural resources underlies most of the MDG targets, either directly or indirectly. In some cases, a potential role for landscape ecologists is obvious, such as the need to ensure that assessments of land under protection or biodiversity loss (under MDG7) consider ecological patterns and processes at multiple spatial and temporal scales. A less obvious but critical role would be contributing to the design of sustainable agricultural systems for small farms, as 85% of the world's farmers use <2 ha of land (Polak 2008). MDG targets for education, child mortality, and maternal health all depend upon landscape management strategies that can ensure adequate water, sanitation, and nutritious food production. Climate change poses a particularly daunting challenge to many developing countries, especially the poorest, which are likely to have reduced food production capacity and water availability under climate change, and have less capacity to adapt or be protected from natural disasters (Challinor et al. 2007; Watkins et al. 2007). For example, the IPCC reported that by 2020, between 75 and 250 million Africans are projected to be exposed to increased water stress due to climate change and that yields from rain-fed agriculture could be reduced by up to 50% for some countries in Africa (IPCC 2007). This would further adversely affect food security and exacerbate malnutrition. Climate change was not considered in the development of the MDGs and the costs associated with achieving them. Though the relevance of landscape ecological principles seems clear, the specific questions and solutions have yet to be worked out.

Role for landscape ecologists

Research on poverty with a linkage to the environment has a long history, especially in the fields of

environmental economics (e.g., Sen 1976; Azariadas 1996; Dasgupta 1998; Banerjee et al. 2006), geography (Turner and Shajaat Ali 1996; Gray and Moseley 2005), agronomy (e.g., Blaikie and Brookfield 1987), sociology (Narayan, 1999), anthropology (Booth et al. 2006), environmental justice (Bryant 1995; Beckerman and Pasek 2001), natural resource management (USAID 2006), sustainability science (Palmer et al. 2005; Wu 2006; Musacchio 2009) and political ecology (Bryant 1992), to name a few. Landscape ecologists need to be apprised of this large body of work from many related disciples as they consider where their expertise can contribute to the issue. Many of the core themes (IALE 2008) of landscape ecology are echoed in research in these related fields. How can landscape ecologists contribute? For one, any additional scientific endeavors to join in the battle could be helpful in a world short of research and data. Because of landscape ecology's specific emphases to understand pattern and process, we also outline five main areas where we believe landscape ecologists can contribute toward a better understanding of poverty. These areas build upon some of the key themes of landscape ecology (Urban et al. 1987; Turner 1989; Wiens 1992): (1) understanding spatial and temporal scales at which poverty occurs in relationship to ecosystem services; (2) examining landscape structure and its relationship to poverty; (3) studying the relationship among patterns, processes, and poverty; (4) examining the interplay between conservation and poverty; and (5) utilizing and extending the landscape ecologist's "toolkit".

Scale and poverty

Landscape ecologists can play a key role in helping frame the debate on these topics and ensure that proposed actions are evaluated at the relevant set of spatial and temporal *scales* (Wu and Hobbs 2007). In addition to examining the fundamental relationships between poverty and various aspects of ecosystem pattern and process, landscape ecologists can contribute a spatial perspective to such questions. Do the same patterns of poverty and landscape pattern hold at the national, regional, and local scales? The identification of such scale-specific patterns could help disentangle the interacting effects of complex processes. Landscape ecologists also commonly look for temporal or spatial thresholds where there might be a change in direction or rate of poverty metrics or related drivers, and thus could examine long-term legacies of poverty (or poverty-induced land-use practices) in ecosystem structure and function. In particular, adopting a spatially explicit approach to the mapping and analysis of poverty and its determinants may improve the effectiveness of development efforts. For example, some of the debate about the relationship between natural resource development and poverty alleviation could be informed from disjunct geography or a scaling of the benefits (e.g., increased income, education opportunity, and health services) versus environmental costs (e.g., land degradation, pollution, and fragmentation) of the development activities. Also, targeting specific geographic areas containing "hot spots" of poverty is likely to be more effective than broad-based efforts that do not account for spatial heterogeneity in both human populations and the landscapes in which they inhabit (Baker and Grosh 1994; Amarasinghe et al. 2005; Salvatore et al. 2005). As suggested by Salvatore et al. (2005), "one of the most pressing challenges of our time—the reduction and eventual elimination of poverty and hunger from the globe—cannot be effectively addressed without accurate knowledge about who the poor and hungry are, where they live, and what factors present in their immediate surroundings are contributing to their distress".

Landscape structure and human well-being

Landscape *context* or structure of landscapes (*in sensu* Pickett and Cadenasso 1995) is likely to be particularly important when examining poverty in rural communities where human livelihood and welfare are closely linked to the environment through agricultural productivity. These 'slow' variables with slow turnover times (e.g., soil fertility or climate regime) have been shown to be better indicators, relative to 'fast' variables with fast turnover times (e.g., fluctuation in precipitation patterns or pest outbreaks) of overall poverty condition or the need for intervention (Reynolds et al. 2007). For example, soil fertility and growing season length were found to be correlated to the underweight status among children in rural areas of sub-Saharan Africa (Balk et al. 2005). Similarly, soil suitability for agriculture and the ratio of precipitation to evapotranspiration were related to the percentage of the population

falling below the rural poverty line in Kenya (Kristjanson et al. 2005). Soil type and area under cultivation were found to be related to the nutritional status of rural communities in Indonesia (Kusumayati and Gross 1998). In contrast, agricultural productivity, climate, and soil quality were shown to have little influence on the spatial distribution of poverty in an aggregated, coarse–scale analysis in Malawi (Benson et al. 2005). Landscape ecological concepts such as connectivity may also have an important role in understanding the spatial distribution of poverty. In particular, the isolation of rural communities may be a determinant of poverty if it limits access to employment, markets, and health care facilities (Kusumayati and Gross 1998; Farrow et al. 2005).

Social and ecological processes linked to spatial patterns in landscapes

Interaction of disease, landscapes, and poverty illustrates a key principle of landscape ecology; that is, the *pattern and process* are coupled through a variety of complex direct and indirect effects (IALE 2008). One important way in which landscapes influence human welfare is through their capacity to support and spread pests and disease. For example, the burdens of malaria and poverty are intimately connected across much of the developing world. Malaria contributes to poverty through lost income associated with illness or death as well as the direct costs associated with obtaining treatment. Spatial patterns of land cover and land use have been shown to have strong influences on vector habitats and the resulting risk posed by malaria and other vector-borne and zoonotic diseases (Patz et al. 2004). In central Africa, deforestation results in open, sunny environments that are conducive larval habitats of major mosquito vectors such as *Anopheles gambiae* and *Anopheles funestus* (Guerra et al. 2006). A study in the highlands of Kenya found that the locations of malaria "hot spots" were related to a variety of social and physical environmental factors including distance to swamps, distance to roads, elevation, human population density, and distance to health care (Ernst et al. 2006). In some cases, economic development efforts may have unintended consequences for the health of local communities. Although reducing the isolation of rural communities through road building may have positive influences on local economies, roads can also influence the spread of infectious diseases to previously unaffected areas (Eisenberg et al. 2006).

Biological conservation and poverty

DeClerck et al. (2006) provide a good summary of the relationship between conservation biology and poverty alleviation. Although much has been said about the synergy between the goals of sustainable resource conservation and poverty alleviation, it is still not clear to what degree these goals might actually be compatible. To date, very little research has been conducted to elucidate the connections between *poverty and ecosystem functioning* and even fewer studies have taken a landscape approach to simultaneously address both local economic development needs and conservation priorities. Though there is evidence that such goals are often complementary, particularly as highlighted in agroforestry and agro diversity projects (e.g., Garrity et al. 2002; McNeely and Scherr 2003; Scherr and McNeely 2007), the degree to which these goals are compatible and sustainable in many different ecosystems is still not well defined. For example, poverty is often assumed to be linked to increased deforestation (Angelsen and Kaimowitz 1999; Bierregard et al. 2001; Chomitz 2007). Some studies support this hypothesis (e.g., Deininger and Minten 1999), whereas others suggest that increasing incomes can actually exacerbate deforestation (e.g., Zwane 2007). Indeed, economists are split over the causal mechanisms underlying the relationship between poverty and deforestation, and have also argued for both possible outcomes. Moreover, although deforestation is an inherently spatial phenomenon, most studies do not consider the spatial aspects of land clearing as it pertains to the poverty status of the local populations (Angelsen and Kaimowitz 1999). In a traditional peasant community in the Peruvian Amazon where villagers practice swidden-fallow agriculture, poorer households own fields that are more widely dispersed across the landscape than their relatively more affluent neighbors, thus potentially increasing local forest fragmentation (J. Rhemtulla, unpublished data). Similarly, ecosystem service payments are often promoted as one way to simultaneously address conservation and poverty alleviation (McNeely and Scherr 2003). But little attention has been paid to the spatial configuration of poverty and to what degree

payments might thus influence landscapes and cause unintended side-effects. Much more research of this type is urgently needed.

Landscape ecologist's toolkit

One of the major strengths of landscape ecology and some highly related disciplines have been in the development of maps, models, decision support systems, and other tools that have been widely applied in the fields of conservation and natural resource management. Landscape ecologists thus possess a powerful *toolkit*. Similar types of tools could be developed and applied as a part of sustainable development efforts to alleviate poverty. For example, spatial analytical methods integrating demographic, socioeconomic, and ecological data could be used to develop maps of poverty "hot spots" where development efforts can be concentrated (Amarasinghe et al. 2005). Environmental indicators derived from satellite remote sensing have been proposed as a technique for identifying areas with high poverty concentrations where detailed social and demographic data is unavailable (Kusumayati and Gross 1998). Spatial modeling techniques can be applied to predict the risks of famine (Boken et al. 2005; Verdin et al. 2005), diseases (Grover-Kopec et al. 2005), natural disasters (Asante et al. 2007; Iverson and Prasad 2007) or other hazards to which impoverished communities are likely to be especially sensitive. For example, the Famine Early Warning System (www.fews.net) is an exemplary system showing real time hunger and poverty locations throughout much of the poorest regions on earth. Aside from such centralized, expensive systems, inexpensive toolkits that run on open-source software in user-friendly environments are needed so that they can be used by local managers and activists, be they government or nongovernmental entities, with little cost.

The suggestions from the five above themes are just some ideas among many others that could be explored to assist in poverty alleviation. Studies that explore spatial and temporal variability in the social and environmental determinants of poverty can aid in determining the types of interventions that are most likely to be effective in particular communities and also assist with prioritizing different regions of the landscape for different development and conservation objectives.

Future directions for landscape ecologists

To encourage research and action on these issues, we suggest several ways that landscape ecologists can contribute to addressing issues surrounding this Grand Challenge. These suggestions address both the need for an integrative framework to approach landscape-poverty questions and the potential to develop specific spatial tools and applications. In so doing, they are by no means exhaustive, but rather are intended to prompt further discussion within and beyond the landscape ecology community.

Employ integrative frameworks

We need to construct new integrative frameworks that relate how poverty impacts landscapes and how landscapes impact human well-being across different spatial, temporal and contextual scales. In particular, we need to:

(a) Gain a better understanding of important issues related to poverty by investigating and reporting on aspects of social science research that may be relevant to landscape ecological pattern and process, but have not traditionally been addressed by landscape ecologists. These could include such topics as land-tenure, war/conflict, institutions, governance, coping strategies, risk assessment, hazards, and innovative knowledge diffusion strategies.

(b) Establish comparative studies, addressing the context of poverty in different areas of the world and at different scales to identify general conditions under which poverty alleviation and resource conservation have compatible goals.

There are many conceptual frameworks that could be used to help study poverty and the ecology of landscapes. The Vulnerability Framework of Turner et al. (2003a) is a particularly useful conceptual framework which illustrates the many dimensions of poverty using coupled natural-human systems (Fig. 1). These dimensions include spatial and temporal scales, driving forces, and consequences to changing human and environmental conditions. The crux of the framework is a focus on the resilience of coupled human–ecological systems in the face of constant perturbations. This framework (Turner et al. 2003b) builds from the recognition by many ecologists (e.g., Holling 1973) and social scientists (e.g., Folke 2006) that systems are constantly changing and

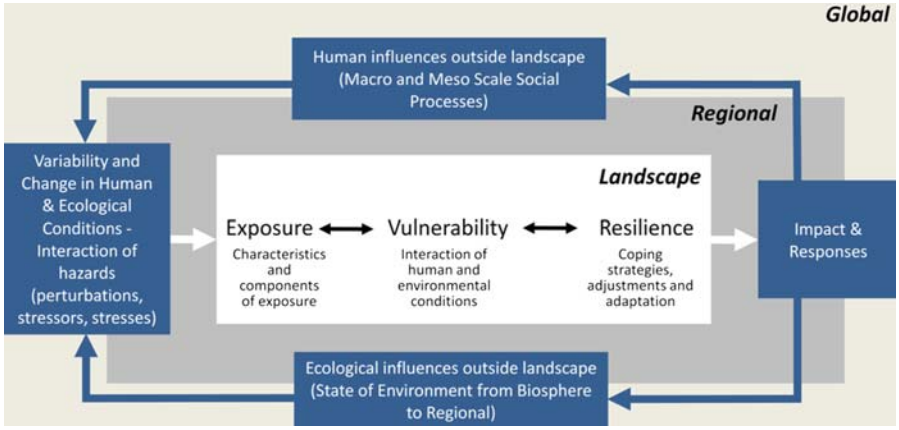

Fig. 1 The vulnerability framework of Turner et al. (2003a) (simplified) that could serve as a means for landscape ecologists to think about the coupling of human and ecological systems

the capacity of a system to cope or respond to these changes is paramount to its sustainability, or to the amount of natural and social capital of a system. Perturbations to the system and responses from stressors also transcend different spatial and temporal scales; indeed, cross-scale interactions is a major theme of landscape ecology.

Contribute disciplinary expertise with prudence

What we are proposing here, that is, to elevate social issues to a higher level of importance for study by a community of scientists, is not new to the field of ecology. In fact, over the last 20–30 years, ecologists have embraced the coupled systems concept many times. Initiatives like the resilience alliance (www.resalliance.org, cf. Walker and Salt 2008), the coupled human and natural systems (CHANS) network (Liu et al. 2007, and www.chans-net.org), and the Drylands Development Paradigm (Reynolds et al. 2007) all point to the need to have a societal grand challenge, like poverty alleviation, as a main goal of research; collaborations between social and natural scientists have been productive. However, historically, some social scientists have seen the interest of biophysical scientists in social issues to be somewhat threatening. Thus, our call is also blended with a message of caution, in that biophysical scientists should not over-extend their "reach" into the social or development sciences without meaningful multidisciplinary partnerships with social scientists or without appreciation for social scientists who have studied these problems for a long time. Moving forward, landscape ecologists, may, in fact, find themselves as the only biophysical scientist on research teams, struggling to comprehend the nuances of a problem that social scientists have grappled with for decades.

Connect to parallel efforts in the ecological sciences

The five research themes that we present here as potential contributions by landscape ecologists are similar in nature to high priority research themes proposed by the joint International Geosphere–Biosphere Programme (IGBP) and International Human Dimensions Programme (IHDP) Global Land Project (GLP, 2005) and the United Nations Millennium Ecosystem Assessment (MEA 2005) Project. Indeed, at the nexus of ecology and poverty is land-change science (Turner et al. 2007), a major theme of landscape ecology (Turner et al. 2001). On the human subsystem, the Economic and Social Research Council's STEPS Center Programme (www.steps-center.org) and the International Forestry Resources and Institutions (IFRI) (http://www.sitemaker.umich.edu/ifri/home) focus on development studies, natural resource use, and human well-being from a strongly social science viewpoint. These, among others, will continue as avenues that ecologists and social scientists can use to bridge disciplinary boundaries that are required to address poverty alleviation.

Develop critical databases

We also argue that we need to promote and support projects which acquire, archive, and analyze high

quality data for locations in developing countries. Several such projects already exist which would benefit from increased use and support from the landscape ecology community. Priority topics would likely include mapping and modeling land use potential, water resources, food production, land degradation, and predicted impacts of climate change. A large need for data to support these topics has already been identified. Continent-wide monitoring has been undertaken for many years by various organizations, primarily via United Nations programs. Satellite data play the primary role for regular investigation of remote, difficult to access, or large regions. The primary components of such monitoring systems are rapid assessments on the state of the vegetation and the water stored at the surface and in the soil. Besides the Famine Early Warning System already mentioned, a recent initiative is the European Space Agency's (ESA) TIGER (Fernandez-Prieto and Palazzo, 2007) program with focus on water-related issues over Africa. Projects utilizing these data so far include studies of water quality and quantity, malaria control, and transboundary water allocation. A quarter of these projects are in the pre-operational stage for continuous, online assessments of status and trends. Once these initiatives reach the operational stage, dissemination of the information within the affected regions and transfer to other areas become major issues. Currently, data transmission poses an obstacle in many countries although datasets are provided free of charge. Specific ways for landscape ecologists to support these projects include the identification of the links between poverty and remotely sensed landscape patterns on all scales. These efforts would raise awareness and thus enhance the application of these valuable resources with greater involvement of the local authorities who finally make things happen on the ground.

Extend current toolkit

It is clear that we need to develop and apply landscape ecology data and modeling toolsets towards understanding poverty-environment relationships and designing sustainable development alternatives that acknowledge the hierarchical nature of ecological and social systems. There are several areas that we believe are promising which include the need to:

1. Study the interactions of water quantity and quality (and sanitation) with poverty, food production, diseases, and societal well-being at various scales and domains. Then add the impacts of various climate change scenarios on these interactions.
2. Link agent-based models (e.g., Parker et al., 2003; Alexandridis et al., 2007) that simulate social and environmental determinants of human behavior to landscape attributes;
3. Assist in designing landscape-based, sustainable means of protection against natural disasters, especially storms, floods, and droughts. One example is the modeling of vulnerability to storms and tsunamis in the wake of the December 2004 tsunami (Iverson and Prasad 2007).
4. Assist in planning for urban growth that also sustains agricultural productivity using appropriate water, soil, and food management systems.
5. Assist in designing infrastructure for sustainable energy alternatives in developing countries with maximum positive human impact and minimum negative environmental impact. These include best management practices for biomass fuels, as well as harnessing solar power or other energy alternatives for rural communities.
6. Assess socio-economic and ecological impacts of wide-spread adoption of low-cost appropriate technologies such as water pumps and irrigation (e.g., Polak 2008).
7. Explore mechanisms for scaling locally successful pilot projects (e.g., how to conserve species and reduce extreme poverty) across large landscapes and in diverse regions.

Build capacity

Research on poverty will require societal and institutional capacity building in developing countries that creates bridges between researchers and practitioners. For example, a recent UNEP report on Africa's environmental outlook suggests that the enormous natural resources may constitute the basis for poverty alleviation and economic renaissance of most African countries (UNEP, 2006). Scientific and technological innovations have often been touted as the key to unlocking such vast resource potential in developing countries. Therefore,

effective integration of scientific knowledge (in this case, landscape ecology), information technology, and geospatial science to benefit developing countries will require innovative appropriate knowledge transfer and application mechanisms including end-user or stakeholder-driven distance education or novel e-learning tools. These will include the need to:

1. Partner with developing countries to distribute high quality data and provide training in modern methods to utilize these data to answer relevant questions. Focused attention on e-learning tools for knowledge delivery and local data analysis is essential so that researchers in developing countries will have immediate access to innovative research and developments in landscape ecology and related geospatial tools that can be applied to solve poverty-related questions. Effective partnerships could include broader support of interactive workshops, faculty exchanges, and visiting scholar programs. For example, to our knowledge, there is currently no curriculum for landscape ecology in any institutions of higher education in the sub-Saharan African countries. However, both researchers and resource managers have shown tremendous interest in the use landscape ecology principles and tools. Thus there is an opportunity for landscape ecologists in developed countries to contribute to the development and implementation of an e-learning based landscape ecology curriculum that is germane to the unique socio-economic context of sub-Saharan Africa.
2. Ensure that the landscape ecological training includes both the human dimensions as well as the natural resources aspects of the science. Training is needed for subjects including sociology, economics, property rights, culture, and customs. Similarly, international development and other social science curricula would benefit from a deeper understanding of spatial dynamics and other landscape ecological processes that shape societies.
3. Identify sources of funding, likely from non-traditional avenues, such as private foundations, that can provide support for colleagues in developing countries who are often engaged in projects that combine action and research and thus fall outside the mandate of traditional granting agencies.

What next?

There are at least two possible ways that IALE and the landscape ecology research community can respond to this call to accept this Grand Challenge. The first is to embrace this charge as an informal mandate which we hope would increase the amount of work that focuses on poverty alleviation and ecological impacts. Perhaps this course of action would result in special sessions at meetings, special issues in the journal *Landscape Ecology*, or facilitation of proposal collaborations to promote more research in this area. A second approach is to consider this, and possibly other challenges (e.g., sustainability and landscape ecology, see Naveh 2007), as Grand Challenge Topics that are incorporated into the IALE mission. We would see this as a deliberate response which would require a formal adoption by the society. The timing might be ripe as we reflect back on our contributions of 25 years of high quality research and look forward for ways that our expertise can positively impact society and the environment in the next 25 years. Of course, the authors of this perspective recommend that both avenues be pursued.

Conclusion

In summary, landscape ecologists have specialized expertise that can contribute to relieving some of the world's most pressing problems, including poverty. Given the negative impacts of climate change already underway on food production and water resources, and the relatively greater impacts climate change will have on the poor, it is crucial that we mobilize and galvanize our effort to work towards this Grand Challenge of understanding the interactions of poverty and ecosystem services inherent in landscapes of developing nations.

Irrespective of any movement on these two courses of action that we suggest here, with the 2015 target date for cutting several indicators of poverty in half (from 1990) within the framework of

the Millennium Development Goals fast approaching, it is more important now than ever to pull together as landscape ecologists in helping the international community lessen the prevalence of poverty. With collaboration among landscape ecologists and with partners in other related fields, we can make many worthwhile gains in addressing key poverty-related issues, and consequently contribute to mitigating the problems associated with the vicious cycle of poverty. As Sachs (2005) ends his book, may we also adopt: "Let the future say of our generation that we sent forth mighty currents of hope, and that we worked together to heal the world".

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