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PERSPECTIVE

Globalization and land use in Latin America.

Forest recovery in the slopes, low-density urban expansion and agriculture intensification in the flatlands. The urban-natural interphase between Great San Miguel de Tucuman in subtropical Argentina and the San Javier range. Land cover trends characteristic of current processes in Latin America.

Credit: Matilde Malizia

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Coverpage

Globalization and land use in Latin America.
Designed by Magno Studio

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EDITORIAL

Interdisciplinary Research Towards Sustainability

We are happy to release the issue number 10 of the GLP News. The International Project Office (IPO) of the Global Land Project (GLP) in Brazil has now completed two years and has just hired new personal. Since the release of our last Newsletter in 2012, GLP has reached important achievements and our community has kept growing steadily. More than 600 scientists from all over the world gathered together at our Second Open Science Meeting, held at Humboldt-Universität Berlin, Germany in March 2014 to discuss topics centered on land change science and solutions towards the sustainability of land use systems.

As the largest international and interdisciplinary network in land science, GLP has been witnessing the expansion of the field across disciplines and scales, and the development of approaches and tools to address the increasing complexity of our globalizing world. The scientific contributions complied in this issue show us pathways on how land science may be thought across disciplines and scales in a near future.

The paper by Erle Ellis takes us across unusual time scales, showing how land change intensifications began surprisingly long before the Holocene. The next paper, by Andreas Heinimann and Peter Messerli (originally published in Global Change Magazine No 80- IGBP), takes us across spatial scales by discussing the abrupt inclusion of Laos smallholders' land into the global land market. Rüdiger Schaldach and Benjamin Stuch tackle pressures on land and water resources over the 21st century. A. Cristina de la Vega-Leinert discusses the land sparing vs. land sharing debate that has provoked a vivid exchange of views on which land use strategies are most appropriate to best face present and coming challenges. Evangelia G Drakou, Ilaria Palumbo, Dorit Gross, Juliana Stropp and Joseph Tzanopoulos focus on science-policy dialogue for managing land use change. Aliyu Salisu Barau shows how geospatial technologies can improve governance-related issues affecting sustainability in developing countries, Meine van Noordwijk and Grace B. Villamor provide valuable information on tree cover transitions in tropical landscapes, Géraldine Bocquého, Rebecca Mant, Aline Mosnier, Gilberto Câmara, Valerie Kapos, Michael Obersteiner and Martin Tadoum introduce us to the project REDD-PAC and show how it can provide support to REDD+ policies. Ayansina Ayanlade, Nicolas Drake and Mike Haward draws our attention to how remote sensing and GIS can help monitor land transformations at global and local scales, Xiangming Xiao, Chandrashekhar Biradar, Pavel Dorovskoy, Jinwei Dong present the Field Photo Library project that enable researchers, stakeholders and citizens to share, visualize, and communicate their data. Jasper van Vliet talks about a workshop at the Environmental Synthesis Center (SESYNC) that aimed to determine next steps within a larger research effort of the Global Land Project on globalized understandings of land changes. Gregory B. Greenwood presents The Mountain Research Initiative (MRI), a programme that continually searches for the next steps in promoting global change research in mountains. Thales Sehn Körting describes a free data mining toolbox and a new method for classifying time series of remote sensing images.

The highlight of this issue is an article by Martha Bonilla-Moheno, H. Ricardo Grau, Mitchell Aide, Nora Álvarez-Berríos, Judith Babot, who point out to the effects of the increasing demand for food and minerals on land cover change in Latin America.

A big challenge for GLP in the coming years is its transition from IGBP to the Future Earth Programme by 2016. In this perspective, the IPO co-hosted a regional consultation workshop for Future Earth research priorities, "Research Priorities in Latin America for the Future Earth agenda for global sustainability", chaired by Dr. Mark Stafford Smith in May 2014. The main focus of discussion in this informal consultation was to complement the dialogue already established in the region and motivated a bottom up approach for co- learning and co-motivate of knowledge necessary in the new platform.

GLP has also been endorsing a full range of new research projects, such as GEOSHARE: Geospatial Open Source Hosting of Agriculture, Resource & Environmental Data for Discovery and Decision Making, GLUES – Global Assessment of Land Use Dynamics, Greenhouse Gas Emissions and Ecosystem Services, Biodiversity impacts of future land use trajectories, REDD-PAC – REDD+ Policy Assessment Center, Sustainable Land Management Programme and Sustainable futures for Europe's heritage in cultural landscapes: Tools for understanding, managing, and protecting landscape functions and values (HERCULES). Requests for endorsement are still being received and analyzed with great pleasure by the GLP-IPO.

Finally we would like to take this opportunity to welcome the new members of the GLP Scientific Steering Committee: Mrs. Roy Rinku Chowdburry, Mr. Patrick Meyfroidt and Mrs. Allison M. Thomson, as well as to thank the former members, Mr. Hideaki Shibata and Mrs. Dawn C. Parker, for their valuable commitment.

We will be honored to receive new contributions for issue n. 11 and we hope that you will enjoy reading the papers published in this new issue.

Sincerely,

Dr. Sèbastien Boillat

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Martha Bonilla-Moheno[1] | H. Ricardo Grau[2]
Mitchell Aide[3] | Nora Álvarez-Berríos[3]
Judith Babot[4]

Globalization and land use in Latin America.

Latin American Land Use History

The Americas were the last continents to be colonized by humans. Their arrival, in the late Pleistocene (c 15000 years before present), can be considered the first mayor global influence on American land use. Despite their low population densities it is quite likely that these earlier land "users" had an enormous impact on biodiversity and biotic communities' structure. In North America, the extinction of nearly half of the megafauna genera (e.g. saber-tooth cats, giant slots, horses, mammoths and mastodonts) was contemporary with the development of the Clovis culture and Younger Dryas climatic change event. Although less well established, megafaunal extinctions in South America were roughly synchronous, mostly occurring within a few millennia following the arrival of humans.

By c. 5000 BP, agriculture was already present in specific regions of the Americas. The two major centers of agriculture domestication and development, Mesoamerica and Perú, remained largely isolated from each other, although there was some exchange of crops. During the next 4500 years, agriculture expanded to other regions of the Americas and the extension of land impacts varied from local (e.g. Southern Chile, Amazonia) to extensive (e.g. Central America, tropical Andes).

The arrival of the European in the 15th century initiated a period of major environmental change. By introducing new diseases and disrupting the socioeconomic systems, the native populations decreased by 60-80%, which resulted in the collapse of many agricultural systems. Although the Americas had extensive arable lands, well-developed and diverse agriculture systems, the Europeans were much more interested in expanding silver and gold mining activities.

In general, the cultivated area increased little between the 16th and 19th century. However, the introduction of cattle for meat and horses and donkeys for transport, largely for the mining industry initiated major ecological changes that have continued to the present. The exception was the expansion of sugar cane plantations. Sugar cane, which was mainly planted in the Caribbean and the Brazilian coast, was the first commodity crop in the Americas. Sugar and molasses (used for rum) were valuable enough to be transported to Europe where they were eagerly consumed. Sugar production was labor intense, which further depleted local populations, and led to the forced immigration of African slaves. The emerging commercial triangle (sugar traveled from the Americas to England, firearms and textiles from England to Africa, and slaves from Africa to the Americas) resulted in the conversion and reduction of the Caribbean tropical forests and the Atlantic Brazilian forests.

During the 20th century, technological development (e.g., invention of the steam engine and powered boats, as well the development of industrial refrigeration) helped Latin America countries turn into important exporters for Europe and North America. Argentinean, Uruguayan and Brazilian pampas became major exporter of meat and grains (mainly wheat and corn), and tropical countries of fruits (lead by Bananas), and agro industrial products (coffee, rubber, and cacao).

The 21st Century

The 21st century has been characterized by the rising economic importance and development of Asia, which has had indirect effects on land use patterns in Latin America.

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The meat and soybean connection

During the 20th century, global industrialization and urbanization resulted in a major dietary change towards higher meat consumption. During this period Latin America was the major exporter of meat to the European and North American markets, but during the last decade there has been a rapid increase in the Asian demand for meat, which has greatly affected land use in Latin America.

As a result of the fast economic growth of China (and to a lesser degree other southeastern Asian countries), millions of Asian have change their consumption habits and are experiencing a diet transition, from almost a purely vegetarian diet to a moderate inclusion of pork, chicken, and dairy products. A key component of the pork and chicken fed is soybean, given its high caloric and protein composition.

Tropical, subtropical and temperate flatlands of South America (Brazil, Argentina, Uruguay, Paraguay and Bolivia) have excellent conditions for soybean production; consequently during the past two decades this crop has expanded rapidly in these regions, replacing traditional croplands (wheat, corn, sunflower), pastures, and forests (Chaco, Cerrado, Amazonian Mato Grosso). In fact, most of the current deforestation in Latin America is aimed to produce meat, either by planting pastures to feed livestock or by planting soybean to supply feedlots.

In the past, research focusing on soybean and pastures/livestock has tended to treat them as separate and alternative land use pathways. Currently, globalization-driven economic forces favor the economy of scale of large agribusiness companies, and producing both soybean and livestock appears to provide flexibility and resilience to market and political fluctuations. Increasingly the key deforestation and food production actors of Latin America are involved in both of these activities.

The gold connection

Gold mining is an important example of how economic globalization has affected land change. Over the last thirteen years, the price of gold has risen more than fourfold in response to an increase in its global demand. This rise in global gold prices has been associated with an intensification of gold mining activities by multinational companies and by small-scale gold miners throughout the world, and these activities have had significant negative social and environmental impacts.

Gold and silver mining has been the key export commodity of Latin America since the 16th century, but during the last 10-15 years there has been a new gold mining boom. In many regions of Latin America and the Caribbean, mining activities have resulted in significant environmental impacts, such as water pollution, as well as in removal of vegetation for mining pits, transportation access (roads, railways), and human settlements. In fact, deforestation rates due to mining have become a major threat to some of the most remote and better-conserved old-growth forested areas in Latin America. For instance, the Department of Madre de Dios (Peru), globally recognized as one of the most biologically rich areas on Earth, lost ~6600 ha in forest due to mining between 2006 and 2009.

Despite the extensive number of studies on deforestation and agricultural expansion, little is known about the contribution of mining activities to forest loss in Latin America and the Caribbean. Initial analyses show forest loss has been an important environmental consequence of the increasing in mining activity, particularly within the Tropical Moist Forest biome in Peru, Colombia, Suriname, Venezuela, Brazil, and Nicaragua.

The tequila connection

The increasing demand for meat, grains, and metals is not surprising, given their importance in cultures around the world, but globalization can also impact local products and the land use patterns associated with their production. For example, local products such as Peruvian or Chilean Pisco, Amazonian Acai, and Mexican Tequila are experiencing a global boom.

According to international laws, Mexico is granted the right to the word "tequila", a distillated beverage made from blue agave, and this has important economic implications. During the last decade, tequila has become a trendy drink around the world. In 2012 more than 250 million liters of tequila were produced, and more than 50% was exported.

According to Mexican laws, to be recognized as "tequila" the distillate must come from agave cultivated in the state of Jalisco, or specific municipalities of Guanajuato, Michoacán, Nayarit, and Tamaulipas (i.e. regions of "designation of origin").

The combination of an accelerating demand and the site specificity of the product have influenced land change in these regions. During the past 30 years, the area of agave plantations has increased more than 1,000% (from 8,806 ha in 1982 to 137,626 ha in 2012), mostly during the last decade in the "designation of origin" areas. In addition, from 2000 to 2012, the number of countries importing tequila increased from less than 10 to over 100, and the revenues from agave production increased by more than 100 million dollars. These dynamics have reduced the area for producing food crops and they have expanded over dry forests and arid vegetation regions, which have important conservation value in Mexico.

The oil palm connection

The global concern about the potential effects of global change has promoted the expansion of crops for biofuels. This is influencing the dynamics of Latin America traditional "caloric" crops such as sugar cane and maize, and more recently, oil palm.

The impact of oil palm plantations on forests and biodiversity in South East Asia has been well documented, but much less is known about the impacts in Latin America. Although the crop has been in production in Latin America for decades, particularly for cooking oil and other products, its use as a biofuel has stimulated the expansion of oil palm plantation in many countries during the last decade.

Although some oil palm plantations have been established in areas that were previously forested, the majority of new plantations are replacing areas that were previously under some other type of agricultural use. For example, in Honduras and Costa Rica, most of the new oil plantations occurred in area previously used as banana plantations, while in Colombia most of the new plantations occurred in pasturelands. Although the direct impact on forested areas was less than expected in preliminary research, if countries are going to meet their internal legislated quotas for biofuel production and expand exports, the impact on intact forest ecosystems is likely to increase. Furthermore, given that oil palm is well adapted to acidic tropical soils were most conventional crops do no perform well, there is a potential risk of deforestation in areas of tropical rainforest that so far have been protected due to their soil characteristics.

Concluding Remarks

Human consumption has become one of the most influencing factors of global change. During the last century the growing demands for food, commodities, and energy have produced irreversible impacts on ecosystems, mainly by influencing land change. Although deforestation in one is one the most devastating consequences of land change, global pressures for particular products have also affected the extension of land devoted to meet local or regional needs.

Historically, Latin America has satisfied much of global consumption demands, and this has resulted in the conversion of >40% of the region to agriculture and pastureland. Current global forces, however, have driven regional increase in production and extraction of traditional commodities such as grains, meat and metals, but also of once locally consumed products, such as tequila and of newly emerging products such as biofuels.

Current predictions of global consumption point out to scenarios where more natural areas in Latin America will be converted to mines, agriculture, and pastures. But, at the same time, vast areas, particularly in mountainous regions, are experiencing forest recovery, and environmental protection in part as a result of globalization influences. Understanding these complex dynamics, and predicting their outcome in the coming decades is a major challenge, but it is utmost importance given the regions importance in producing food for the world, providing environmental services, and conserving biodiversity.

Suggested readings:

Aide T. M., M. L. Clark, H. R. Grau, D. López-Carr, M. Levy, D. J. Redo, M. Bonilla-Moheno, G. Riner, M. J. Andrade Núñez, y M. Muñiz. 2013. The deforestation and reforestation of Latin America and the Caribbean (2001-2010). *Biotopica* **45**:(262-271) DOI: 10.1111/j.1744-7429.2012.00908.x

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Grau HR, Aide TM. 2008. Globalization and land use transitions in Latin America. Ecology and Society 13 (16).

Erle C. **Ellis**

Using the Planet

Introduction

200,000 years ago, Homo sapiens arose in Africa amid other tool-making, fire-using species of the genus Homo (Sterelny 2011). It would be another 100,000 years before H. sapiens distinguished itself from prior species by rapidly expand its range across the planet, leaving a trail of culturally advanced archaeological evidence (Kirch 2005, Sterelny 2011, Henn *et al*. 2012). By the end of the Pleistocene, human populations were well established across Earth's habitable regions, sustaining themselves using an astonishing array of sophisticated socially transmitted technologies within ecosystems already reshaped by their ancestors to enhance their productivity (Kirch 2005, Ellis *et al*. 2013). Even before the advent of agriculture, H. sapiens had initiated an entirely new process of planetary change. Earth would never be the same.

Recent global changes in Earth's atmosphere, climate, lithosphere and biosphere are unprecedented in human history, if not the history of the planet, prompting the call to recognize the Anthropocene as a new geological epoch starting with the rise of the Industrial Revolution (ca. 1850) or its "Great Acceleration" since 1950 (Steffen *et al*. 2011, Syvitski 2012). Yet the evidence from archaeology, paleoecology and environmental history is clear: human societies have been reshaping the terrestrial biosphere, and perhaps even global climate, for millennia (Kirch 2005, Ellis 2011, Ellis *et al*. 2013, Ruddiman 2013, Smith and Zeder 2013). The entire Holocene might simply be renamed the Anthropocene (Ruddiman 2013, Smith and Zeder 2013).

Formal recognition of the Anthropocene is ultimately a decision for geologists. Nevertheless, global change science has much to learn by viewing humanity's role in Earth-system dynamics through the lens of geologic time. By focusing on the dramatic changes of the past two centuries, prior anthropogenic changes have been discounted as localized, globally insignificant and of little value to understanding contemporary processes of global change. This is a major oversight. Though industrial systems are now driving massive changes across the Earth system, the long-term transformation of the terrestrial biosphere by human populations and their use of land is no less massive, and likely represents the single greatest anthropogenic global change yet wrought by humanity (Ellis 2011, Ellis *et al*. 2013, Smith and Zeder 2013). Still, the most important reason to explore the long-term dynamics of human transformation of the terrestrial biosphere is to better understand the social processes that have made it possible for a single species to alter the course of Earth's history (Ellis and Haff 2009, Ellis 2011, Ellis *et al*. 2013).

A tale of two planets

Recently, two different spatially explicit global reconstructions of human populations and their use of land across the Holocene have been developed that enable quantitative assessment of the long-term dynamics of human use of the terrestrial biosphere for the first time (Fig. 1 (Ellis 2011, Ellis *et al*. 2013). While contemporary global patterns of land use and population are reconstructed using data from census and remote sensing, land use prior to historical records (ca. 1700 in most regions) must be "backcasted" from contemporary patterns using models of per capita land use. As is evident in Fig. 1, the results of these two reconstructions are so different that they might as well come from two different planets: one with ancient and extensive human use of land (KK10; Kaplan *et al*. 2011) and one with land use becoming globally significant mostly in recent centuries (HYDE; Klein Goldewijk *et al*. 2011). HYDE predicts that outside Europe's more developed regions, human use of land was insignificant before A.D. 1750. In KK10, land use is globally significant far earlier in the Holocene, with more than 20% of Europe and Asia already in use by 3000 B.C., and large areas of Earth's land in recovery from higher levels of land use in earlier periods.

The difference? HYDE, the first and most popular Holocene land use reconstruction, assumes that land use per capita remained nearly constant over time. KK10 takes an entirely different approach,

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A Tale of Two Planets: Two different models of global land use history

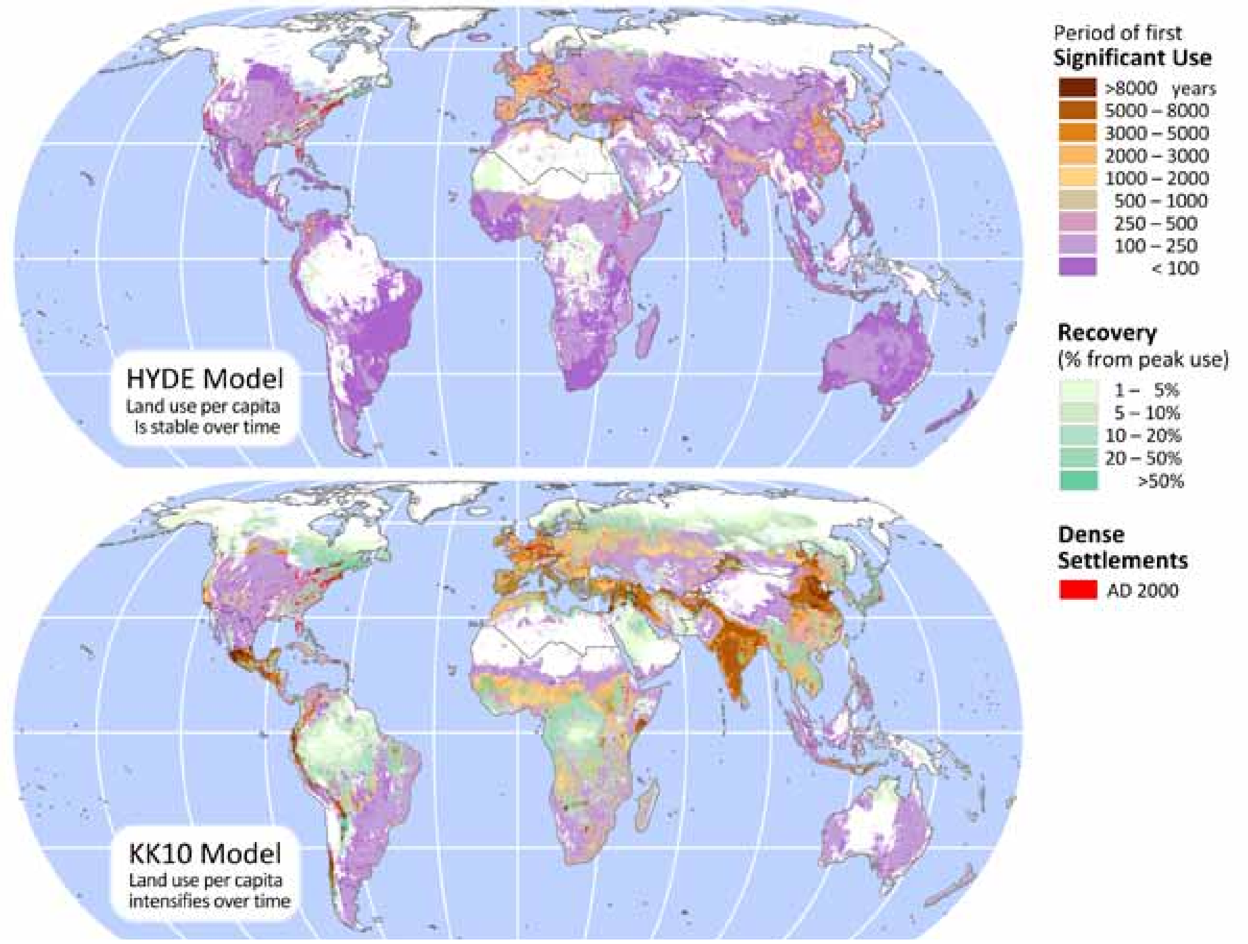

Figure 1: *Global maps of land change history based on historical reconstructions from the HYDE and KK10 models (After Fig 1. in (Ellis et al. 2013). Time period of first significant land use and recovery from peak land use, 6000 B.C. to A.D. 2000,*

estimating land use from population by means of empirically derived nonlinear relationships with population density, such that low-density populations with high per-capita land use first expand to fill all usable land and then intensify their use of land (use less land per capita) as population densities increase over time.

So which model comes closer to the truth? At present, it is not yet possible to conclusively validate global models of Holocene land use against empirical data. The massive task of compiling and standardizing the requisite archaeological and paleoecological data has yet to be undertaken. Nevertheless, by comparing existing models with what we know from archaeology, paleoecology, geography, and environmental history, it is clear that by incorporating adaptive changes in land-use per capita over time, a more spatially detailed and plausible assessment of our planet's history is revealed, with a biosphere long ago affected by humans. Land-use intensification is potentially pivotal in understanding human transformation of the Earth system (Ellis *et al*. 2013).

Land use intensification as a global change process

Broadly defined, land-use intensification is the adaptive response of human populations to demographic, social and/or economic pressures leading to the adoption of increasingly productive land-use systems (Ellis *et al*. 2013). Put simply, humans don't make the effort to use land efficiently unless they must, to feed growing populations on the same land, or to satisfy social or commercial demands. Though land use intensification tends to drive general increases in land productivity as populations grow, with low density populations using more land per capita than denser populations, the relationship between any given population and the productivity of its land-use systems is dynamic and multidimensional, driven not only by population but also by social and economic processes regulating resource demand, land availability and suitability, barriers to technology adoption and availability, and the potential for intensive use of land to degrade its productivity over time. As a result, a general trend towards increasingly productive use of land is produced not by a smooth and continuous process, but through a complex succession of land system regime shifts, some of them regressive, subjecting populations to both surplus production and productivity crises as illustrated in Fig. 2.

Land use intensification began early, long before the Holocene. Archaeological evidence in the form of plant and animal remains, charcoal, isotopic records and other legacies demonstrate that human hunter-gatherers long ago engaged in pre- and proto-agricultural land use intensification practices to support larger populations on the same land, including dietary broadening (eating more species once preferred megafauna were rare or driven extinct), burning vegetation to enhance hunting and foraging success (ecosystem engineering), processing plant and animal foods to enhance nutrient availability (cooking, grinding, etc.), and the propagation of useful species (Kirch 2005, Ellis *et al.* 2013). As a side effect, these practices likely facilitated increasing reliance on grasses and other species that would later become crops, putting them on the road to domestication (Ellis *et al.* 2013).

Pre-agricultural technologies for ecosystem engineering were much less productive than the agricultural technologies that replaced them. Nevertheless, they still enabled human populations to grow far beyond the capacity of unaltered ecosystems to support them. As populations grew, more intensive land-use practices were adopted to sustain them or populations migrated to areas with less intensive use (extensification), including uninhabited wildlands. By the early Holocene, hunter-gatherers had expanded their populations across the Earth and required early land use intensification processes to survive and to grow and lived mostly within ecosystems that had already been transformed by their ancestors to enhance their productivity, setting the stage for the rise of agriculture.

To make a long story short

Agricultural populations grew more rapidly than those of hunter-gatherers, ultimately replacing them across Earth's most productive lands. Intensification continued, with long fallow shifting cultivation replaced by systems with

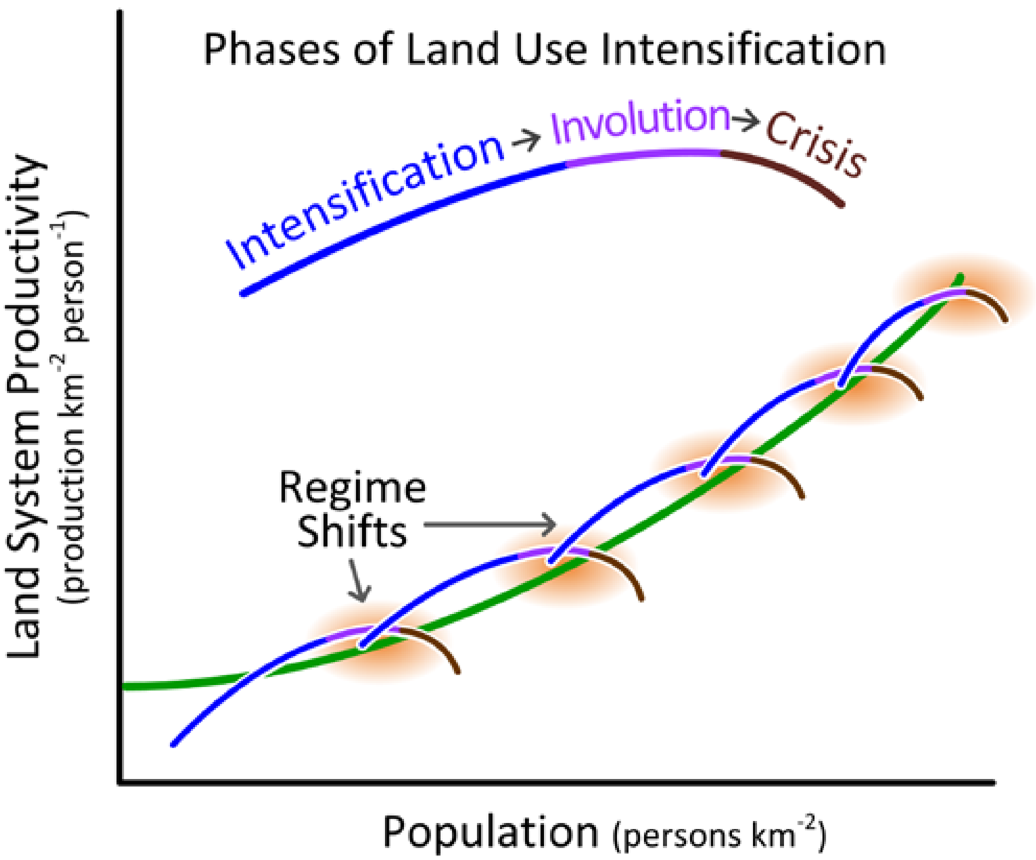

Figure 2: *A general model of adaptive land use intensification (After Fig 3 in (Ellis et al. 2013). Arcs depict individual land-use systems with three phases: Intensification (technologies enable productivity to increase faster than population), Involution (technology-driven productivity increases become exhausted, such that only net increases in labor or other costly inputs enable increases in production), and Crisis (all capacity to enhance land productivity is exhausted and food production cannot keep up with increasing populations). Regime shifts drive changes from less to more productive land systems. Green line highlights general trend toward increasing productivity with population.*

shortened fallows, and eventually continuous cropping enhanced by the plow, irrigation, manuring and other increasingly productive land use technologies. Intensive agricultural systems gradually proliferated across Earth's most productive lands, supporting densely populated villages and eventually supplying food surplus to growing urban populations. As the demands of urban populations grew, they were sustained by ever larger scales of farming operations, trading systems, and technological institutions, ultimately leading to the high-yielding industrial "green revolution" land-use systems by the 1950s and continuing today, sustained by fossil energy and other industrial inputs.

Industrial technologies, especially mechanization, have increasingly decoupled human labor from productivity growth in agriculture, thereby allowing the majority of human populations to live in urban areas for the first time. Increasing agricultural intensity has also helped prevent rapid population growth and progressively richer diets from translating into accelerating per capita demand for arable land- an indicator that may now be leveling off (Ellis *et al.* 2013). As agriculture continues to intensify and migration to cities depopulates the rural landscapes of many regions, lands less suitable for industrial-scale agricultural are being abandoned, allowing forests to recover in regions where economics and governance systems support this.

Global consequences.

Land clearing by hunter-gatherers and farmers, soil tillage, and wet rice production all emit major amounts of carbon dioxide and methane. As a result, early human use of land might have initiated global changes climate long before human use of fossil fuels (Ruddiman 2013). While this "Early Anthropocene" hypothesis remains an active area of research (e.g. Kaplan *et al.* 2011), understanding the role of early land use in determining both the onset and magnitude of anthropogenic climate change is necessary to evaluate the biosphere's role in both current and future climate change, including the prospects for biofuels and reduced deforestation and tillage to mitigate carbon emissions from fossil fuels.

The effects of human populations and their use of land on biotic communities and ecosystem processes are increasingly recognized as profound and persistent over periods from centuries to millennia. Evidence is growing that many habitats once thought to be only recently disturbed by human activities actually represent the bio-cultural legacies of human interactions over millennia. While the most densely settled and intensively used landscapes tend to be the most altered, even the least intensively used rangelands, seminatural ecosystems and seemingly undisturbed areas with proximity to human populations share a tendency toward biotic communities and ecosystem processes transformed by exotic species invasions, altered fire regimes, nutrient pollution and other pervasive human influences (Ellis 2011, Hobbs *et al.* 2013). Efforts to acknowledge this profound and extensive human influence is now leading to a wholesale rethinking of ecological science and conservation to reflect the essential long-term role of humanity as permanent stewards of the biosphere (Hobbs *et al.* 2013).

Learning from the ancestors.

The first spatially explicit global histories of land-use across the Holocene make clear that land-use intensification has played an essential role by enabling human populations to grow well beyond the capacity of the unaltered biosphere to support them (Ellis *et al.* 2013). Despite major setbacks from epidemic disease and social collapse (Butzer and Endfield 2012), the global growth of human populations has been sustained from millions at the start of the Holocene to billions today.

Our species has been changing the planet at global scales since the late Pleistocene. As a result, we have inherited a used planet from our ancestors. Unlike prior geological time periods, the long-term driving forces of global change in the Anthropocene are not within the realm of physics, chemistry, or even biology. The ultimate drivers of the Anthropocene are inherently social, emerging from H. sapiens' unprecedented ability to accumulate and transmit adaptive technological and social innovations across individuals, societies and generations (Ellis and Haff 2009, Ellis 2011, Sterelny 2011, Ellis *et al.* 2013). As a key social process of the Anthropocene, land use intensification has been essential to sustaining the emergence of large, technologically sophisticated, affluent, and interconnected societies with the power to alter the course of Earth's history (Ellis *et al.* 2013). As we move deeper into the Anthropocene, strengthening our scientific understanding of the long term social processes that sustain humanity has never been more important.

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Coping with a land-grab world: lessons from Laos

In late 2012, oxfam published a report entitled *Our Land, Our Lives: Time out on the global land rush*. Pointing to the deleterious consequences of large-scale land acquisitions in developing countries, Oxfam called on the World Bank to freeze its own land investments and review its policy and practice to prevent "land-grabbing". And earlier this year the Rights and Resources Initiative, in its 2012/2013 review, suggested that developing nations faced a stark choice: they could turn their rural citizens into landowners or landless labourers. these documents are only the latest in a series of reports and media articles on the topic of land grabs that have been published during the past few years. Clearly, the issue – which came to prominence in 2008 – is not simply a passing fad.

Despite the continuing attention, it has been challenging to acquire reliable data at the global scale (Cotula 2012). Existing estimates have relied on a combination of media stories and research reports (Friis and reenberg 2010). The Land Matrix project – a partnership between several research institutions – is addressing this gap by systematically collating and verifying information on large-scale land acquisitions (Box 1). the Land Matrix is an online public database that permits all users to contribute to and improve data on land deals, and for this data to be visualised (http://landportal.info/landmatrix).

Global patterns of land acquisitions are important for the overview they provide. But acquiring quality data on a global scale is challenging and considerable limitations persist in terms of data sources, data quality and definitions used. Nevertheless, the growing evidence base of the Land Matrix allows the identification of broadly generalisable patterns. In contrast, local case studies entail more robust data and can yield insights into context-specific processes and outcomes. Yet, their results are difficult to generalise.

Few studies have focused on the middle ground – detailed and spatially explicit inventories of land deals that cover large areas (for example, entire nations). The Lao People's Democratic republic (hereafter referred to as Laos; see Box 2) is a rare exception. Here, government agencies in collaboration (2007-2010) with the German Agency for International Cooperation (GIZ) carried out an inventory based on land-concession and land-lease agreements that were actually signed. In this article we first assess the global picture, relying primarily on the findings of Anseew *et al.* (2012), before zooming into Laos.

The global picture

The Land Matrix reveals reported land deals covering 83 million hectares (ha); these deals were initiated, negotiated or implemented over the period of 2000-2010. This confirms that the rush for agricultural land is real and represents neither media hype nor a short-term reaction to the food price spikes of 2008. Even if only half of these deals were to be confirmed they would amount to 5% of the available agricultural land in the most affected countries: 56.2 million ha in Africa, followed by Asia (17.7 million ha) and Latin America (7 million ha).

Most of the countries that have sold or leased land have agrarian economies and high rates of malnourishment. Small landholders dominate agriculture in such countries, but the institutional mechanisms to safeguard their rights tend to be weak. Indeed, numerous case studies around the globe show that governments are often selling or leasing land over which smallholders have customary user rights. Large shares of the land deals (45%) seem to be taking place predominantly in regions where small-scale agriculture is practised. This increases greatly the chances of intense competition for cropland with local communities.

The big players engaged in land deals are the Gulf States and the emerging economies such as China, India and Brazil. Deals made by such nations exceed those by the OECD countries. Strong intra-regional and involve private and

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state-owned companies, investments fund and provate public partnerships. Less than a third of the investments target food production, the vast mojority of which is exported. Moreover, investors are seeking flexibility by using the so-called flex-crops-such as sugar cane, soya and oil palm - that can be used for multiple purposes (25% of all investments). Plants not used for food - such as tree plantation, cotton and non-flex crops used to make biofuels - make up the rest of investments.

Zooming in on Laos

But what is happening at the national scale in the countries that sell or lease land? In 2012, the Centre for Development and Environment (CDE) of the University of Bern conducted an extensive analysis of land deals in Laos with the support of the Swiss government (SDC) (Schoenweger *et al.* 2012). This shows that the last decade has seen a dramatic expansion (over 50-fold in terms of project numbers) in the granting of land concessions and leases in Laos. Part of this been driven by "open-door" policies aimed at attracting foreign direct investment as a means of achieving economic development objectives.

This analysis revealed 2600 land deals in Laos that cover 1.1 million ha, a figure that may pale in comparison with the immense land deals being sealed in Africa but is very significant in the context of Laos. It amounts to roughly 5% of the nation's land and is more than the total land used for the production of rice – the staple diet and the principal agricultural export of Laos. Clearly, these deals form some of the most significant land transformations in Laos' recent history. Interestingly, the Land Matrix points to only 49 deals covering an area of over 0.48 million ha for Laos. This vast underestimation underscores how global assessments tend to show only the tip of the iceberg, at least for some countries.

Foreign Direct Investment dominates the land leases (> 72% of all land granted). Vietnam, China and Thailand, all of which share extensive borders with Laos, are the major foreign investors, suggesting that proximity to Laos remains a major factor in investors' interest. Thai investments focus on the agriculture subsector, whereas Vietnam and China both hold much more land in mining and tree plantation projects. Because of the very limited capacity for value addition via processing in Laos, most of the products are exported to the investing countries in raw form.

Land deals occur in a range of economic sectors, but are overwhelmingly focused on the primary sector constituted mainly by mining, agriculture and tree plantations. 50% of the total land concession/leases granted involve mining (mainly copper and gold). Agriculture and tree plantation (mainly rubber and eucalyptus) cover a large share of the remaining area. A closer look at investments in the agriculture and plantation subsectors suggests that a substantial transition in agricultural production is under way. In contrast to the traditional emphasis on rice, subsistence crops and a diverse range of cash crops and forest products, there is now a strong focus on a very limited diversity of export-oriented products. The main agricultural products are non-food or flex crops (sugar cane and jatropha, for example). As far as the plantations are concerned, a single product – rubber – makes up almost half of all plantations (140,000 ha). This low diversity points to a high dependency on international markets and price fluctuations.

Interestingly, most of the land granted to investors is located in accessible and relatively well-off regions (Figure 1). The investors' demand for accessibility seems to outweigh the government's aspirations to use land acquisitions for regional development, especially in marginal areas with poor infrastructure.

Almost half of the granted lands were formerly small-scale agricultural landscapes with a mosaic of cultivated land, bush fallows and patches of forests. Crops grown in, and the forest products and other edible material gathered from, these landscapes are a crucial element of the food security, particularly of the poorer households of local communities (Foppes and Ketphanh 2004, De Schutter 2011). Also, prior to their transformation such multifunctional landscapes provided an array of ecosystem services such

Box 1. On land deals

Large-scale investments in land often involve transnational companies backed by financial investors. These companies seek to secure access to land in developing countries to produce food and non-agricultural commodities as well as biofuels. Land may be purchased, but more often investors are granted long-term leases on government-owned land. Such land transactions are commonly referred to as land-grabs when they lack transparency, violate human rights, lack the participation and prior and informed consent of land users, and do not take into consideration social and environmental impact assessments. These criteria are summarised in Oxfam (2012) and further information can be found in the Tirana Declaration of the International Land Coalition. www.landcoalition.org/about-us/aom2011/tirana-declaration.

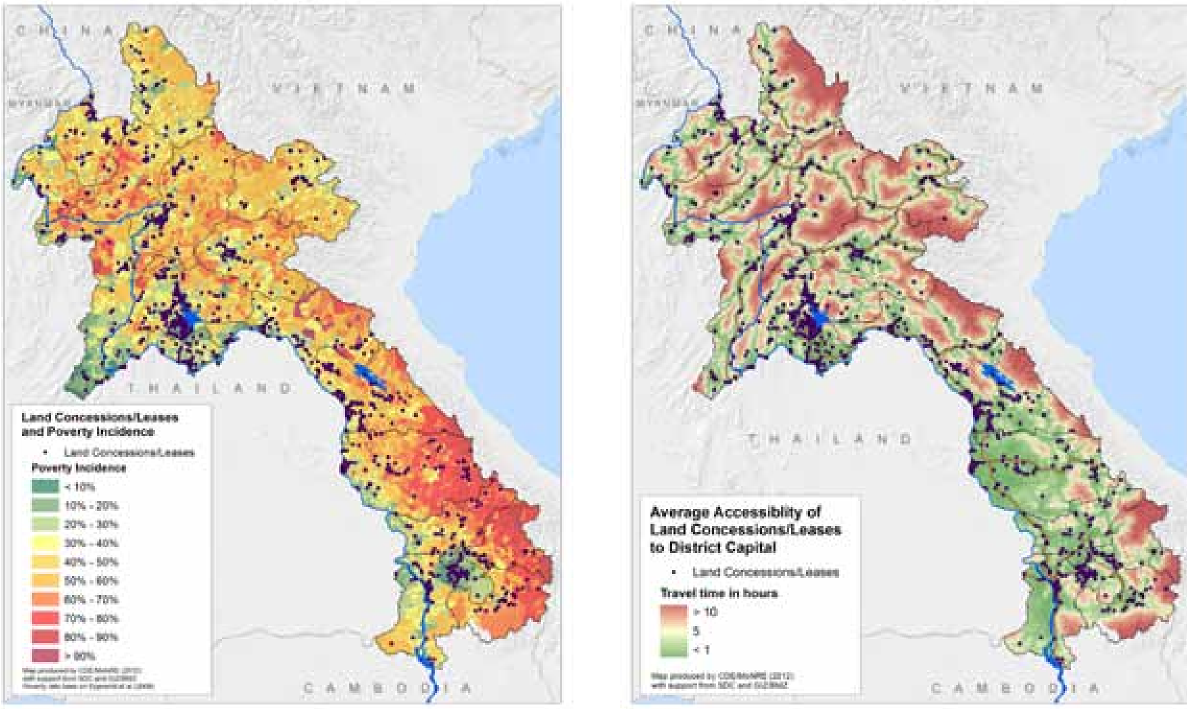

Figure 1: *Investments in Laos with respect to poverty incidence (Panel A) and accessibility (Panel B). The maps show that the poorest and most remote areas benefit far less from the investments accompanying land deals than better-off and more accessible areas. Contrary to what is sometimes claimed, this suggests that investment in land neither prioritises nor is able to successfully address the issues of rural poverty alleviation or infrastructure development in marginal areas.*

as, for example, preserving biodiversity and sequestering carbon.

The wide range of services delivered by multifunctional landscapes challenges the wisdom of the homogenisation trends currently being witnessed in the global South. this is relevant to the continuing debate (for example, Fischer *et al.* 2011 and Castella *et al.* 2013) on whether agricultural production should:

a) make use of multifunctional landscapes (land sharing) or

b) target existing cultivated or marginal lands thereby setting aside other areas, for example for biodiversity conservation (land sparing). Opinion seems to be converging on the understanding that the former alternative – land sharing – is preferable overall, although trade-offs have to be accepted in certain intensively used areas. The holistic, land-system architecture proposed by turner II *et al.* (2013) promises to further improve our understanding of the human-environment systems with a view to devising options to mitigate and adapt to global change.

Lessons from Laos

The nations targeted for largescale land acquisitions are often portrayed as offering abundant land reserves in combination with high yield gaps. The Laos analysis challenges this portrayal by showing that investments target high-value and easily accessible land. This push from investors for the best land had been reported before (see Cotula 2012) but lacked confirmation from detailed national studies such as the present one.

The global picture and the data for Laos both suggest that far from being located on "idle lands", much of the investment targets agricultural landscapes used by smallholders leading to land conflicts. Smallholders tend to be at a comparative disadvantage in such conflicts and are hence frequently the losers. Even if the conflicts were to be mitigated, it remains valid to challenge the prudence of large-scale, fossilfuel dependent monoculture replacing smallholder systems. Particularly when it threatens the food security of a large percentage of the population. No wonder, then, that there have been calls to re-evaluate the future of agriculture and its related economic, environmental and socio-cultural benefits and costs (e.g. De Schutter 2012, IAASTD 2008).

Land acquisitions by foreign corporations/nations can be portrayed as helping to foster agricultural intensification, modernisation and poverty alleviation from a macroeconomic perspective. At least for Laos, such claims receive little support at the sub-national level given the observation that investment tends to avoid the most needy areas. Indeed, past experience shows that the negative impact of the loss of access to land – often arising from a disregard of customary land rights (IIED 2012) – tends to outweigh the potential local benefits of the Foreign Direct Investment.

An effective dialogue on land investments requires reliable data on the global as well as national level. This is now being addressed through various initiatives, for example the Land Observatory initiative of ILC (International Land Coalition) and CDE (Centre for Development and Environment) of the University of Bern). At the same time, we need to better understand the land-grab phenomenon in the context of globalisation and its attendant specificities of trade, governance and power (see Margulis et al. 2013). The insights yielded by a combination of these two approaches could pave the way for policies and innovations in governance that help safeguard underprivileged communities from exploitation.

Box 2. A look at Laos

Laos is a mountainous country in the heart of mainland Southeast Asia endowed with abundant natural resources. It ranks as one of the poorest countries in the region. The last decade has seen an unprecedented transformation of land use in rural areas fuelled by government policies in support of growth and a market-based economy. Laos has emerged as a supplier of raw agricultural commodities, plantation products and minerals as well as hydropower for the large and dominant economies of China, Thailand and Vietnam that share its borders. Almost half of the growth in Gross Domestic Product of between 7 and 8% comes from the natural resource sector (dominantly mining and hydropower). A majority of the rural population continues to depend on small-scale and often subsistence-only agriculture for their livelihood. Laos is ruled by the communist Lao People's Revolutionary Party. This implies that all land belongs to the state and that investors can get access to land through land leases or concessions (typically between 25 and 50 years).

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Challenges for Land-System Modeling in the Domain of Food, Bioenergy and Water

Pressures on land and water resources – the food, bioenergy, water nexus

According to recent UN projections, world population is likely to increase to more than 9 billion people until mid of the 21st century. Together with an improving living standard and changes in diets, this will lead to a significant higher global demand for food, energy and water. Strong incentives for substituting fossil energy carriers by biofuels driven by concerns of national energy security, rural development and mitigation of climate change often result in a strong competition for land which is suitable for agriculture. In particular in some tropical countries such as Brazil or Indonesia (e.g. Fearnside, 2007; Lapola *et al.*, 2010; Carlson *et al.*, 2012) this resulted in the conversion of natural and semi-natural ecosystems to cropland or rangeland. Inadequate agricultural management may then lead to further degradation of ecosystem services such as soil fertility and biomass productivity, for example due to wind and water erosion. Tilman *et al.* (2009) address this problem complex as a food, energy, environment tri-lemma.

Looking at the global level, agriculture is the largest anthropogenic user of freshwater. The main water demand in agriculture is by evapotranspiration from the cultivated crops. In dry regions where precipitation is not sufficiently available to sustain crop yields, irrigation plays an important role to provide additional water to secure food production. Already in the year 2000 about 30% of the global crop production was grown on irrigated areas accounting for almost 24% of the total cropland (Portmann *et al.*, 2010). In turn, intensive agriculture is responsible for nutrient and pesticide emissions to streams and groundwater with negative effects on water quality. Climate change is an additional pressure on both water and land resources. Increasing air temperature and changing precipitation patterns might have adverse effects on crop yields and may also have strong impacts on irrigation requirements.

The analysis of these complex relationships requires an integrative view on land and water resources. New knowledge in this field is an important prerequisite for the development of sustainable strategies that help to secure global food and bioenergy production while preserving a functioning environment. Possible approaches can concentrate on the demand and supply side. While demands for food and bioenergy might be limited by more sustainable consumption pattern and more efficient food and energy systems that avoid losses during the processing and distribution chain, a higher supply can be achieved either by expansion of agricultural area or by further intensification. An important challenge is to find trade-offs between losses of ecosystems and their functions due to land conversion and the potential negative effects of intensive agricultural production e.g. on water quality and farmland biodiversity (e.g. Tilman *et al.*, 2011). Additionally, the future water availability need to be considered as a constraint for the further expansion of irrigated area.

Land-system models

During the past years spatially explicit models have been developed to facilitate the analysis of complex human-environment interactions in land-systems. Commonly changes in land-cover and land-use are calculated on a geographic raster that can be visualized with standard GIS software. Regarding their modelling philosophy these land-system models can be divided into Top-Down approaches that distribute a predefined area of different land-use types or amounts of agricultural commodities to the geographic raster using statistical or rule based techniques and Bottom-Up approaches where land-use changes are the result from the interaction of the modelled land decision makers (Verburg *et al.*, 2004). Land-system models combine socio-economic and environmental drivers of land-use change and are successfully used for the analysis of competition between food and bioenergy production as well as for environmental impact

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assessments. Up to now only few models include the integrative way on land and water resources which would be necessary to address the relationships between agricultural production and water that we have outlined in the previous paragraph. A prerequisite for such kind of analysis is the coupling of the modelled land-use pattern to environmental processes such as crop growth, agricultural management and water fluxes (e.g. Lotze-Campen *et al.*, 2009). Not until then effects of land-use on water use and water quality as well as the feedbacks from changing water availability either due to climatic changes or due to the competition with other water users such as households and industry on agriculture can be assessed. In the following we will sketch general ideas of how these linkages can be included into land-system models and present an example that illustrates the prototypic realization of some of these elements.

Adding water as a new dimension into land-system models

In a rough attempt we can identify three key processes that need to be integrated into land-system models to facilitate analyses related to the nexus of food, bioenergy and water:

- Expansion of irrigated area under given resource constraints.
- Crop growth and agricultural management.
- Water flows, nutrient loadings and water pollution.

An important element of a model based analysis of linkages between land and water resources is the development of the extent and location of irrigated area over time. A static global map of irrigated area that can serve as a starting point for scenario analysis has been published by Portmann *et al.* (2010). Besides introducing irrigated crops as a separate land-use type and taking into account 'typical' land-use constraints (slope, protected areas etc.) it is essential also to consider water-related constraints that may limit the expansion of irrigated area within land-system models. This includes information on local or regional water availability and water quality but also on competition with other water-use sectors such as households and industries (e.g. Alcamo *et al.*, 2003).

Crucial information that is required both for assessing the impact of agriculture on water resources and for determining the location and extent of irrigated area are the consumption and withdrawals of water for irrigation purposes. These processes are strongly connected to crop growth and the respective agricultural management. For the simulation of crop growth and crop water requirements, a variety of process-based models exist for application on local up to global level, as shown in the AgMIP model inter-comparison exercise (Rosenzweig *et al.*, 2012). State of the art models include climate change impacts as well as effects of agricultural management (e.g. irrigation and fertilizer application) on crop productivity. For a coupling to land-system models in particular the incorporation of spatial

Figure 1: *An agricultural landscape in Germany showing the food, energy, environment tri-lemma*

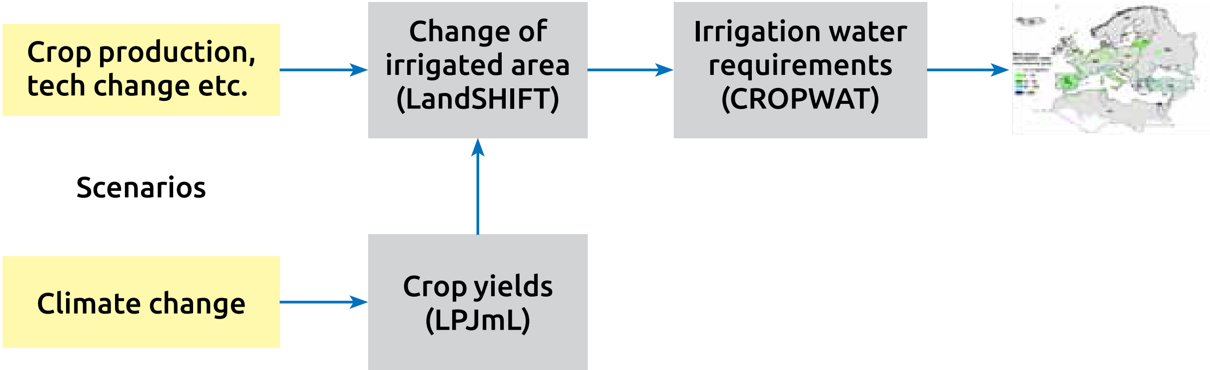

__Figure 2:__ Block diagram of a modelling framework designed to simulate the expansion of cropland area and the resulting irrigation water requirements in a Pan-European study.

information on agricultural management will be a key task (e.g. Ellis *et al.*, 2013; Potter *et al.*, 2010).

Based on this management information in combination with spatial environmental data e.g. on soil structure and climate conditions, loadings of nutrients and agrochemicals to ground and surface water can be calculated and linked to the respective water flows. For this purpose a variety of hydrology models exist (e.g. Arnold *et al.*, 2012).

In a recent simulation study Schaldach *et al.* (2012) assessed the expansion of irrigated area and the resulting net irrigation requirements for Pan-Europe under different socio-economic and climate change scenarios until 2050. The spatially explicit top-down land-system model LandSHIFT (Schaldach *et al.*, 2011) was modified with routines to calculate changes in location and extent of irrigated cropland on a 5 arc-min raster. Effects of climate change on crop yields were determined by the process-based LPJmL model (Bondeau *et al.*, 2007) while irrigation water requirements were calculated with the CROPWAT approach (Smith, 1992) as implemented within the water-use module the global water model WaterGAP (Alcamo *et al.*, 2003). A block diagram of the modelling framework is shown in figure 2. The study was designed to quantify the influence of the respective scenario drivers on location and extent of irrigated area and the associated water requirements. In comparison with a reference simulation using current climate, the two analysed ensemble realizations of the SRES A2 climate scenario both led to an additional expansion of irrigated area that could be attributed to negative effects of increasing temperatures on crop growth. It also became clear that in the selected scenarios the effects of changes of agricultural production and yield increases (socio-economic drivers) had a larger impact on the expansion of irrigated area and the related crop water requirements than the climate change signal. The effect of agricultural management on irrigation water requirements was further demonstrated by adapting the crop sowing dates to the changing climatic conditions. This measure helped to overcome seasonal water deficits and resulted in a lower consumption of irrigation water than calculated for the non-adaptation case.

The implemented modelling framework includes only a sub-set of the above-mentioned processes but already in this early stage the results from the simulation study underline the importance and added value of an integrative view on the linkages between agricultural production and water within spatial land-system models. We see a large potential that further enhanced modelling tools will help to draw a more comprehensive picture of anthropogenic pressures on land and water caused by increasing food and bioenergy demands and that they can provide valuable contributions to the development of management strategies for a more sustainable use of these resources.

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Can UNESCO Biosphere Reserves bridge the apparent gap between land sharing and land sparing?

Land sparing vs. land sharing debate: towards a convergence on sustainable intensification?

Agricultural land is in most parts of the world a scarce resource while demand for land for multiple purposes is growing against a backdrop of climate change and increasing land degradation (Lambin and Mexfroidt, 2011). The current land use/ land cover transformations are closely related to multi-scale processes, from world commodity chains and markets, globally driven conversion of natural vegetation to local livelihoods and coping strategies (Lambin *et al*, 2001; Andersen, 2010). Moreover, land use change is associated through ever expanding actor constellations, so that the environmental and societal impacts of commodity production are increasingly spatially decoupled from trade pathways and consumption patterns.

In the last decade, the **land sparing vs. land sharing debate has provoked a vivid exchange of views on which land use strategies are most appropriate to best face present and coming challenges**. Most stimulating from the scientific point of view has been the construction of contrasting argumentations, based on a range of modelling simulations and insights from detailed case studies, which are testing the key assumptions encapsulated within what, at first sight, appear irreconcilable conceptualisations of land use management.

In a nutshell: the debate centres on the pressing challenge of how to secure global food and energy needs, while preserving life-sustaining ecosystems despite climate change (Godfray *et al*, 2010). To address this, proponents of land sparing emphasise functionality through specialisation and spatial segregation. This implies agricultural intensification where possible, the abandonment of low-yield agriculture in marginal areas and the formal designation and effective management of conservation areas (Green *et al.*, 2005; Phalan *et al.*, 2011). Further, it encourages the concentration of rural population and rural-urban migration (Aide and Grau, 2004; Grau and Aide, 2008). The major players here operate in international and national political arenas from governmental, agro-industry and conservation sectors.

In contrast, advocates of land sharing foster the spatial integration of agricultural and conservation activities framed under sustainable development (Harvey *et al.* 2008). Key is to use the agricultural matrix to connect fragmented landscapes and ecosystems to enable ecological corridors and species migration (Vandermeer and Perfecto, 2006; Perfecto and Vandermeer, 2010). This approach encourages the maintenance of traditional, cultural landscapes, fosters agro-ecological diversification, has a local to regional focus and is compatible with dispersed rural population. It further highlights the essential role smallholder farmers play in producing their own food as well as important commercial crops, while it stresses structural obstacles, which governments and national and international actors should contribute to resolve (Altieri, 2000; Tscharntke *et al.*, 2012).

Interestingly much of the land sparing vs. sharing controversy is related to the starting point of reflection and the specific lenses one chooses to wear to address the conundrum. Land sparing appears particularly congruent from a macro-scale perspective, based on formal quantitative modelling, where the priority lies on optimising the return of land resources, whether these are food, energy or biodiversity, while limiting trade-offs (see for e.g. Ewert *et al.*, 2009; Hodgson *et al.*, 2010). Main critiques, however, question: 1) the underlying assumptions on food production, security and access; 2) the main hypothesis, that land spared from agricultural intensification would be used for conservation; 3) the lack of consideration of the environmental impacts of agricultural intensification; and 4) the danger of formulating land use policy based on simple models of limited validity (Vandermeer and Perfecto, 2005; Fischer *et al.*, 2011; Tscharntke *et al.*, 2012). On the other hand, integrated,

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contextualised case study exploration of land use changes and possible applied agro-ecology management strategies (e.g. Robson and Berkes, 2011; Pretty 2003) primarily appear to underscore the land sharing alternative. Critiques have here primarily: 1) highlighted the risk that land sharing may promote further conversion of natural ecosystems; 2) questioned the capacity of agro-ecological systems to maintain biodiversity while maintaining high yields, and 3) stressed the lack of quantitative / monitoring data to support the contention that land sharing is effective (e.g. Phalan *et al* 2011b; Green *et al*, 2005b).

Recently the dichotomy between land sparing and sharing is being left aside and scholars tends to converge on the issue of whether sustainable intensification of agriculture is a possible and desirable middle path to addresses the critical challenges ahead (e.g. Bacon *et al* 2012; Lawrence *et al.*, 2011). Beyond disciplinary perspectives, the outcomes of this debate are critical, since academic land-use conceptualisations and analyses can yield explicit recommendations towards environmental and development policy, subsidies and natural resource management (see e.g. Balmford *et al.*, 2012; Grau and Aide, 2008; Whittingham, 2011; Pretty, 2003). The way these recommendations are incorporated by governments will in turn strongly influence local livelihoods, land-use decisions, migration patterns and wider transformations in rural – urban systems.

UNESCO Biosphere Reserve as living laboratories for a transition to sustainability?

A key assumption of land sparing proponents is that strict conservation in protected areas can and should be enforced. However, this often implies the exclusion of local communities in the designation, governance, management of natural protected areas, while depriving them of customary rights to land and resources (Adams and Hutton 2007). This in turns results in recurrent non-acceptance and non-compliance with restrictions of use (Holmes 2007). Consequently, although ca 13% of the Earth's land area is officially under some form of protection, many of the designated areas remain ineffective paper parks (Dugelby and Libby 2003; Fischer, 2008).

In this context, one interesting avenue to explore how to reconcile land sharing and land sparing in practice is the framework of UNESCO Biosphere Reserves. The UNESCO Man and the Biosphere (MAB) Program, defined by Batisse (1993: 3), as "the first deliberate international effort to identify ways and means of sustainable development of terrestrial ecosystems" was introduced in the early 1970s to push forward three major aims: (i) conservation, (ii) local development, and (iii) logistic support for education, capacity training, monitoring and research. To achieve these goals, Biosphere Reserves, a distinct protected areas model, conceptually allow the integration of conservation with multiple land use and settlement, based on a tripartite zonation system (UNESCO, 1984; Ishwaran *et al*, 2008).

Land sparing is effectively embedded within Biosphere Reserves, since these clearly demarcate areas set aside for strict conservation (core zones), where neither settlements nor land use are permitted to allow ecosystems restoration and maintenance, while in peripheral zones agricultural land use proceeds. At the same time, Biosphere Reserves actively support a conversion to sustainable agricultural practice and ecologically sound activities in transition and buffer zones in keeping with the land sharing approach. Thus the flexibility of the Biosphere Reserves concept allows a broad range of land use and conservation management strategies, which can help to create a continuum and gradient between land sparing and sharing. For example, biologically diverse cultural landscapes may be protected by maintaining traditional agricultural systems (See e.g. Mitchell *et al*, 2009). Processes of conversion to organic cultivation, agro-ecological certification programmes, regional brands / quality labels and emergent green job markets may be actively encouraged (see e.g. German MAB Committee, 2005). Biosphere Reserves also provide an adequate framework to foster environmental education, capacity building and improve local participation in land and resource decisions (Stoll-Kleemann *et al.*, 2010). Finally, since they are often located at the periphery of important urban areas, they can play an important role in maintaining critical ecosystem services for urban population (e.g. water supply, recreation, etc.) (de la Vega-Leinert *et al.*, 2012).

The World Network currently comprises currently 621 BRs located in 117 countries and is rapidly growing. Biosphere Reserves are envisaged as living laboratories to foster a transition to sustainable development and good environmental governance (UNESCO, 2008). Their overall framework offers interesting exploratory grounds to identify and test land use strategies towards sustainable agricultural intensification, while securing areas for strict ecosystem protection and encouraging a landscape matrix, which supports ecological niches and corridors. Though the designation of Biosphere Reserves per se is no panacea and by no means guarantees that conservation regulations will be better enforced than in traditional protected areas, they offer a very versatile guiding structure to address a wide range of current critical socio-ecological challenges. At times of complex and threatening transformations of our environment, it is precisely integrative frameworks and platforms, which enable social learning, adaptive management and cross-fertilisation between scientific disciplines and between science, policy, management and society, which are most needed to debate, decide and implement together the land use strategies most appropriate to face them.

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Science-policy dialogue for managing land use change: bridges and barriers

Ecosystems have undergone intense changes in their land use over the past centuries, particularly in Europe. These changes have altered the global environment at unprecedented rates, with severe consequences for biodiversity and ecosystems' resilience as well as its capacity to sustain human needs (Tzanopoulos *et al.*, 2013). Effective policies are urgently needed to halt or at least abate ecosystem change and mitigate their impact on human livelihoods (Gerlak, 2013).

These policies are implemented through several conservation strategies; the designation of protected areas that are mostly selected based on their ecological importance, is one of them (Hamilton *et al.*, 2013). Other strategies may focus on safeguarding the livelihoods generated by biodiversity by e.g. introducing payment schemes for ecosystem services (PES) in areas of ecological importance (Swetnam *et al.*, 2011), or the establishment of global initiatives like REDD+ (Reducing Emissions from Degradation and Deforestation). To add to these policies, the technological advances in remote sensing techniques allowed for substantial progress in the field of monitoring and managing land use change (Krishnamoorthy *et al.*, 2002; Boentje & Blinnikov, 2007; Brink & Eva, 2009; Gross *et al.*, 2013). Whether these advances are actually contributing to policy implementation remains questionable and case-specific (Easterly, 2006; Paloniemi *et al.*, 2012). To ensure that environmental change is well addressed and managed an open dialogue between policy makers and scientists is essential. At the same time, ecological, economic and social parameters and the interaction among them, need to be taken into account by both parts (Padilla *et al.*, 2010; Tzanopoulos *et al.*, 2013).

Typically, environmental policy sets the requirements, which are then forwarded to the scientific community and guide scientific research. The research output should then give feedback to support the land use management and planning to address policy requirements (Perrings *et al.*, 2011; Egoh *et al.*, 2012; Maes *et al.*, 2012). The interaction between science and policy is thus inevitable to successfully deal with nature protection (see also Figure 1). Despite it's obvious significance, this interaction has been frequently criticized as inefficient (e.g. Paloniemi *et al.*, 2012) fact that has been attributed to different types of barriers (e.g. political, economic, ecological, social) (Apostolopoulou *et al.*, 2012). For instance, many examples of misinterpretation of scientific research outputs by the policy makers have been documented (Primmer & Furman, 2012) and have been attributed to different types of parameters, like social and ecological complexity (e.g. Paloniemi *et al.*, 2012).

In our study we will investigate **whether there is indeed a barrier in the communication channel between policy and scientific research regarding land use management and explore some of the parameters that could be affecting this communication**. We focus on areas that lie under management regimes either protected by specific Directives or any other management schemes (e.g. PES) and lie within the European continent. Europe is at the forefront of developing and implementing multinational conservation efforts, such as the Habitats' (92/43/EEC) and the Birds Directive (79/409/EEC) or the Common Agricultural Policy (CAP, 1962) towards a fair standard of living for farmers, a stable and safe food supply at affordable prices for consumers and a balanced development of rural areas throughout the EU. Europe is also one of the most densely populated continents where natural areas have experienced major alterations compared to other parts of the world and has a long history of human-dominated landscapes.

We carried out a systematic review of scientific and grey literature (e.g. technical and project reports) on the management of land use change regarding protected areas in Europe. We focused on **indicators** used to assess and quantify land use change. We extracted information on the spatial, temporal and administrative **scale** of the indicator, but also the **terminology** and **technology** used to assess and communicate the research results. In other words, for each indicator we extracted

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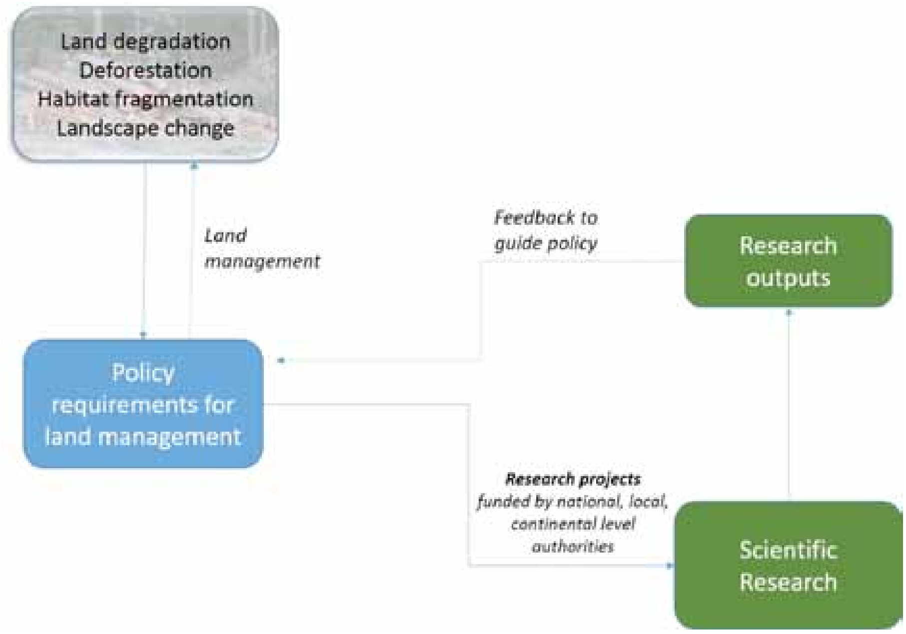

Figure 1: Science-policy interaction for the management of land use change. The blue rectangles represent the policy component while green that of scientific research. The continuous arrows stand for an established link, while the dashed ones are those whose nature we are investigating.

information on how it is being used/assessed/calculated in scientific research and how it is being used/received/interpreted across the different stages of policy. By doing that we obtained a broad overview of three major components (scale, terminology and technology), which potentially interfere in the science-policy dialogue. On the issue of scale for example, depending on the level at which policy requirements are being made and the level at which they are being implemented and managed, potential mismatches can occur thereby affecting the governance of a specific piece of land. European policies usually follow top-down approaches, are driven by national, regional, continental level requirements and are applied at the local /regional /national level needs (Figure 2).

The outputs of this review will be used during one workshop to open the floor for discussion among the participants. The participants will be divided into smaller groups and participate in round-table discussions focusing on specific topics: one for scale, one for terminology and one for technology. During the discussion participants will be invited to give their opinion based on their working experience on each of the three different topics. Each discussion group will be facilitated by experts on the fields of scale, terminology and technological advances used for land use management. The workshop organisers will have the role of the "rapporteurs" recording the participants' contributions.

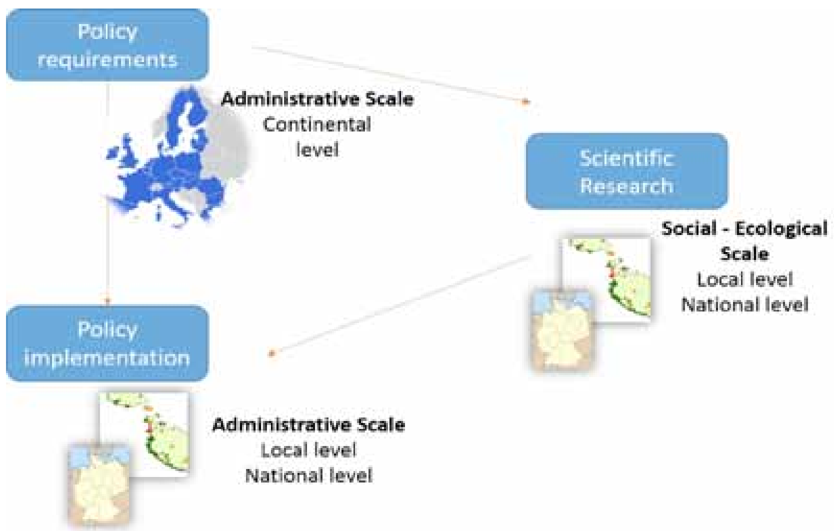

Figure 2: Example of scale mismatches on the governance and management of land use change. The policy requirement is made at a continental level (EU member states) and the scientific research carried out to give input to this policy requirement happens at the local or national level of the ecological scale. The output of this research is then reported at the EU level in order to apply specific measures at the administrative scale where the decisions are being made. The up and downscaling made at the different stages of this process could be problematic and there have been many examples of misinterpretation of scientific research by the policy makers due to similar issues (Primmer & Furman, 2012) .

Using the feedback from the participants in combination with the review outcomes, we will draft a research article aiming at presenting in a systematic way the steps that are needed to have a more efficient science-policy dialogue when managing land use change (Figure 3). This workshop can be the first step towards the formulation of a working group that will be addressing these issues.

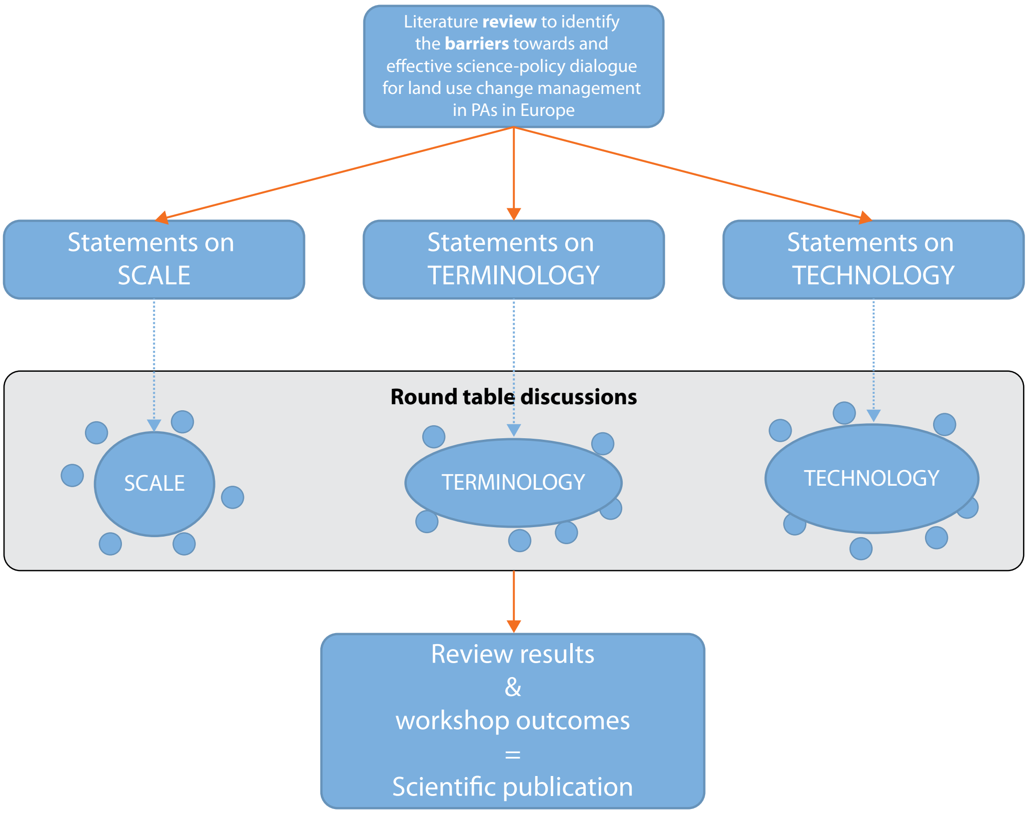

Figure 3: *Graphic representation of the workshop structure. Continuous orange arrows represent the work carried out by the working group before and after the conference. The blue dashed arrows represent the interactive work carried out during the Open Science Meeting.*

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Geospatial technologies, indigenous institutions and sustainable land governance in developing countries

Introduction

For many years, several developing countries have experimented with several models to answer their land questions. Often times, governments in the Global South introduced centralized tenure systems that fail to integrate indigenous land governance institutions. Indigenous institutions are based on traditional regulatory practices including custodial responsibilities for managing communal resources and reducing conflicts (Davidson-Hunt, 2003; Oldekop *et al*. 2012). Thus, the indigenous institutions are significant for fostering sustainability of land resources and livelihoods. The land questions in the Global South essentially border on access, allocation and sustainability of land resources. These are basically issues relating to governance, which Palmer *et al*. (2009) viewed as "complex mechanisms, processes and institutions through which citizens and groups articulate their interests, exercise their legal rights and obligations, and mediate their differences." On the other hand, the contemporary concept of governance in the opinion of Biermann [with Turney] (2013), involves a non-hierarchical decision making, decentralized policies and involvement of public and private sector in steering society towards sustainability. It is not only decisions that need to be decentralized, knowledge systems could also help towards better understanding of the landscapes and promote their sustainable use by the local people that are embedded in them. The best way to address land related challenges is by integrating modern technologies in managing landscapes associated with people's needs as guided by indigenous value systems. Hence, this paper explores the potentials of coupling indigenous institutions and geospatial technologies towards achieving sustainable land governance in the Global South.

The term geospatial technologies embraces numerous Earth system data capturing technologies such as remote sensing, Global Positioning System (GPS), Geographic Information System (GIS), field sensors, space syntax among others. These technologies handle geographic data to complement various techniques and methods of investigating state of land use and land cover. Thus, Naik *et al*. (2013) suggested that the potential of geospatial technologies in improving the quality of data gathering in the developing countries has increased considerably due to needs for sustainability research. The potential of geospatial technologies has also increased with their integration with mobile and web-based GIS are technological innovations that revolutionise resource management (Abdalla and Li, 2010). One of the most important functions of geospatial technologies is mapping of various land units. Mapping facilitates understanding of land surface processes, its resource base, hazards and chronological evolution. According to Bishop *et al*. (2012), conventional mapping involves terrain classification into conceptual spatial entities such as "morphology (form), genetics (process), composition and structure, chronology, environmental system associations (land cover, soils, ecology)" and how these relate to spatial patterns of landforms. However, what geospatial technologies could add to this are new capabilities that synthesise science and information for better and decentralised decision that favour sustainability and interests of individuals and groups whose lands and landscape systems depend on the traditional land management systems. Such traditional land systems are associated with agricultural landscapes that offer a number of life support services such as foods, energy, biodiversity conservation, local businesses and traditional ecological knowledge.

Indigenous Societies' Landscapes

Most of the indigenous land systems threatened by existing land governance arrangements are

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agricultural landscapes. In recent years, issues such as land grabbing in the Global South attract attention in policy and research cycles because of the huge challenges that it poses to small-scale indigenous land use systems' food security and sustainability dimensions (Anseeuw *et al*. 2012). The main problem of land grabbing is that it favours large-scale land developers, and in this way it swallows small scale land uses. This situation jeopardises poverty reduction and increases risks of environmental sustainability (McNeety, 1995; Schutter, 2011). Many agricultural landscape systems are documented or flagged as systems that need to be conserved. Though, these agro-ecological landscapes could be found in every part of the globe, those found in the Global South are less protected and appreciated by law partly because of lack of robust landscape governance tools similar to the European Landscape Convention (ELC). Presently, there are few global efforts towards conserving some of the agricultural landscapes. The most prominent of such initiatives is known as GIAHS - Globally Important Agricultural Heritage Systems (http://www.giahs.org/giahs/en/). This project was initiated by the UN Food and Agricultural Organisation (FAO) in 2002. The goal of this project is to promote public understanding of agricultural heritage systems based on the need to safeguard the social, cultural, economic and ecological goods and services these systems provide to indigenous peoples. This initiative supports an integrated approach and thus combines sustainable agriculture and rural development. Examples of GIAHS listed agro-ecological landscapes are listed in Table 1.

The list given in Table 1 is not exhaustive of various agro-ecological landscapes found across developing countries. Though most of them are small-size farming landscapes nevertheless, they are fairly distributed across geographic areas that often cut across national boundaries.

Table 1: *Indigenous agricultural landscapes*

S/N	Indigenous agricultural land use system type	Examples from Global South
1	Mountain rice terrace agro-ecosystems	*Pays Betsileo, Betafo; Mananara in Madagascar; Ifugao rice terraces in the Philippines; rice-fish culture or rice-fish-duck systems in Himalayas*
2	Multiple cropping/poly-culture farming systems	*Maize and root crop-based agroecosystems of the Aztecs (Chinampas in Mexico); waru-waru systems or suka collos in and around Lake Titicaca in Peru and Bolivia*
3	Understory farming systems	*Taro-based or root cropping systems intercropped with endemic plant varieties in Papua New Guinea, Vanuatu, Solomon Islands and other Pacific small island countries*
4	Nomadic and semi-nomadic pastoral systems	*Highland, Tropical/sub-Tropical dryland /Arctic systems such as Yak pastoralism in Ladakh and the high Tibetan plateau (India/China); rangelands of Mongolia and Yemen; Maasai pastoral system in East Africa)*
5	Ancient irrigation, soil and water management systems	*Qanat ancient underground water distribution systems for diverse cropping systems in Iran, Afghanistan and central Asian countries and their home gardens and endemic blind fish species living in underground waterways; oases agriculture of the Maghreb/Sahara deserts; traditional valley bottom and wetland management in Lake Chad, the Niger river basin and interior delta and other ingenious irrigation systems in the Bamileke region, Cameroon; Dogon tribescountry in Mali and Diola in Senegal; village tank system in Sri Lanka and India).*
6	Complex multi-layered home gardens	*Home garden systems in China, India, the Caribbean, the Amazon (Kayapó) and Indonesia's East Kalimantan and Butitingui regions*
7	Below sea-level systems	*Kuttanad wetlands in Kerala, India; floating gardens in Bangladesh and South Asia)*
8	Tribal agricultural heritage systems	*Seethampheta in Andhra Pradesh, the Apatani rice fish culture, the Zabo system, the Darjeeling system in the Himalayas)*

Source: based on http://www.giahs.org/giahs/agricultural-heritage-systems/en/

How can Geospatial technologies help?

The most important question is in what way can geospatial technologies play role in improving governance or governance-related issues affecting sustainability of these landscapes on whose existence many poor people depend for their survival. There is no doubt that many local researchers in the Global South understand the value of these technologies in mapping, monitoring and evaluation of these landscapes. However, in most cases, the researchers are constrained by costs of acquiring software packages or licensed extensions of proprietary software. This challenge is offset by proliferation of several open access geospatial data, archives, software packages, and online forums that offer researchers real time assistance to conduct research at zero cost. At the forefront of disseminating open source geospatial information tools is a non-profit organisation namely, Open Source Geospatial Foundation (OSGF) (http://www.osgeo.org/content/foundation/about.html). The open access facilities that this organisation promotes include the following:

- Web Mapping (deegree, geomajas, GeoMoose, GeoServer, Mapbender, MapBuilder, MapFish, MapGuide Open Source, MapServer, OpenLayers)
- Desktop Applications (GRASS GIS, Quantum GIS)
- Geospatial Libraries (FDO, GDAL/OGR, GEOS, GeoTools, OSSIM, PostGIS)
- Metadata Catalogs (GeoNetwork
- Outreach Projects (Public Geospatial Data, Education & Curriculum, OSGeo Live)

According to Bocher and Neteler (2012), the idea for free and open access geospatial technologies started more than 25 years ago, and so far, it has generated more than 350 facilities. What governance aspects need application of the new technologies? In general, these technologies are needed to complement the traditional tools by offering opportunities to enhance accuracy and speed of undertaking land governance related programmes. The application of these technologies do not differ remarkably from issues raised in the World Bank's Land Governance Assessment Framework (LGAF) which according to Deininger *et al.* (2011) include five policy intervention areas covering legal and institutional framework; land use planning, management and taxation; management of public land; public provision of land information; and disputes and conflict management. All these policy intervention area would greatly benefit from application of geospatial technologies. For instance, Whitehead and Marbell (2012) noted that land titling as a land administration activity could be enhanced by geospatial technologies through identifying and integrating relevant spatial/physical information about state of the land. Similarly, these tools could facilitate mapping and spatial analysis of encroachments by mega land development into marginal indigenous landscapes.

In this concluding remark, it is important to highlight that the potentials of geospatial technologies could be realised through their integration into land governance issues in the countries of the Global South. It must be acknowledged that many developing countries remain imbued in land governance crises owing to lack of established pro-poor and pro-sustainability tenure systems. In that regard, civil societies could liaise with local researchers to investigate nature of threats confronting such important landscapes. Consequently, other modalities to protect the interests of communities that depend on such landscapes could be developed and or absorbed into existing land reform agendas. A good example of where this function could be used effectively is mapping of age-long grazing sites of many African herdsmen that were illegally overtaken by the powerful political class and the effect of that has been perennial conflicts between herdsmen and arable farmers.

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Tree cover transitions in tropical landscapes: hypotheses and cross-continental synthesis

Forest transition theory was primarily developed to explain the process of decline (deforestation) and recovery (regeneration) of forest area in both temperate and tropical areas. Most forest transition theory literature use national statistics on forest cover, which refer to a diverse range of tree cover types. As qualitative change between tree cover types is a prominent aspect of the regeneration process, the term 'tree cover transition' may be a more appropriate and useful identification.

It seems that 'trees' were relegated when the world moved its focus to 'forests' as part of the climate debate. The term 'forest' is first of all an institutional marker; there are forests without trees and trees outside forests. Moreover, debates about forest transition have often tried to replace time as the primary X-axis with macroeconomic variables that indicate the changing roles of forest areas once economies develop. However, in the context of tropical countries, the existing hypotheses lack agency- and context-specific explanations. While the logarithm of human population density accounts for 70-80% of variation in the national forest cover fraction, forest transition points can occur at almost any population density and forest cover fraction (Figure 1). They seem to be more likely, however, in countries that already had above-average forest cover in relation to their population density. The identified limitations of forest transition theory include the loose definition of forests (combining primary, secondary and planted forest types), a lack of detail about the forest cover dynamics involved, including its spatial and (multi-)temporal scales, and few explanations of context-specific transitions (Perz, 2008).

Tree cover transition and the underlying hypotheses

Tree cover in landscapes changes in quantity, quality and spatial pattern—and therefore in function—along the forest transition pattern of decline followed by return of trees in a non-linear fashion (Figure 2a). The same total amount

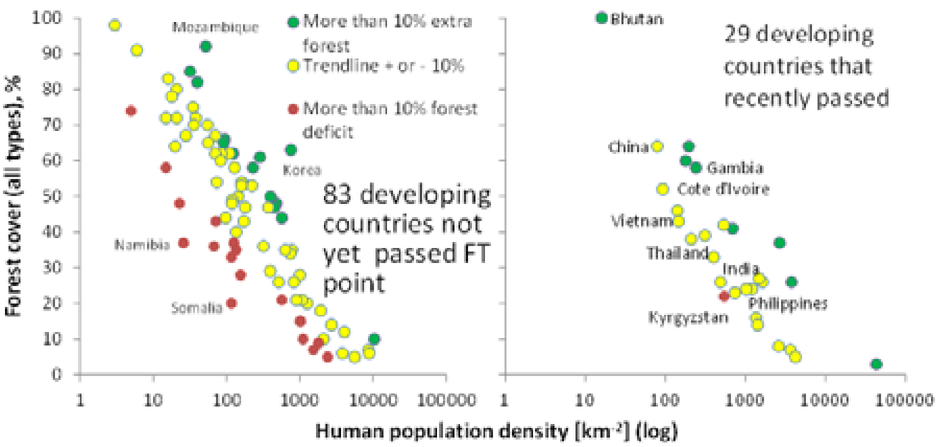

Figure 1: *Relationship between human population density and percentage forest cover at the national scale, with indication of countries that are more than 10% above or below the average trend, and distinguishing between the countries before (left) and after (right) a reported increase in national forest cover (forest transition (FT) point); based on the dataset found in Kothke et al. (2013). The graph on the left shows countries that have not (yet) reached the FT point; the graph on the right shows those that have, at the population density and forest cover shown.*

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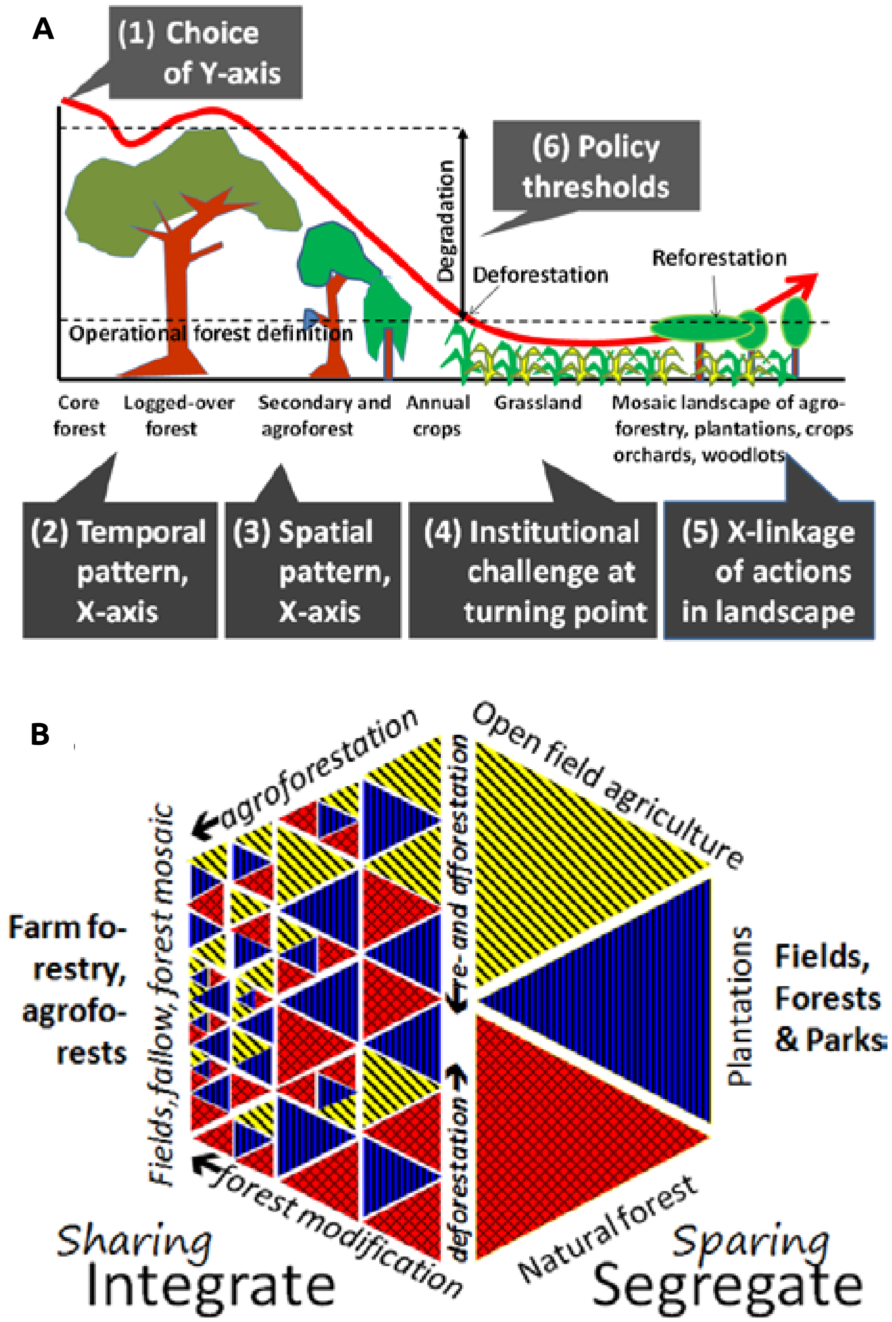

Figure 2: *Tree cover transition in the landscape (a), and spatial pattern of different land use types associated with the sharing versus sparing approaches, respectively (b).*

of natural forest area, open field agriculture and tree (crop) plantations, respectively, can be arranged in an integrated or segregated spatial pattern (Figure 2b) using both land sparing and land sharing approaches to achieve the multifunctionality that local communities want and/or need. Tree cover is best described as a spatially and temporally dynamic continuum, with trees— established spontaneously or planted. Land use policies, however, dissect this continuum into a forest versus non-forest dichotomy; this tends to give undue weight to a forest definition, which is a major challenge to both the fairness and efficiency of policy implementation (van Noordwijk *et al.*, 2012a).

In a global comparative study of the dynamics of forests, trees and agroforestry (FTA) by the CGIAR research program, we framed 12 hypotheses related to the multiple versions of a tree cover transition to test under the CRP 6 FTA program. The hypotheses span a full circle that connects actors, underlying drivers and leverage points, as well as consequences, stakeholder evaluations and opportunities to manipulate points of leverage (Figure 3).

As specified in hypothesis 4, an increase in desirable types of tree cover is often triggered by a transition from forest to agrarian rules of land tenure, due either to generic policy reform or to location-specific reclassification of land.

Until recently European Union rules assumed that trees and agricultural land use were incompatible, but changes that allow and encourage trees and crops to be combined on the same land unit, are now forthcoming.

'Resilience' (to certain environmental risks and events) has become a popular concept, but it remains difficult to quantify and study. It may be more fruitful to focus on the related concept of 'buffering' (for example, are insurance premiums being paid? Are wetlands and overflows that buffer river flow retained?) as this can be assessed continuously, while resilience is only expressed in response to calamities. Trees have always been valued for their microclimatic buffering roles and, more contentiously, they are often considered to have a positive meso-climatic role as well (van Noordwijk *et al.*, 2013).

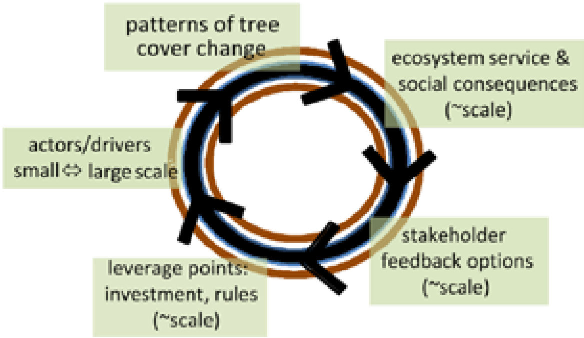

Figure 3: *Logical loop linking patterns of tree cover change to consequences, stakeholder feedback, leverage points, influencing drivers, actors and, ultimately, tree cover change*

Main hypotheses:

	Hypotheses	
1.	Basic forest transition hypothesis	Tree cover in landscapes shows a forest transition pattern of decline followed by recovery.
2.	Population density and welfare hypothesis	Tree cover transitions in time show that an increase in human population density is linked to a decrease in natural forest cover.
3.	Spatial forest transition hypothesis	The spatial pattern of tree cover expanding outwards from centres of human habitation show more than a coincidental resemblance to the temporal dynamics of hypothesis 2 (Dewi et al., 2013). (On the often misunderstood "agroforestation" phase, see Fairhead and Leach, 1995.)
4.	Agroforestation or tenurial reform hypothesis	Institutional change from a forest focus to an agrarian regime of tenure and control is essential for supporting the transition from decline towards increase and recovery of tree cover (Akiefnawati et al., 2010).
5.	The 'sparing' hypothesis	What happens in one part of the tree cover transition is linked at the driver and/or actor level to other parts of the landscape (leakages). (Lusiana et al., 2012; van Noordwijk et al., 2012b). Sparing can be a positive opportunity to protect trees.
6.	The driver change hypothesis	Drivers of tree cover transition are space/time dependent and knowledge of past drivers in a particular landscape cannot be directly extrapolated to predict future changes; there may, however, be more predictability in the succession of drivers.
7.	Trade-off hypothesis	Land use types that are part of the tree cover transition differ in their effectiveness in provisioning and environmental goods and services (Santos-Martin and van Noordwijk, 2011; Villamor et al., 2011).
8.	Integration, buffer and resiliency hypothesis	Tree cover of all types and at all stages is positively associated with buffer functions in an ecological, social and economic sense, with the spatial pattern and degree of integration linked to human resilience and adaptive capacity in the face of climate and market variability (Figure 1b) (Nguyen et al., 2013; van Noordwijk et al., 2013).
9.	Diversity of stakes hypothesis (including gender specificity)	Appreciation of tree cover and its associated ecosystem services varies according to gender and ecological knowledge (Villamor et al., 2013; Villamor and van Noordwijk, 2011).
10.	'No silver bullet' hypothesis	Feedback mechanisms from beneficiaries of (certain types of) tree cover to drivers/agents can take multiple forms and produce various outcomes (rules, incentives, suasion, investment in value chains and technology, and so on) (Jackson et al., 2012; Lopa et al., 2012; van Noordwijk et al., 2012a). Context-specific feedback is most effective.
11.	Negotiation support hypothesis (including gender specificity)	The dynamics of tree cover changes can be influenced by multi-stakeholder negotiation support processes that recognize the diversity of knowledge, perceptions, stakes, power and influence (Villamor et al., 2013).
12.	Impact pathway hypothesis	Public discourse on aspects of tree cover transition and the relevance of interventions follows a policy issue cycle (Clark et al., 2011; Minang and van Noordwijk, 2013).

The analysis of tree cover change in current landscapes is often part of negotiation support, rather than decision support science (Clark *et al.*, 2011), as multiple stakeholders have different claims to the legitimacy of their knowledge and interpretation of a complex reality. Rather than having a single 'footprint' value, many commodity value chains have a wide management swing potential (Davis *et et al.*, 2013). An 'issue cycle' is occurring, in which new issues are constantly being framed and proposed, with only some reaching the level of wider public and policy concern and fewer still reaching the stage of policy solutions. The role of scientists varies with the phase of the cycle. While 'impact pathways' are more easily framed for mature issues with imminent solutions, science plays at least an equally important role in the early sifting of new concerns, and in recognising which issues merit of further exploration.

Global comparative landscape networks

Tree cover transition is considered to be a unifying concept encompassing issues related to livelihoods, landscapes and governance. A global comparative network of landscapes where the socio-ecological, economic, political and institutional aspects of tree cover change are closely monitored can help to produce a salient, credible and legitimate perspective on issues at all stages of the policy cycle. A global network of landscapes like this is utilized in the on-going research programs of the various institutions involved in the CGIAR's Sentinel Landscapes Project in Cameroon, India, Indonesia, Malawi and Vietnam, together with scientific contributions from partner institutions in West Africa, particularly in Burkina Faso, Ghana and Mali (Figure 4).

We welcome further partnerships and cooperation in this effort to combine local, national and international scientists and stakeholders seeking solutions based on the functions of tree cover in multifunctional landscapes, replacing the current emphasis on form and formal forest definitions.

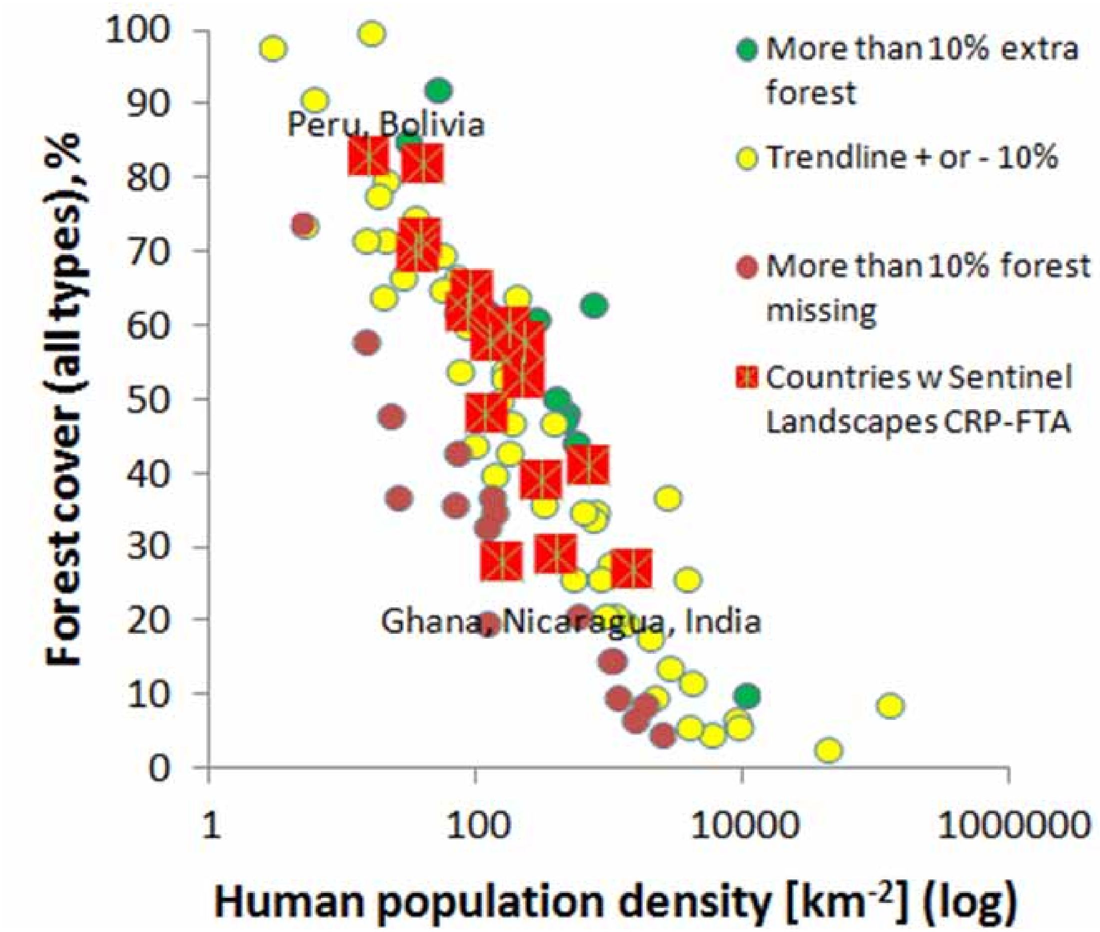

Figure 4: *Countries included in the network of Sentinel Landscapes studies by the CGIAR research program on forest, trees and agriculture (CRP-FTA).*

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REDD-PAC: Modeling land-use at global and national scales to support REDD+ policies

Reducing Emissions from Deforestation and Forest Degradation, plus conservation and enhancement of forest carbon stocks and sustainable management of forests (REDD+) has become a major component of continuing negotiations under the United Nations Framework Convention on Climate Change (UNFCCC). REDD+ aims to achieve sustainable and efficient emissions reductions through the generation of measurable, reportable and verifiable REDD+ credits that are linked to a robust financing regime.

Implementation of REDD+ potentially requires a wide range of policies and activities. Such REDD+ programmes have the potential to deliver multiple benefits, including ecosystem services and social benefits, and also carry some social and environmental risks. Recognition of the potential for risks and benefits prompted the UNFCCC to put in place safeguards for REDD+, which highlight some specific risks that should be addressed and include a request to 'enhance other social and environmental benefits' (UNFCCC 2010). An increasing number of countries are interested in planning for multiple benefits from REDD+, and in anticipating its potential impacts, including on biodiversity.

Currently, there is a need to build furthercapacity and technical know-how on issues that will ensure the efficiency, effectiveness and environmental integrity of REDD+ implementation, ranging from the development and implementation of methodologies for identifying reference emissions levels for REDD+ to basic planning for multiple benefits and the operationalisation of safeguards. Consequently, there is a need for support to countries on REDD+ and land use planning in relation to the safeguards negotiated under the UNFCCC and the objectives of the CBD. This includes assistance in undertaking initial spatial analyses on potential benefits, as well as in developing high quality, spatially explicit assessments of the impacts of REDD+ policy options.

REDD-PAC aims to help support countries in REDD+ planning by refining a global land use model (GLOBIOM) for use in scenario analysis of land use changes under different REDD+ policies up to 2030 (or even later). The output of the project will be a jointly developed cluster of fully integrated regional and national land-use models. Data about land cover, land use, deforestation drivers and biodiversity will be combined with physical and economic models in a globally consistent way so as to provide a spatially-explicit and multi-criteria assessment of country-relevant REDD+ policy options. Analyses will take account of existing land use policies and assess the impact of potential future policies, including policies that incorporate biodiversity conservation priorities into REDD+ planning. The land use change outputs of the model will be used to assess the economic and biodiversity impacts of different REDD+ policy options, and their potential role in contributing to progress towards specific goals, such as the CBD's Aichi Biodiversity Targets, economic growth or food security.

The geographical focus of REDD-PAC is on Brazil and the Congo Basin, two regions that encompass 60% of the world tropical forest area. There is a contrast in the situation between these two areas with respect to deforestation. Brazil has experienced a high historical deforestation level but the recent trend is a decrease in the deforestation rate. On the contrary, the Congo Basin has experienced a low historical deforestation level but the recent trend is an increase in the deforestation (and degradation) rate.

The project involves two international research institutes --- namely, the International Institute for Applied Systems Analysis (IIASA), through its activities in integrated modeling of ecosystems services led by Dr. Michael Obersteiner; and the UNEP World Conservation Monitoring Centre (UNEP-WCMC), focusing on forests and their biodiversity in relation to climate change through Dr. Valerie Kapos. The regional project partners ---

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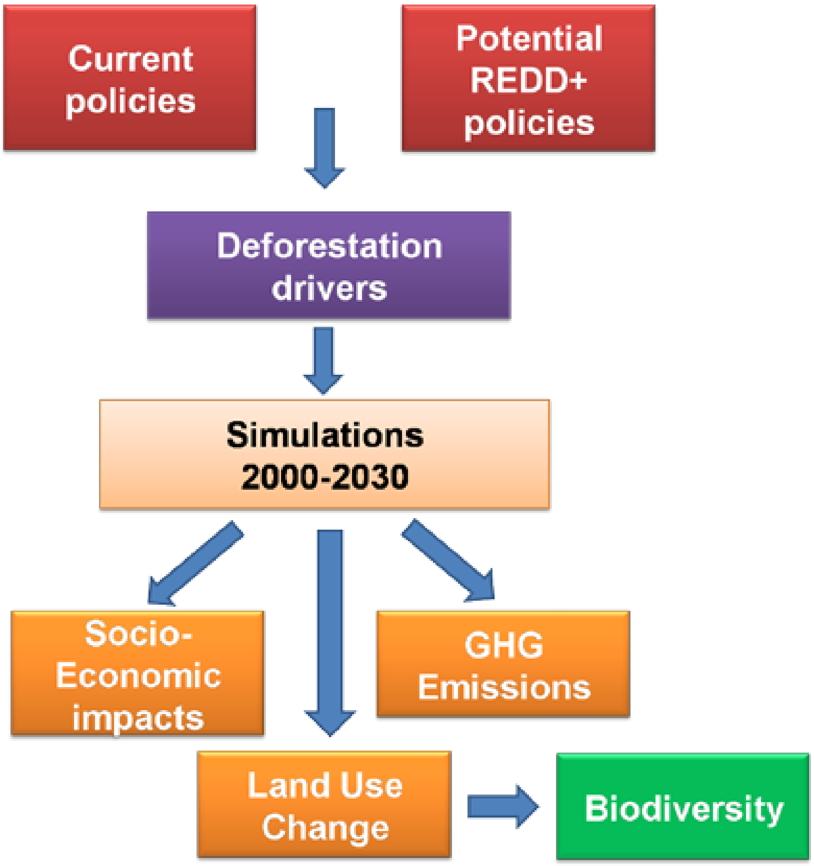

Figure 1: *Scenario analysis in REDD-PAC.*

the National Institute for Space Research (INPE), with Dr. Gilberto Cámara; and the Central Africa Forests Commission (COMIFAC), with Mr. Martin Tadoum --- will lead in identifying and defining policy options for REDD+ and land use. They will also participate in developing the regional/national versions of GLOBIOM by incorporating new data and adapting the land-use change data and mechanisms to the local specificities.

The project is also supporting work on multiple benefits from REDD+ with national partners in a further six countries (China, Ecuador, Peru, the Philippines, Uganda and Vietnam). Led by UNEP-WCMC, this work will draw on spatial analysis of potential benefits from REDD+. The work in each country will betailored to the specific needs of the country, and therefore will vary amongst them.

For a maximum policy impact of the work undertaken within REDD-PAC, close cooperation and consultation with national experts, including REDD focal points and decision makers interested in climate change and biodiversity conservation, is crucial. A first technical workshop was organized in Brazil with second-level policy advisers who have a detailed understanding of policy design. It produced a synthesis document reviewing the current land-use policies in Brazil and the way they can be integrated in land-use models (Ywata Carvalho *et al.*, 2012).

This information will be used for building a scenario reproducing the current policy situation. This scenario will be tested on the 2000-2010 period to calibrate GLOBIOM, and run on the 2010-2030 period to provide first tentative results about land-use change expectations if no additional policy is implemented in the future. In a second step, these results will be presented to higher-level policy makers and adjustments will be discussed with the technical group from the first step.

National expertise will be also leveraged for the validation of the input data, for instance through remote computing via a Geo-Wiki interface. Geo-Wiki is a geospatial crowdsourcing tool which allows users to view spatial data on the Google Earth platform and to validate them based on their local knowledge or the Google Earth images (Fritz *et al.*, 2012).

As far as the Congo Basin is concerned, a similar strategy will be adopted to interact with local stakeholders. In this region, REDD-PAC builds on a previous modeling exercise involving IIASA and COMIFAC and aiming at assessing the impact of development trajectories on the Congo Basin forest cover by 2030 (Mégevand *et al.*, 2013). The simulations showed that planned transportation infrastructures had the potential to increase deforestation by a factor of three in the Congo Basin. In contrast, a global agreement on reducing greenhouse gas emissions from deforestation could achieve important cuts in emissions from deforestation in the same area. However, it could also lead to substantial increases in food imports and food prices, which are in contradiction with the food security objectives (Mosnier *et al*., 2012). Within REDD-PAC, the analysis at the regional level will be fine-tuned through improved data, and downscaled at the country level for four pilot countries, namely Congo, the Democratic Republic of Congo, Cameroon and the Central African Republic.

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(Note: REDD-PAC deliverables and project reports can be accessed at http://www.redd-pac.org/documents.php)

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Monitoring global and local land transformations: how can remote sensing and GIS help?

Monitoring and modeling global and local land cover transformations has been an environmental challenge over the past decades. Different methods have been used to assess Landuse and Land cover change pattern in all part of the globe, including both conventional ground survey methods and remote sensing techniques (Lambin *et al*. 2003; Mmom and Arokoyu 2010; Fasona *et al*. 2011). Studies have shown that monitoring landuse and landcover change with conventional ground survey methods takes much time and it is labour intensive. **It is very difficult also to monitor spatiotemporal changes with conventional methods**. Remote sensing and geographic information systems are known for technological robustness to meet challenges of spatial and temporal monitoring of landuse and land cover change (Ouyang *et al*. 2010). The application of remote sensing and GIS techniques in landuse and landcover change analysis has been widely employed by researchers. It has been shown in these studies that this method is not only good for preparing precise landuse and landcover maps, and observing changes at regular intervals of time, but it is also cost effective and time efficient (Wang *et al*. 2010). In local level, using the Niger Delta as a case study, remote sensing offers a variety of advantages in data collection compared to other forms of data acquisition. The Niger Delta has an land extent of about 112,000 square kilometres and makes up 7.5% of Nigeria's total land mass, according to the Niger Delta Regional Development Master-plan [NDRDMP], (2006) report. Multi-dates Landsat images were used for this pilot study. Both remote sensing and GIS techniques were used in this research to quantitatively examine environmental change in the Niger Delta. The research activities include: assessing spatiotemporal change in landuse using classification, post-classification and GIS overlaying methods; examining vegetation degradation using Normalized Difference Vegetation Index (NDVI) techniques, and evaluating coastline change as a result of coastal erosion using principal component analysis, colour composite and GIS analytical techniques.

Security issue is major long standing concern in the Niger Delta, which has hindered quality research in the region. The region is known as a region rife with violent, conflicts, kidnappings and frequent killings (Aaron 2006). Despite these obstacles, there is no doubt that in-depth understanding and qualitative research on environmental change in the region is increasingly needed for better management and future planning. Therefore, this study attempts to use remote sensing to quantitatively examine spatiotemporal change in the environment of the Niger Delta. Remote sensing method is employed in this study because it is a fast method of acquiring up-to-date information over unsecure geographical area like the Niger Delta. Also, Remote Sensing offers a variety of advantages in data collection compared to other forms of data acquisition. Data from satellite imagery are not biased, unlike other means of data collection in which human irregularity and uncertainty are predominant. Using Remote Sensing techniques in this research, it is possible to measure occurrence and rate of environmental change in the Niger Delta without being affected by insecurity anxiety in the region.

The results from this preliminary study show that remote sensing techniques are sufficient to assess environmental change in the Niger Delta. The results also show a significant change in landuse in zone1 between 1984 and 2001, with an increase in urban and farmland, increase in the rate of forest degradation while mangrove started to regenerate drastically from 1999. This pilot study has also shown that several protected areas in the zone have been degraded over the years due to: commercial and communal logging, rapid increase in urban expansion, and conversion of forest to taungya system of farming. The landuse change classification results (Table 1 and Figure 1) revealed three important changes that were consistent throughout the various time slices: an upward trend for urban and farmland; Forest vegetation show a downward trend; Bare ground significantly increased during 1984 -1987

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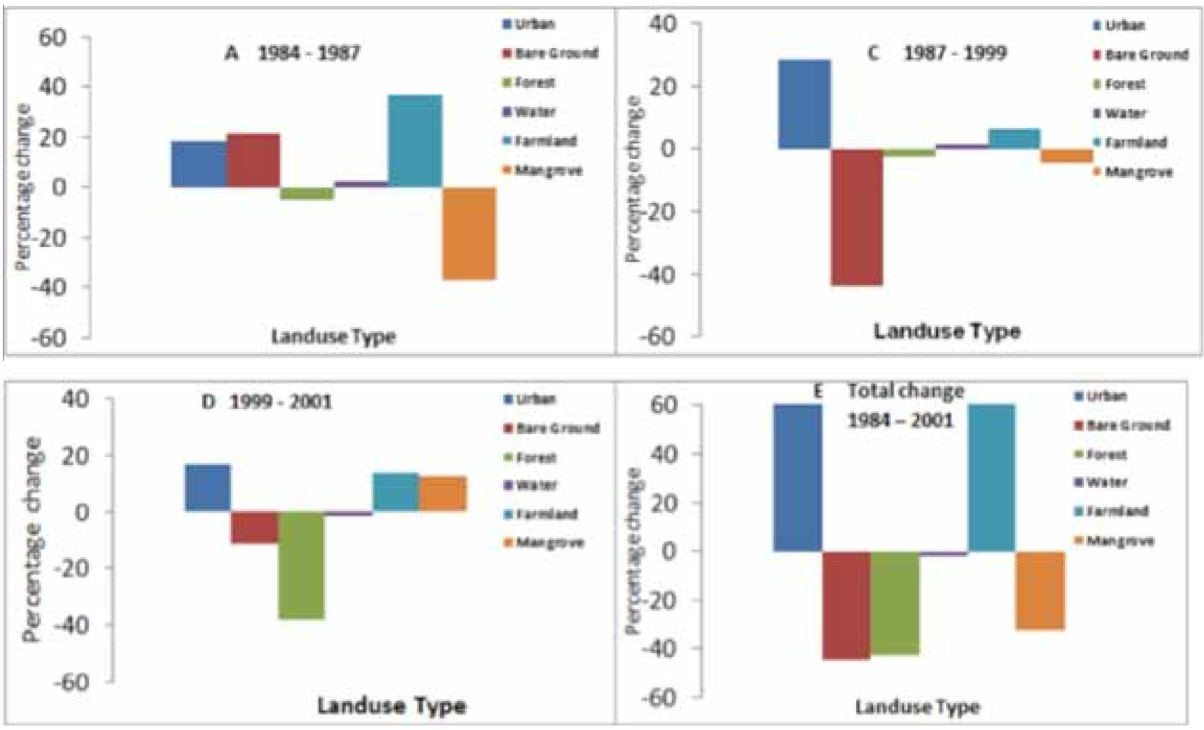

Figure 1: Percentage change in landuse at various times. The figure shows increase in urban and farmland while forest vegetations depict decrease and mangrove decreased during 1984 to 1987 but slightly increased during the subsequent years.

Table 1: This table presents the results of total change in landuse between 1984 and 2001. Urban, bare ground and farmland increased rapidly while vegetation reduced within the periods.

	1984		2001		Total Change (in km²) 1984-2001	
Landuse/Landcover	Square km	%	Square km	%	Square km	%
Urban	544.5	1.1	971.3	2.1	426.8	78.4
Bare Ground	633.1	1.2	382.3	0.7	-280.8	-39.6
Forest	5260.4	10.2	3011.5	5.9	-2248.9	-42.8
Water	38,028.1	75.1	38950.8	78.4	922.7	2.4
Farmland	2625.4	6.3	4340.3	8.7	1714.9	65.3
Mangrove	2998.8	6.1	2025.4	3.9	-973.4	-32.4

and later decreased during 1987-1999 and 1999-2001; while mangrove vegetation decreases during 1984 and 1987 (Figure 1A), but later, a slight increase in mangrove was observed during 1987-1999 (Figure 1B) and 1999-2001 (Figure 1D)

These classification results are complex. In some areas, there are switches between different classes. In some years, there are switches between urban and bare ground while in others there are persistent occurrence of bare ground (Figure 2). Urban change maps have the tendency of overestimating the settlement changes. This confusion of urban and bare ground might be due to the effects of climate seasonality in the study area. To eradicate this error, two steps were taken: (1) climate data for the study area› (from 1984 to 2002) were analysed to observe annual variation in the climate and seasonality and (2) possible landuse changes over time were conceived using decision rule table. This aids our understanding of possible changes that could occur between urban and bare ground classes over the period of study.

In general, the major findings of this study is that during the past few decades, environmental degradation in the Niger Delta has resulted to change in landuse; forests degradation; environmental pollution from oil and gas activities; numerous floods and coastal erosion have been the foremost environmental problems confronting the Niger Delta of Nigeria. These environmental problems have led to losses of arable land, lives and properties. Environmental

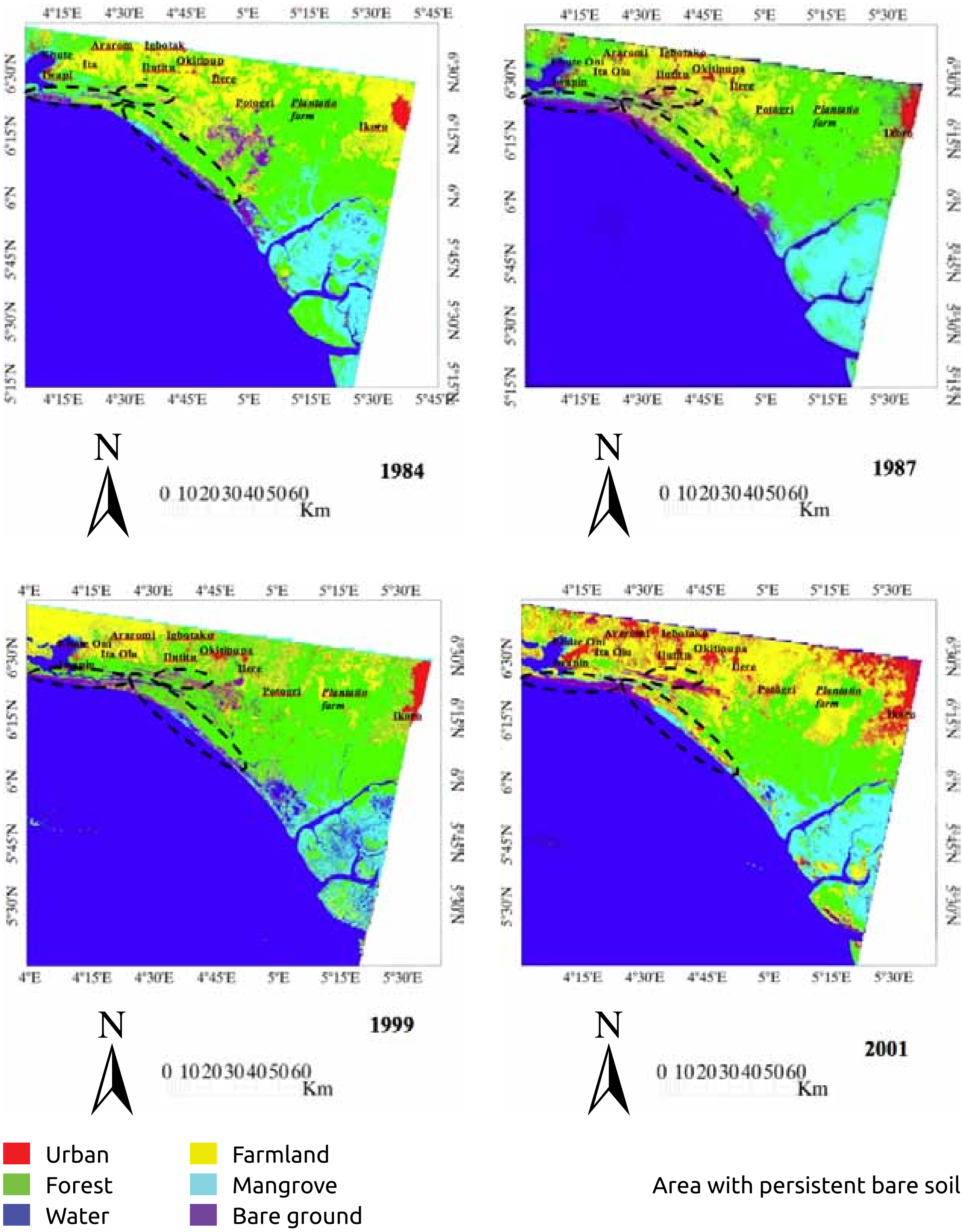

Figure 2: *Landuse change maps of zone1 of the Niger Delta. Maps are classification results showing changes in landuse at various times. Urban and farmland increased while forest decreased but mangrove regained vegetation during 1999-2001.*

change in the Niger Delta is a critical issue, though political and economic issues take center stage in national subject matter nowadays and environmental degradation in the region is yet to be seen as a problem. On the other hand, the people of the Niger Delta are highly dependent on this decaying environment for their source of livelihood. Local inhabitant traditionally made their living as farmers, fishermen and hunters through exploitation of the resources from land, water and forest. However, the environment, health, social and the economic activities of the people were distorted as a result of the environmental degradation resulting from uncontainable environmental exploitation activities of multinational oil companies and other industries in the region. A report in the Niger Delta Regional Development Master-plan [NDRDMP] of

2006 stated that water-related diseases are one of the most critical health problems in the Niger Delta and the health issue most closely linked with environmental degradation. Moreover, the outcome of this research offers an inimitable opportunity for developing a multi-disciplinary approach to the appraisal, management and control of environmental change in the region. **This is highly indispensable if the Niger Delta is to recover from decades of environmental decline inflicted on the region by a variety of oil and gas explorations and other human activities.**

Figure 3: *Photo taken during field work in Okomu.*

Figure 4: *Photo taken during field validation of remote sensing analysis.*

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Global Geo-Referenced Field Photo Library

Land cover maps are fundamental information for understanding the dynamics of the biosphere and its interaction with the geosphere. The accuracy and reliability of land cover maps depend on, to a great degree, the quality and quantity of ground truth or reference samples. Numerous studies have used GPS and digital cameras to document land cover; however, few of those field photos are shared among the research community, which greatly hinders development and evaluation of land cover maps across scales from regional to global. In an effort to support community remote sensing, researchers at the University of Oklahoma released the Global Geo-Referenced Field Photo Library (http://www.eomf.ou.edu/photos) in December 2011, which allows researchers to share geo-referenced photos from their field surveys. It also serves as a citizen science data portal, so that people with GPS cameras and smartphones can contribute geo-referenced photos of landscapes they care about. **This Field Photo Library project enables researchers, stakeholders and citizens to share, visualize, and communicate their ground truth data.**

Who needs the Global Geo-Referenced Field Photo Library?

Ground truth samples are always a critical concern for algorithm development and map validation in the study of land use and land cover change. In the past few decades, researchers have used digital cameras to take photos during field surveys, together with GPS receivers to record where they took photos. In recent years, significant technological advances have been made in integrated GPS cameras and smartphones. Geo-referenced photos of landscapes have always been used as a key element for land use and land cover mapping in individual research projects, but few photos are shared among the research community. There is an urgent need to rescue (or archive) those field photos taken years ago, and there is also a need to share field photos taken in the past and in the future. The Global Geo-Referenced Field Photo Library at the University of Oklahoma (http:/www.eomf.ou.edu/photos) is a data portal that aims to address these needs in the research community (Xiao *et al.*, 2011). In addition, as millions of people are using GPS smartphones, the Field Photo Library also provides an opportunity for engaging a large number of stakeholders and citizens to participate in field data collection through taking photos of landscapes they visit. It now hosts approximately 62,000 geo-referenced field photos as of March 2013 (Figure 1).

Figure 1: *Spatial distribution of photos in the Global Geo-Referenced Field Photo Library (http://www.eomf.ou.edu/photos).*

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How to contribute to the Field Photo Library?

A registered user can upload, query, and download the geo-referenced field photos in the library (Xiao *et al.*, 2011). The privacy setting for individual photos includes both public and private modes. A public photo is shared with the public but a private photo is used and available only to the photo provider. Photo providers can choose which photos will be "public" or "private", and can change permission of photos at any time. The photo uploading process is simple and convenient, and the platform allows for batch uploading. The uploaded photos are shown in a WebGIS interface with Google Earth as the base map (Figure 1). **Users are encouraged to annotate their photos by providing detailed land use and land cover information and field notes**. Users can search photos by several methods, including attribute and spatial queries. Photos selected from query results can be downloaded in three formats (CSV, KML, and ArcGIS shapefile). Detailed instructions are available on the webpage (http://www.eomf.ou.edu/photos/), including how to take field photos for different targets (e.g., land cover types, Figure 2), how to upload, edit and download photos, and how to link GPS information with photos that are not geotagged.

Applications supported by the Field Photo Library

The Field Photo Library has been linked to the global MODIS image database (from 2000 to present), including MODIS land surface reflectance products (MOD09A1). Users can retrieve time series MODIS data for a MODIS pixel where a field photo is located and download the data in Excel files. Users can also visualize the time series MODIS data online with graphs (Figure 3), for example, to identify cropping intensity (single, double), crop calendar and phenological phases. **This service greatly expedites exploratory data analysis for users.**

Geo-referenced field photos have been used to support algorithm development and map product evaluation in the study of land cover classification. **Users can download selected field photos into a KML file and open them in Google Earth**. Google Earth hosts very high spatial resolution images (as low as 1-m resolution) in many parts of the world. The photos provide precise and detailed land cover and vegetation characteristics that can be considered points of interest (POIs). They can be used to assist in image interpretation in Google Earth and digitizing polygons of land cover types as regions of interest (ROIs). The resulting ROIs can be converted and opened in image processing software (e.g., ENVI and ERDAS), and can be used for both training and validation samples. This workflow from field photos and Google Earth to land cover map was successfully implemented and reported in two recent papers (Dong *et al.*, 2012b; Dong *et al.*, 2012a).

Broaden participation and use of the field photo library

The Global Geo-Referenced Field Photo Library was originally designed for researchers to share, visualize and archive field photos that document croplands, forests, grasslands and wetlands at a worldwide extent, and will continue to serve the community who studies land use and land cover change. In addition, we also believe that it can be customized and used to support several other domains of studies that need location-based information. For example, hydrologists use geo-referenced field photos to record water levels and flood events. Weather and climate scientists use geo-referenced field photos to document the impacts of severe drought on the agriculture and water resources. Geo-referenced field photos can also be used to document the color of rivers

Figure 2: *A simple, standard protocol for taking photos in the field. Taking photos from the center of the area of interest (downward and upward if applicable) as well one in each direction (N, E, W, and S) will give a general idea of the landscape, size of the area and neighboring features. Upward photos are not necessary in some landscapes grasslands and croplands, but useful in tropical forest areas.*

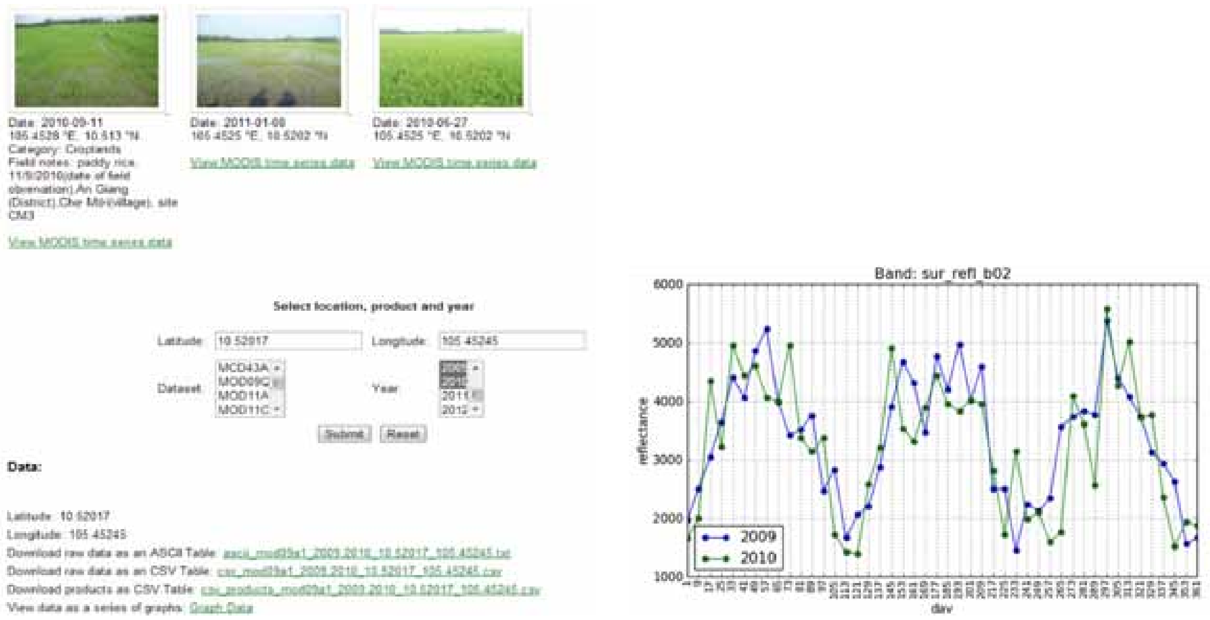

Figure 3: *Extraction of time series MODIS data product (MOD09A1) based on selected photo. The results are available in ASCII text, CSV formats (left figure), and online graphs (lower panel).*

or lakes that reflect water quality and harmful algal blooms. Zoologists can use geo-referenced photos to record the locations of species occurrence, which help to improve ecological niche models to predict species distributions. Epidemiologists take geo-referenced field photos during zoonotic infectious disease surveillance to record landscapes where disease outbreaks occurred, and the resultant information will better track disease transmission. We encourage more scientists, stakeholders and citizen scientists to participate in the acquisition of geo-referenced field photos and contribute to the library.

In an effort to better serve the community of land cover mapping, we continue to improve the performance of the field photo library, and plan to add new functions and services. For example, in addition to hosting photos, POIs, from the field, we plan to develop a capacity to generate and host regions of interest in the format of polygon KML files that can be used directly for land cover classification. We believe the forthcoming ROI database will greatly promote global land cover mapping efforts in the future. However, a comprehensive ROI database will require contributions from users and colleagues all over the world while continued maintenance and updating of the platform will depend on whether it is widely used by scientists. We encourage the Global Land Project community to join the field photo library and believe that this platform will provide valuable information and tools for your current and future research activities.

Acknowledgements: The Geo-Referenced Field Photo Library project was funded in part by the NASA Land-Cover/Land-Use Change Program (NNX09AC39G), NASA Public Health Program (NNX11AF66G), NIH Fogarty International Center (R01-TW007869), and NSF Experimental Program to Simulate Competitive Research (NSF-0919466).

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Jasper van **Vliet**

Globalizing Our Understanding of Land-use Change

A geographer, ecologist, anthropologist, and economist walk into a research center …

No, it's not the beginning of a bad joke, but **the beginning of a very productive workshop that convened recently at the National Socio-Environmental Synthesis Center (SESYNC)**. Earlier this month, Principal Investigators Dr. Jasper van Vliet of the University of Amsterdam and Dr. Erle Ellis of the University of Maryland – Baltimore County led scholars, from an array of disciplines and institutions, through an examination of land-use change. Land-use change is broadly understood as how humans use land—to fulfill, for example, our demands for food, forest products, and energy—and how those uses change land cover, including beaches, agricultural lands, and urban environments. Specifically, the group was interested in **finding patterns among and cultivating shared perspectives on the causes and consequences of land-use change on a global scale.**

Although geographers, ecologists, anthropologists, and economists have most certainly researched and synthesized data related to land-use change before, the workshop participants hadn't all done so together. Scholars from these disciplines have their own journals; their own conferences; their own ways of thinking about problems and approaching solutions. This SESYNC workshop offered these researchers who, in most cases, had never before worked with one another—an opportunity to sit at the same table to formulate shared understandings of the drivers and outcomes of land-use change.

The workshop's principal focus was to determine next steps **within a larger research effort of the Global Land Project on globalized understandings of land changes**. One theme that emerged was the importance of disseminating research results to communities that make decisions about and are impacted by changes in land use, especially policy makers. "Co-designing" the team's research agenda—i.e., planning research objectives and approaches together with stakeholders who would use the knowledge generated—will help close the gap between what scientists do and what information policy makers need.

By integrating new perspectives, this workshop is driving the team's work forward in novel and exciting ways. According to Dr. Ellis, the experience "open[ed] the door on broadening the thinking about how land changes and how we can synthesize our knowledge about that. And that, of course, is a little bit scary. You get out of your comfort zone—what is it that we aren't really sure about? That's the cutting edge. And we're definitely there."

About SESYNC

The National Socio-Environmental Synthesis Center (SESYNC) is a national research center funded through a National Science Foundation grant to the University of Maryland.

Located in Annapolis, MD, SESYNC is dedicated to solving society's most challenging and complex environmental problems. We foster collaboration amongst scholars from a diverse array of the natural and social sciences (such as ecology, public health, and political science), as well as stakeholders that include resource managers, policy makers, and community members.

Socio-environmental synthesis is a research approach that accelerates the production of knowledge about the complex interactions between human and natural systems. It may result in new data products—particularly ones that address questions in new spatial or temporal contexts or scales—but may also involve evaluating textual or oral arguments, interpreting evidence, developing new applications or models, or identifying novel areas of study.

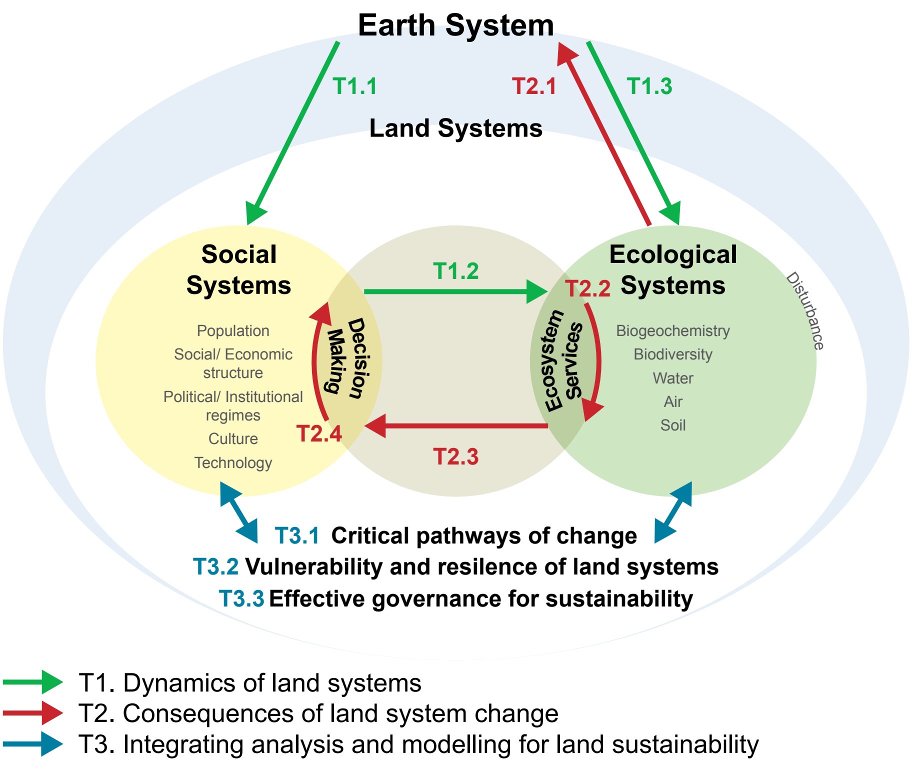
Gregory B. **Greenwood**

The Mountain Research Initiative (MRI): Concerted efforts in mountain research

The MRI continually searches for the next steps in promoting global change research in mountains. Since the Swiss National Science Foundation (SNF) renewed the MRI's funding in 2010, the MRI has pursued its program of global and regional networking activities, synthesis workshops, and new communication modes, but is going beyond them now to investigate more sustained efforts.

While any research into global change in mountains represents progress, research that adds to an understanding of the "whole system" - the coupled human-natural system within mountains as it is embedded within the planetary earth system of atmosphere, oceans and continents - is one of MRI's principal scientific goals. **The MRI makes liberal use of the analytical structure of its parent scientific organization, the Global Land Project**, as it captures the linkages and the embedded-ness and speaks as well to the evolution of the whole system toward or away from sustainability.

This emphasis on whole systems creates a certain tension in MRI's work, as research by its analytic nature, tends to focus on mechanisms and parts of systems. This is as it should be: to create an integrated understanding, one must have parts to integrate! Thus, while encouraging research on specific parts of the coupled human-natural system, MRI must at the same time promote the continual interrogation of how these parts come together to create a whole system.



The Global Land Project Analytical Structure (GLP 2005).

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To achieve an understanding of the whole system, MRI must work to create true community out of a collection of disparate researchers and institutions. Whenever MRI invokes "community" it is perhaps more a statement of a goal than a characterization of the current condition. MRI works toward community via entities such as its regional networks in Africa, Latin America, and Europe and via sister organizations such as CIRMOUNT under the presumption that more frequent exchange between researchers working in the same region will lead eventually to more collaboration on the understanding of the whole system.

Building community requires years, if not decades, while MRI is funded on a three year cycle by the Swiss National Science Foundation (SNF). As such each successive proposal to the SNF tracks progress toward this long term goal. For several years we have been using the 4 I's as a heuristic to describe our program: Initiation of activities, Implementation of research, Integration of results and Information for stakeholders. To date we have concentrated our effort on Initiation via our Key Contact Workshops and regional networks, Integration via our Synthesis Workshops and Information through Mountain - TRIP. As we are not funded to do research ourselves, it is difficult to approach Implementation directly. The best we can do is to attempt to align researchers in different countries around common research themes, so that their research, funded through their particular mechanisms, creates a longer-term coherent program.

In 2012 MRI ran two workshops on topics key to both GLP and MRI to achieve this synthesis. The first one Building Resilience of Mountain Social-Ecological Systems to Global Change took place in May under the leadership of Julia Klein (Colorado State University) and Anne Nolin (Oregon State University). The workshop will lead to the publication of a synthesis paper based on the 13 case studies presented at the workshop, and a proposal to the US NSF for a Research Coordination Network focused on coupled human-earth systems in mountain regions.

The second workshop - Qualities, Vulnerabilities, and Management of Ecosystem Services in Mountain Regions - took place in Switzerland in September. Participants examined the two hypotheses: Hypothesis 1. Ecosystem services in mountain regions show similar characteristics in terms of the provision, demand and governance patterns. Hypothesis 2. Mountain ecosystem services are the product of landscapes with long land use histories. As such they are highly vulnerable not only to climate change but also to socio-economic transformations. In the course of four days, participants decided to create not two but four synthesis papers looking at different aspects of ecosystem services in mountain regions.

Figure 1: *Nam Co, Tibet. Endorheic lakes in Tibet are expanding over time most likely due to glacier recession. Valuable adjacent grazing lands are thus lost to flooding. © Greg Greenwood*

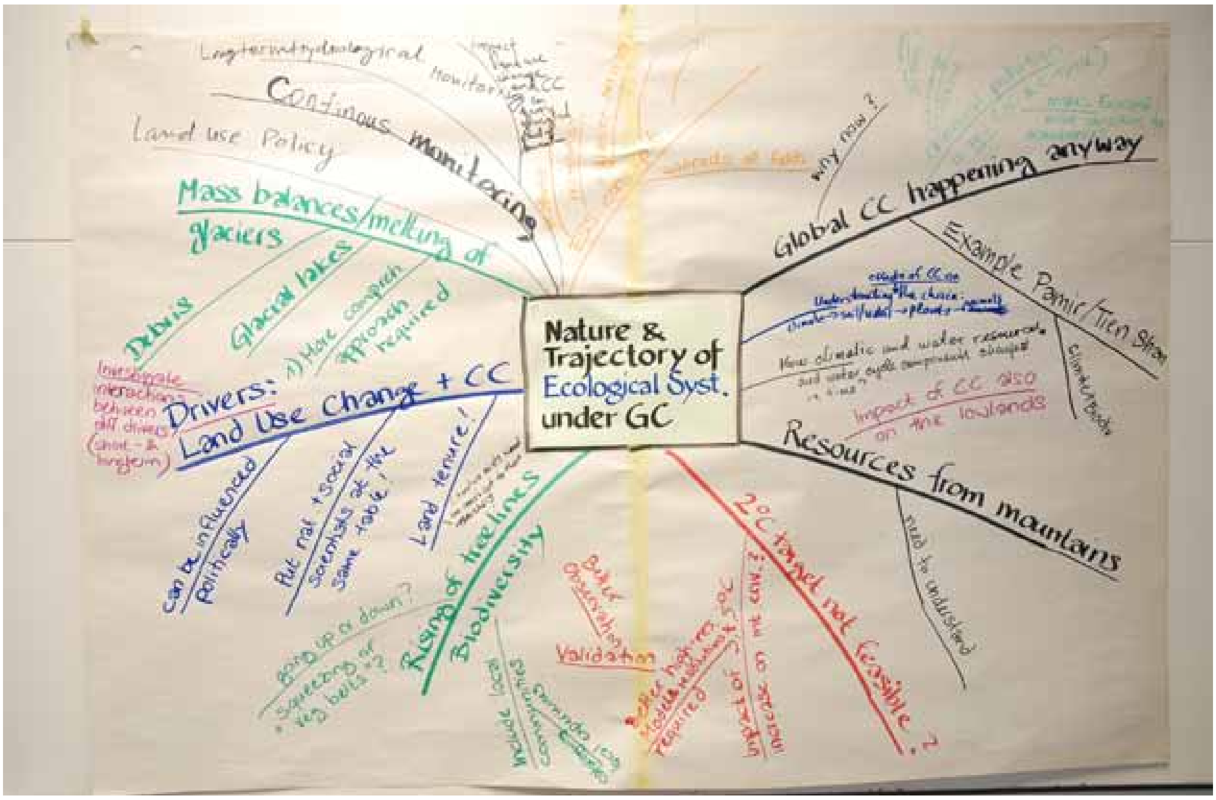

Figure 2: *One of the mind maps resulting of a brainstorming session at the Global Commission meeting in London, in March 2012.*

MRI Global Commission: assessing future research themes

The Conference "Global Change and the World's Mountains" in Perth in 2010 provided a snapshot of the current status of global change research in the world's mountains from which the community constructed assessments of important future research themes (Greenwood 2010, Björnsen *et al.* 2012).

To translate these general themes into more concrete actions, the MRI convened a one-day workshop of the MRI Global Commission at Imperial College on 30 March 2012 immediately following the IGBP Planet Under Pressure Conference. The MRI Global Commission consists of the Swiss Principal Investigators who sponsor the MRI at the SNSF and MRI 's Scientific Advisory Board augmented by active mountain researchers.

The Global Commission brainstormed what the community should do with respect to each of these themes resulting in 10 detailed mind maps. From these mind maps (available at http://mri.scnatweb.ch/gallery/63) MRI created initial descriptions of nine "Concerted Efforts", projects with a longer time frame than that of a workshop.

1. A modeling project to estimate changes in mountain ecosystems with a 3-5° C mean annual temperature.
2. A Global Mountain Treeline Network to detect, classify and understand the changes occurring in mountain treeline ecosystems.
3. A method of quantifying mountain ecosystem services that leads to an atlas portraying ecosystem services from mountain regions worldwide.
4. Locally relevant global change research agendas, developed in ways that promote funding and eventual use of results.
5. A book project that explores why and how decisions are made that strongly influence the trajectory of the coupled human-earth system in mountains.
6. Coupled human-earth system models of specific mountain regions, which can also be part of mountain observing systems (II).
7. A multi-year campaign to answer key question(s) related to high elevation.
8. A network of representative sites in mountain regions around the world wherein researchers follow similar integrated monitoring protocols and address common questions regarding coupled human-natural systems in mountains.
9. A book project on the nature and drivers of human use of mountains.

Much more detailed description of each of these "Concerted Efforts" can be found on the MRI, see link below. In addition I have described certain of these Concerted Efforts in greater detail via a discussion paper posted on the MtnClim 2012 webpage and in the next issue of Mountain Research and Development (N° 32(4)), see links below.

This portfolio of "Concerted Efforts" looks both down to specific issues and up to whole systems, reconciling to the degree possible, the tension embodied in MRI's work. These projects, or ones similar to them, will very likely form a major part of MRI's next three-year program.

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MRI: **http://mri.scnatweb.ch**

Gobal Commission: **http://mri.scnatweb.ch/team/mri-global-commission**

Portfolio of Concerted Efforts: **http://mri.scnatweb.ch/images/stories/Compilation.pdf**

Discussion paper: **http://www.fs.fed.us/psw/mtnclim/program/MRD_Platform_V5_for_MtnViews.pdf**

Mountain Research and Development: **http://www.bioone.org/doi/pdf/10.1659/MRD-JOURNAL-D-12-00096.1**

Thales Sehn **Körting** [1]

GeoDMA: A toolbox integrating data mining with object-based and multi-temporal analysis of satellite remotely sensed imagery

This research describes the PhD thesis presented in August, 2012, by Thales Sehn Körting, describing a free data mining toolbox and a new method for classifying time series of remote sensing images (Körting, 2012). The deployment of a new generation of sensors over the last 20 years has made satellite remotely sensed imagery a very important source of spatial data available for environmental studies of large-scale geographic phenomena. The variety of spatial, temporal and spectral resolutions for remote sensing images is large, ranging from panchromatic images to polarimetric radar images. Despite the great experience in image data gathering and distribution and a diversity of image processing and analysis toolboxes, it is still difficult to find image analysis systems that provide a straightforward fully integrated environment to transform multi-temporal and multi-resolution satellite image data into meaningful information. Taking this into account, the contribution of this work is two-fold.

Firstly, it is proposed and implemented a new toolbox, developed under the Free and Open Source Software (FOSS) foundation, for integrating remote sensing imagery analysis methods with data mining techniques producing a user-centered, extensible, rich computational environment for information extraction and knowledge discovery over large geographic databases. The toolbox is called GeoDMA - Geographic Data Mining Analyst. It integrates techniques of segmentation, feature extraction, feature selection, classification, landscape metrics and multi-temporal methods for change detection and analysis with decision-tree based strategies adapted for spatial data mining (Körting *et al.*, 2013). It gathers remotely sensed imagery with other geographic data types using access to local or remote databases. GeoDMA provides simulation methods to assess the accuracy of process models as well as tools for spatio-temporal analysis, including a visualization scheme for temporal profiles that helps users to describe patterns in cyclic events. Secondly, a new approach for analyzing spatio-temporal data is presented, based on a polar coordinates transformation that allows creating a new set of features which improves the classification accuracy of multi-temporal image databases. As GeoDMA was built on top of TerraView GIS, thematic maps and other results can be produced rapidly, taking advantage of the basic GIS functionalities.

GeoDMA has been applied in different application domains, in contexts of land use and land cover change (Pinho *et al.*, 2012, Reis, 2011 and Saito *et al.*, 2011). Evaluations of the applications pointed out that the GeoDMA toolbox achieved results with a level of integration, from a user perspective, that could not be found elsewhere. More information at http://geodma.sf.net/.

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2014 Global Land Project

2nd Open Science Meeting

Land transformations: between global challenges and local realities

From 19 to 21 March, the Second GLP Open Science Meeting 'Land Transformations: between global challenges and local realities' took place at Humboldt-Universität zu Berlin, hosted by IRI THESys in cooperation with Geography Department.

650 participants from 50 countries met in Berlin to discuss the role of the land system as a platform for human-environment interactions, connecting local land use decisions to global impacts and responses.

The conference aimed to bring together large parts of the international research community working on land change issues, showcase the width and scope of ongoing research, help build a community in this highly interdisciplinary field, inspire new research and facilitate review, theory building and extrapolation.

The conference's main issues were:

1. Rethinking land change transitions:
   Drastic changes in land cover and subtle changes in land management
2. Local land users in a tele-connected world:
   The role of human decision making on land use as both a driver and response to global environmental change
3. Impacts and responses:
   Land systems change to mitigate global environmental change impacts and adapt to increasing demands for food, fuel and ecosystem services
4. Land governance:
   The ways in which alternative approaches to governance of land resources can enhance the sustainability transition

Scientific Steerling Commitee (SSC)

There are four new members in the SSC: Souleymane Konaté, Roy Rinku Chowdburry, Patrick Meyfroidt and Allison M. Thomson

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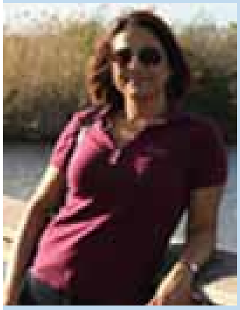

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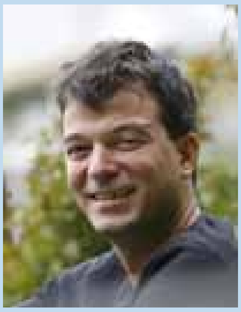

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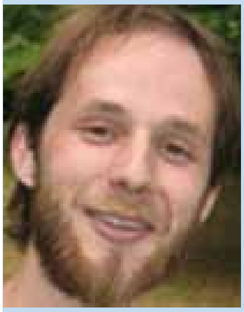

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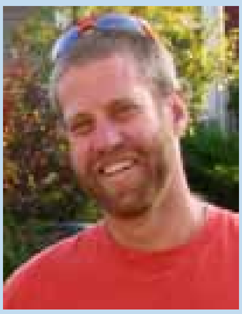

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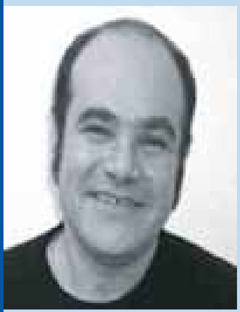

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Christine **Fürst** [1]

New journal launched "Change and Adaptation in Socio-Ecological Systems, CASES"

The interrelations of human beings with ecosystems experience rising importance in sustainable land use planning and lead to the concept of socio-ecological system. **Socio-Ecological Systems (SES) include both, a bio-geo-physical component and the related local to regional actors**. Their system boundaries depend on the problem context and can be either determined by environmental parameters or socio-cultural factors. SES experience constant change and adaptation processes related to utilization, management, policy, ecological, and external influences. **Research on SES is highly inter- and transdisciplinary and faces therefore often problems to find adequate platforms for scientific publications**. Current papers addressing the area are dispersed in journals of different disciplines. Increasingly a larger number of papers on the topics climate and global change and adaptive strategies appears in all related journals. However, these topical journals focus often on narrow, sectoral perspectives (forestry, agriculture, water management, social and economic science research), thus offering little transparency of the reported findings for the exchange of ideas among related disciplines. Other journals that focus on global change, environmental management and planning aspects, on modeling and assessment rarely attempt integrative viewpoints from the socio-ecological system perspective. A further point speaking for a new journal is that studies, related to socio-ecological systems and their change and adaptation, create increasingly cross-disciplinary research results, which frequently face problems to be published in journals with a strict policy of accepting papers within their respective field. The growing body of research of the land system, global and climate change community demands enlarged publication opportunities, especially with a focus on system adaptation. Therefore, a **new journal "Change and Adaptation in Socio-Ecological Systems (CASES)" is launched by Versita / de Gruyter as contribution to the publication activities within GLP**.

CASES aims at offering a forum for R&D (a) on changes that impact the functioning of socio-ecological systems such as climate change or global change and (b) on measures, strategies and policies in tackling and adaption to current and future changes. Focus is laid on inter- and trans-disciplinary work oriented on solving questions and problems, but also theoretical papers that provide in depth-analysis and concise overview are welcome.

CASES addresses more in detail (i) observations on highly relevant global, regional and local drivers of changes and their effects on socio-ecological systems, (ii) knowledge, techniques, approaches and concepts of how to further develop, manage and adapt socio-ecological systems in their political, cultural and natural context and (iii) approaches to assess the impact of changes and the efficiency of adaptation and management measures to ensure a sustainable system development.

The scope of CASES is to publish original papers, review and synthesis papers, short communications and research letters addressing an interdisciplinary point of view on change and adaptation of socio-ecological systems from management unit level to policy level. Thematically, CASES aims to address all studies that have a focus on the impact of global change and climate change, on functioning or services of socio-ecological systems and related human-environment interactions, on understanding, monitoring and proposing innovative approaches, tools and technologies to adapt and bring forward system management and development.

Especially welcome are contributions communicating lessons learned from case studies, from the application of methods or the (further) development of methods including (a) monitoring and assessment of global, regional or local changes that impact sustainable resources provision and vulnerability of ecological-economic systems, (b) modeling and simulation of adaptation opportunities at local, regional and global scale including management measures, planning strategies or environmental policies, and (c) evaluation of adaptation measures, resilience, sustainability strategies, and policies. Encouraged are also contributions dealing with critical aspects and failures to enhance the discussion on approaches in socio-ecological systems, their understanding and development, such as through participatory research approaches. Also more theoretical background analysis and review papers are welcome.

Addressed research areas include agriculture, forestry, and their interactions, water management, urban systems and rural-urban interface. We see the focus on highly integrative studies, but also welcome contributions enhancing innovative aspects within one of these areas as long as they address one or more of the following cross-cutting issues: (a) management of the ecological integrity and ecosystem functioning on local, regional to supra-regional scale, (b) adaptive system management under external pressures such as climate or societal changes, land-use change, urbanization processes / development of megacities, (c) socio-economic and political issues such as regional economy, change management, management support, (d) provision of functions, goods and services, sustainable processing of natural resources and regional value clusters, and (e) innovative models and technologies in socio-ecological system development planning support, stakeholder involvement and participatory processes.

More information will soon be available under: www.versita.com/cass.

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NATIONAL LAND RESOURCE CENTRE™

The National Land Resource Centre

The National Land Resource Centre (NLRC) is a science-backed national initiative to improve the way science is used to enhance one of the country's most important asset – the land. Initiated by Landcare Research, the National Land Resource Centre (www.nlrc.org.nz) is a one-stop shop for providing information for policy, business and science, coordinating engagement and foresight into future issues, as well as undertaking capacity building.

The NLRC has three main aims that have been developed in conjunction with stakeholders:

- Engagement with all those interested in the land resources by providing a gateway into available research and resources, workshops, and forums
- Access to the best available, easily consumable and fi t-for-purpose information for policy, business and science users
- National capability building to lift performance for those researching, governing and managing land resources.

For further information about the centre contact Mandy Cains – **enquiry@nlrc.org.nz.**

Biodiversity and Food Security – From Trade-offs to Synergies

The 3rd International Conference on Biodiversity and the UN Millennium Development Goals will take place on October 29-31, 2014 in Aix-en-Provence, France.

This international conference is the third in a series, organized by the French CNRS Institut Ecologie et Environnement (InEE)and the German Leibniz Association (WGL).

The goal is to identify science-based solutions for global sustainability focusing on the issues of biodiversity and food security. Current ecological, economic and societal challenges for development require a holistic understanding of food security and environmental management: from this perspective, biodiversity can be seen as key to overcome trade-offs and to develop synergies between the food system and the conservation of landscapes, ecosystems, and species. The conference seeks to attract scientists from basic and applied research. It involves policy makers and other stakeholders concerned with biodiversity and food security themes who are interested in developing new solutions and strategies. It will connect researchers and stakeholders from natural sciences, social sciences, economics, humanities, technology and related fields.

Further information can be found at: **http://biodiv2014.sciencesconf.org/**

9th IALE (International association for landscape ecology) World Congress

Ecology to understand landscape tissues in an urban world.
July 5-10, 2015 Portland, Oregon

In 2015, 5-10th July, there will be a joint meeting between the International Association of Landscape Ecology World Congress (WC) and the US chapter of IALE (US-IALE). Portland offers numerous amenities that will ensure an excellent and efficient meeting. The city is widely recognized for its commitment to sustainability and progressive land use planning. Portland is rich in parks and has numerous outdoor recreation areas and opportunities for scientific excursions (below). In addition, Portland is easy to access with direct connections to Tokyo, Amsterdam, and most major U.S. and Canadian cities. Portland also offers excellent light rail and street car connections throughout the city.

Further information can be found at: **http://www.ialeworldcongress.org/**

2014 Asia Global Land Project Conference in Taipei, Taiwan - SEP.24-26,2014

In order to enhance the international understanding of dynamics relationships between land system and ecosystem in response to natural and human-induced disturbances at various scales, the Taipei GLP Nodal Office was established in 2012 with the specific theme focusing on "Management and development of knowledge on land-use, ecosystem and their interactions at different spatial scales".

As the Taipei GLP Nodal Office takes an important role in the GLP Science Plan, one of our important missions goes to the Management of knowledge and information through International Services and Development including hosting and organizing GLP conference in Asia so as to:

1. Present the research findings by the members of Taipei GLP Nodal Office and other GLP associated researchers.
2. Sharing the up-to-date knowledge and information related to land-use change and land management among participants.
3. Enhance scientific exchange between GLP regional and international partners.

Further information can be found at: **http://www.glp.taipei.ntu.edu.tw/Asia_Conference_2014/**

Get involved

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We are open to announce events and publications related to GLP science on our monthly GLP e-news or on GLP website. If you want to contribute, please contact us sending an email to: glp@inpe.br

Have your project endorsed by GLP and included in the GLP Website
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