Global LAND Project

The Global land Project Nodal Office on Integration and Modelling, Aberdeen, UK

GLP Workshop on

Data and model integration for coupled models of land use change

Pre-Workshop Booklet
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8.30 Breakfast

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11.30 Discussion in breakout groups

12.30 Reports from breakout groups

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14.00 Land use data: Integrating socio-economic and ecological data within the HANPP framework — Karlheinz Erb

14.30 Data infrastructures and architecture + Ethical data issues — Richard Aspinall

15.30 Coffee

Discussion

16.00 Discussion in breakout groups

17.00 Reports from breakout groups

17.30 End of sessions

19.00 Workshop ‘Gala’ Dinner

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<u>Saturday July 19th</u>

8.30 Breakfast

Session 5 Ethical issues and data protection, environmental data and socio-economic data

9.00 Group discussion on Session 5 issues
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10.30 Coffee
11.00 Reports from breakout groups
11.30 Summary of workshop, outputs and next steps
12.30 Lunch
14.00 Coach departs for Stonehaven Station, Aberdeen Airport and Aberdeen City

Discussion Topics

Prior to the workshop we asked all participants to list topics they would like to discuss in each of the sessions, thank-you for all your contributions. The lists below are just to get the discussion going. During the sessions please feel free to add your own, especially in light of the information given in the presentations.

Session 1. Data Source and Issues

Discussion Topics and Questions

- Environmental data and socio-economic data
- Remote sensing, digital elevation models, soil maps, questionnaires, government statistics, expert opinion, economic data (land and farm)
- Socio-economic data – land tenure, local and social networks, leasing, off-farm activities, family structure
- Accuracy of the data sets and how this differs between different types of data
- Uncertainty, sources and quantification
- Changes in accuracy over time (e.g. agricultural statistics maybe better now than they were 30 years ago, changes in definitions and resolution)
- Mismatches in time and non-synchronicity of data – e.g. using socio-economic data from 2000 and agricultural census data from 2006 to represent 'present' conditions
- Qualitative and quantitative data
- Data purpose – input, parameterisation, initialisation, evaluation, validation, verification
- Dealing with missing data – gap filling 'primary' and 'secondary' data sets
- Global data sets
- Data complexity – e.g. some data sets (soil health) are already made up of other data types (pH, CEC, SOC, texture etc.)

Session 2. Using data sets of different scales, merging, scaling and aggregation issues

Discussion Topics and Questions

- Multi-level models
- Data fusion techniques
- Spatial attributes
- Aggregate behaviour
- Hierarchy theory
- Weighting inputs to models (data obtained from participatory methods)
- Combining data – analytical hierarchy process and indexes (can we talk about 'land system health' in the same way as 'agro-ecosystem health'?)

- Modelling absolute values versus modelling rates of change – different data needs and levels of accuracy needed e.g. land use at time A versus land use at time B or the transition in between
- To what extent can you assume traits at one scale will remain important at other scales?
- Time intervals within data sets (daily, monthly, annually etc.)
- Data issues in combining empirical statistical (non-causal) modelling with process-based (causal) modelling
- Describing macroscopic phenomena with microscopic theories – a means of dealing with data gaps?

Session 3. Collecting data for modelling

Discussion Topics and Questions

- How should data be collated in the future to inform integrated land system modelling?
- Formatting issues, deciding how much effort/time should go into reformatting data?
- Changes in geographic boundaries over time (e.g. new Municipios created in the Brazilian Amazon and New Local Development Authorities created in Lagos megacity, as they become more populated)
- Data purpose, parameterisation, initialisation evaluation etc.
- Geographical data format (grid, polygon etc.)
- Functional landuse changes over time especially in urban cities of developing countries (e.g Ikoyi and Victoria Islands of Lagos Megacity)
- Methods of quantification

Session 4. Data infrastructure and architecture

Discussion Topics and Questions

- Cataloguing data
- Metadata
- Accessibility
- Compatibility
- Noting accuracy

Pre-workshop Input

Introduction – Dr Eleanor Milne

Thank-you to everyone for producing extended abstracts for this pre-workshop booklet. The purpose of this booklet is to provide some background to the workshop presentations and to allow those who aren't presenting to give some information about their expertise and research work.

The scientific community are increasingly confronted with the need to understand complex interactions among human and natural systems at diverse spatial, temporal and organizational scales. Integrated models of land systems provide tools for the representation of land systems, projection of land system change and analysis of varying scenarios. The Global Land Project Science Plan recognises the need for such models, advocating:

'the development of integrated decision making models, dynamic global land models, data model fusion techniques and remote sensing applications'

Integrated models require a variety of data to drive them. Data can be for different spatial and temporal scales (from the global to the local) and record different aspects of the land system (socio-economic, biophysical etc.). The aim of this workshop is to explore some of the opportunities, constraints and problems that arise when using different data types and sources in integrated models of the land system. By exploring these issue from a variety of disciplinary angles, we hope to assess the state of the art, learn from each other's experiences of data and model integration and identify gaps in our understanding. We hope that an output from this workshop will be a set of recommendations for the GLP and wider scientific community on priorities for improving data and model integration for coupled models of land use change.

Prof. Richard Aspinall – Session 4 Presenter

Chief Executive, The Macaulay Institute, Craigiebuckler, Aberdeen, UK

Email: r.aspinall@macaulay.ac.uk

Research Area/Discipline: Geographical Information Systems, Land Use Change, Environmental Geography

GLP Scientific Steering Committee Member

Extended Abstract:

Data infrastructures and Architecture

Richard Aspinall
The Macaulay Institute, Craigiebuckler, Aberdeen, UK

A *data infrastructure* organises and implements the data, standards, technologies, policies and people necessary to manage data. A data infrastructure also provides a mechanism to facilitate sharing of data among various groups and sectors. A *data architecture* includes both the design specification and computational structures that support use of data in relation to some defined purpose within a given system. Data infrastructure and architecture combine in the design of a database of data and metadata and associated cataloguing and search facilities to support a community and their activities.

In the context of the GLP, a goal for a data infrastructure and architecture is to provide data for modelling and analysis of land change dynamics and consequences of change in land systems relevant to application needs of different users. The data infrastructure and architecture should also be capable of supporting GLP science activities that are designed to compare, integrate and synthesise between the different approaches, projects, and case studies used by participants in GLP. This is no easy challenge but is a set of activities that are necessary for testing of methods and models, for generalisation beyond individual case studies, and for developing robust models that can facilitate links to other IHDP and IGBP core projects.

For the Global Land Project, the design of a data infrastructure faces several challenges. There are no standard or common datasets (or data types) used for all projects, although there are significant sources of data such as remotely sensed imagery, spatial data from maps and surveys, and field data on individuals, groups, and institutions. There are no standard and common source scales, spatial or temporal resolutions, or information contents that provide input to analyses of land change. Different projects and research questions require different data to support their analysis. Additionally, a wide variety of different analytical approaches are used in study of land change dynamics; models aimed at understanding consequences of land system change introduce an even broader range of formal and informal models to address social, economic and environmental impacts of change. The importance of modelling and analysis of land change dynamics and evaluation of consequences raises the question of whether a data infrastructure can be designed in the absence of a companion and linked *model infrastructure* that constructs a compatible organisation of models.

A data infrastructure for land change data and the Global Land Project must, therefore, provide several characteristics

1 a broad management structure capable of integrating a very wide variety of data (field survey, census, map, imagery, longitudinal and spatial data, etc) with structured metadata
2 semantics and ontologies, especially in the metadata, that support the activities and science of the GLP community
3 support for many data formats
4 support for search, retrieval and use of data within a spatial-framework (in order to explore spatial and scalar dynamics)
5 support for search, retrieval and use of data within a time-framework (in order to explore change over time)
6 a facility to integrate different data in a structured and logical, but flexible, manner; this may require augmentation of standard metadata to provide information that guides users on the contextual limits and compatibility of data sets used in combination
7 a capacity to support a full sequence of analyses, including description, management, analysis, and modelling of land change dynamics.

The design of a data infrastructure and architecture for GLP needs, therefore, to consider production of an integrated suite of databases and processing tools that support the range of processing streams and analytical approaches used in land change science. This requires a focus on not only the data, but also the requirements of the applications used to interpret and model land data, and the priority science questions of GLP.

Dr Innocent Bakam

Complex Systems Modeller, The Macaulay Institute, Craigiebuckler, Aberdeen, UK

Email: i.bakam@macaulay.ac.uk

Research Area/Discipline: System modelling

Extended Abstract:

I am working at the Macaulay Institute in modelling research related to socio-ecological systems. In that purpose, one of my main responsibilities is to assist in the collection of appropriate field data as they are required in the modelling process, for running different scenarios and for validation. Sometimes, these data already exist but not in the appropriate format and it is necessary to process them (database queries, statistical analysis) such that they can be used in the models.
My current activities related to data issues concern (i) gathering of data to populate a combined agent-based and biophysical modelling approach to address GHG mitigation policy issues, (ii) gathering of empirical social network data to validate a network paradigm we've developed to illustrate the adaptive cycle metaphor.

Data issues to populate a GHG emission model:
Climate change is widely recognised as the most serious environmental threat facing our planet today, and a major challenge facing society is to find ways to decouple the link between economic activity and greenhouse gas (GHG) emissions. We have used Agent-based modelling (ABM) which is an approach that has been receiving attention as a way of linking the biophysical and socio-economic components of a system, to study such social dilemmas. The People and Landscapes Model (PALM) is a combined agent-based/biophysical model operating at the level of a catchment, and consists of a number of household agents located on a landscape made up of heterogeneous land units. We have examined with PALM ways in which GHG emissions might be reduced and the impact that this may have on farmer livelihoods. Preliminary results from the model show that GHG emissions can be reduced by economic instruments such as (a) imposition of a GHG tax, (b) providing incentives for low emitting land uses, and (c) a combination of the two.
We are currently trying to populate the model with real data on emission factors and economic returns for each land use, relying on the Farm Accounts Scheme which is an annual survey of farms in Scotland, conducted with the primary purpose of providing a body of bio-physical and financial data on Scottish farming.

Data issues to validate a network paradigm for the adaptive cycle metaphor:
The adaptive cycle metaphor suggests a four phase dynamic of socio-ecological systems (SESs) evolving in a three-dimension space defined by potential, connectedness and resilience. Despite the apparent simplicity and attractiveness of this theory, limited evidence has been gathered to support its pertinence and its usefulness. Efforts are being

made both in linking the adaptive cycle to real SESs, and in developing models that can help to identify the mechanisms that lead to these successive phases. The main difficulties concern the availability of enough long-term data for existing systems study, as well as clear definition and measurement of resilience for a modelling approach. We have suggested a network paradigm to understand how low resilience and disturbance lead to collapse in socio-ecological systems, moving the system from the conservation (K) to the release phase (Ώ). We have identified a minimal set of mechanisms made of growing, regular disturbance and neighbour influence necessary to trigger collapses during the conservation phase. We have also suggested a resilience measurement based on nodes' strength that anticipates the occurrence of the collapse.

We are trying to identify existing case studies where it might be possible to apply the network paradigm since the challenge consists of translating the anticipation of these collapses into management policies.

Dr Heiko Balzter – Session 1 Presenter

Centre for Environmental Research, Department of Geography, University of Leicester, University Road, Leicester LE1 7RH, UK

Email: hb91@le.ac.uk

Research Area/Discipline: Remote Sensing

Extended Abstract:

From remote sensing of land cover and vegetation to data / model integration

Satellite remote sensing has become a prime data source for spatial and temporal information on land cover and land use change. With the major international space agencies committing themselves to long-term observational information services in the framework of the GMES (Global Monitoring for Environment and Security) initiative, remote sensing is evolving more and more from an experimental research technique to an environmental monitoring tool. This provides new opportunities for obtaining data sources on land cover and land use change for data and model integration.
The Global Climate Observing System (GCOS) has drawn up a list of Essential Climate Variables (ECV) required to support the work of the UNFCCC and the IPCC. Amongst them are a number of land related ECVs, in particular snow cover, glacier and ice cap extent, extent of permafrost and seasonally-frozen ground, land surface albedo, land cover (including vegetation type), fraction of absorbed photosynthetically active radiation (fAPAR), leaf area index (LAI), biomass and fire disturbance.

My presentation will discuss remote sensing approaches to mapping land cover and land use change, including other descriptors of land surface properties such as biomass, disturbances and photosynthetic activity. Following an overview of remote sensing satellites and temporal and spatial resolution, several examples will be discussed:

1. Semantic uncertainties in quantifying land cover change from multi-temporal land cover maps
   Often, researchers interested in land cover change want to quantify change from different land cover maps that were produced at different times, often by different teams for certain user agencies and utilizing the remote sensing technology that was available at the time. The different class labelling systems, methods and sensors make such change detection difficult. An example of land cover change in Siberia is presented, with a discussion of the differences between land use and land cover. An approach to quantifying uncertainty in spatial data is proposed.
2. Disturbance monitoring
   Methods for vegetation disturbance mapping and monitoring are described, with a focus on fire (burned area mapping). Operational data can provide useful inputs to models, but the error sources and uncertainties involved in generating them must be fully understood to avoid introducing propagating errors into the data/model framework.

3. Observations of vegetation phenology using fAPAR
   Time series of remote sensing images can be used to estimate the timing of the greening up in spring, peak of the growing season and leaf colouration in the autumn. Bearing in mind the limitations in accuracy, repeat-cycle and cloud cover, these datasets can detect changes in the seasonality of vegetation. A case study of Siberia is shown comparing remotely sensed phenological indicators to field observations. An advancement of spring can be observed over the last 20 years.
4. New methods for biomass mapping
   Growing scientific interest is focusing on new methods to retrieve three-dimensional structural parameters of vegetation canopies from remote sensing. LiDAR and SAR techniques have been used to estimate tree canopy height, gap fraction, crown diameter and woody biomass. Examples of experimental airborne data are shown.

It is argued that while a lot of progress has been made on the observational and parameter retrieval side, we have some way to go to get to an operational data service that is suitable for use in land use change models.

Dr Randall Boone – Session 2 Presenter

Research Scientist, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, 80523-1499, USA

Email: rboone@nrel.colostate.edu

Research Area/Discipline: Ecology, Ecosystem Modelling

Extended Abstract:

Linking Maasai Decision Making to Ecosystem Services
Including Data Sources and Scaling Issues

Randall B. Boone[a], Kathleen A. Galvin[a,b], Shauna B. BurnSilver[a,b],
Philip K. Thornton[c], Dennis S. Ojima[a,d], and Jacob R. Jawson[a]
[a]Natural Resource Ecology Laboratory, Colorado State University, the [b]Department of Anthropology, Colorado State University, the [c]International Livestock Research Institute, Nairobi, Kenya and the Institute of Atmospheric and Environmental Sciences, School of Geosciences, University of Edinburgh, Edinburgh, UK, and the [d]H. John Heinz III Center for Science, Economics and the Environment, Washington, DC

Attempts to create future projections in semi-arid areas have often focused on ecological systems, sometimes with effects on human residents inferred. Yet, the wildlife and livestock in the areas and household members who own the livestock, are components of coupled natural and human systems. More recent analyses have considered linked ecosystems and humans explicitly, for example using a simplistic agent-based approach or our population-based pastoral decision making model. We seek to understand relatively complex and non-linear ecosystem and human dynamics, and so require a scientific framework and supporting tools that mirror the depth of those interactions. We had identified problems with modeling pastoral households as mean population responses. Instead, we sought the bottom-up emergent structure that an agent-based approach yields. We therefore constructed a comprehensive agent-based model of livestock-owning households and tightly linked it to a complex ecosystem model. Our construction of the DECUMA (i.e., DEcisions under Conditions of Uncertainty by Modeled Agents) household model and its linkage to the SAVANNA ecosystem model are described, briefly demonstrated in southern Kajiado District, Kenya, and selected data issues that have arisen are discussed.

Kajiado District is a semi-arid region in southwest Kenya inhabited by Maasai pastoralists and other groups. Land use in the district is diverse, but raising cattle, goats and sheep is the main livelihood for most families. Our study area is the southeastern half of the district and includes Amboseli National Park and the slopes of Mount Kilimanjaro.

SAVANNA is a series of connected FORTRAN modules that simulate ecosystem processes through time in a spatially explicit way. Landscapes are divided into cells from 500 m to 5 km in resolution and digitized maps inform SAVANNA of the attributes of cells. Plants and wild animals are modeled as functional groups. Monthly weather data for stations throughout the study area are used to model temperature and precipitation. During a simulation, plants compete for light, nutrients, water and space. Wild herbivores represented gain energy from the food they consume and expend energy through basal metabolism, travel, gestation and lactation. A body condition index compares current mass to maximum and minimum body masses and feeds back to reproductive and mortality rates. SAVANNA simulates ecosystems using a weekly time-step, with summations output for each month.

DECUMA is designed to be generally applicable to agro-pastoral households, but its first use is in Kajiado. Hundreds to thousands of households may be represented, each with their unique location, attributes, resources, and local environment. DECUMA was programmed in both Java and FORTRAN and reads a series of maps that define the study area and its attributes. The program matches the weekly time-step of SAVANNA when modeling livestock land use, and has a monthly time-step for agent modeling. Households own a given number of livestock and graze those animals in places household members select. The DECUMA model includes a graphical interface that allows us to visualize selected results while the model is running. For each simulation, DECUMA produces tabular files that store livestock attributes, cash flows, energy flows and other summaries for each agent. The model also produces spatial data in a form usable by ARC/INFO. BurnSilver collected extensive data for 184 households during 17 months of field work in Kenya. DECUMA uses those household surveys stored in files. To model the 3,820 households we estimate in the region, a location on the landscape is selected based on a household density map, then, the observed household nearest the candidate location is used to set initial conditions for the new household.

A simple preliminary analysis demonstrates the linked models and our scenario approach. In Kajiado District, livestock typically graze up to 10 km (i.e., the herds' grazing radius) from the corral where they are housed at night. This distance may be shortened if herders are confined to grazing in individual parcels owned by the household, a process of subdivision ongoing in Kajiado. That distance may be increased if herders adopt a two-day or three-day watering cycle for their livestock, where the animals graze for multiple days then trek to water. We asked how these changes in grazing radius would alter the number of livestock that may be supported on the area. Presumably as animals are able to graze over larger areas, they will locate more suitable forage patches and gain more energy. After several simulations, we

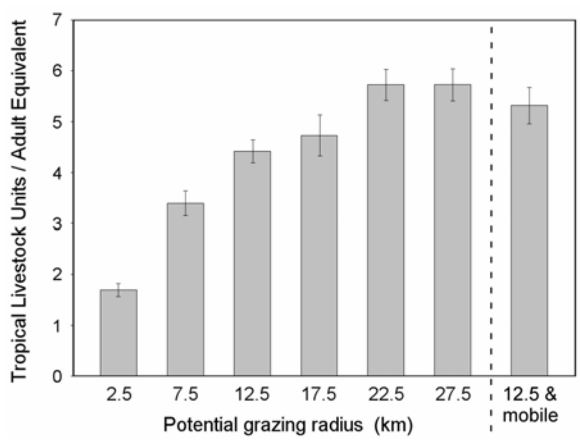

Fig. 1. The numbers of livestock that may be supported in southern Kajiado District given the distance animals may graze from their permanent household location. Tropic livestock units and adult equivalents are standardized livestock and human metrics and twice the stand errors based on 15 simulations indicate 95% confidence intervals on the means. For reference, the number of livestock per person in the base model (12.5 km grazing radius and potentially mobile livestock populations) are shown.

created Fig. 1, using tropical livestock units per adult equivalent, standardized units of livestock and people, respectively. The number of livestock per person declined below 22.5 km, but moving further afield while maintaining a permanent residence did not increase livestock numbers and stressed animals.

Data scaling issues that have arisen in this and our prior integrated assessments include some intrinsic benefits and some challenges. Our modeling approach is itself a multi-scale effort. The bottom-up approach of agent-based modeling means that individual household responses aggregate to population-level responses that we describe as results. At broader scales (national to global patterns), responses that impact policy help define the scenarios we analyze. We seek to model rates of change, including the magnitude and direction of change in systems in the future, isolating the effects of specific changes in management or policy. As such the suite of input data we require is kept manageable.

The sparsity of weather stations in developing countries is a challenge in our work. We must often use correlative spatial surfaces to help interpolate weather reasonably. We find that ecosystem information extrapolates more easily than household information and is more richly supported by regional and global spatial datasets. For example, the information from a limited number of vegetation sampling plots can inform our model well, but a greater density of household surveys is required. In Kajiado, Kenya, for example, we used approximately a 5% sample of household and extrapolated to the full 3,820 household. Ongoing applications include both much greater and lower densities of household sampling. The implications of this and its relationship to household diversity and diversification, are of research interest.

Mr Shawn Bucholtz – Session 1 Presenter

Department of Computational Social Science, Center for Social Complexity, George Mason University, USA

Email: Shawn.Bucholtz@wdc.usda.gov

Research Area/Discipline: Agricultural Statistics

Extended Abstract:

Measurements of cropland and other land uses over time are essential for evaluating the economic and environmental performance of U.S. agriculture. We are now at a turning point in terms of the availability of nationwide data on agricultural and rural land uses from various new and ongoing initiatives within different Federal agencies. These initiatives will transform our ability to track and analyze nationwide land use over time and, in particular, over space. These initiatives to collect agricultural and rural land use data can be broadly categorized into three groups: survey-based, administrative, and remote-sensed.

Each data source is not necessarily useful by itself. In most instances the integration of two or more of these data sources is necessary to produce a relevant data set. For instance, while administrative data may provide land ownership boundaries and conservation structures, it will not provide producer behaviour information, such as the use of working lands conservation practices. A researcher would have to integrate survey data on producer adoption of conservation practices with administrative data in order to produce estimates of water quality impacts from land use changes. In all cases careful attention must be paid to combining data sources, taking into account the nature of the error within the data.

Survey Data

Survey-based data includes data collected through on-the-ground surveys of the landscape and landowners. These efforts may include activities ranging from human interpretation and calculation using ariel photography to questionnaires and door-to-door interviews. The two major survey-based initiatives are the National Resources Inventory (NRI) and Forest Inventory and Analysis (FIA).

The NRI is a longitudinal survey conducted annually across private lands in the US. It is designed and implemented to assess conditions and trends in soil, water and related resources. The FIA is an annual analysis of the ownership, biomass, and type of private and public forest resources in the US and its territories.

Administrative Data

Administrative data includes data collected by U.S. Federal agencies for the purpose of administering their respective programs. Data on agricultural and rural land uses is collected mainly by the U.S. Department of Agriculture (USDA) and the Fisheries and Wildlife Service (FWS).

The USDA administers agricultural programs on behalf of the Federal Government. Over the past 15 years they have undergone a transition to managing data associated with program implementation within a GIS. As a result, the USDA has collected a significant amount of spatially-explicit data on land ownership, land use, and conservation practice adoptions. Administrative data holds great promise for future research.

The two main data set created by the USDA are the Common Land Unit (CLU) and the PROTRACTS. The CLU includes polygon representation of nearly all agricultural fields in the US. This data set forms the basis of the data organization structure for many of the USDA’s farm programs, including loan and conservation programs.

PROTRACTS is also used by the USDA to capture the adoption of Federally funded conservation practices. It includes polygon and point representation of conservation structures and working-lands practices.

FWS collects and administers the Wetlands Geodatabase. The Wetlands Geodatabase is a seamless coverage of wetland points and polygons throughout the U.S. To date, most of the U.S. has been completed. These data set includes consistent classification of wetlands.

Remote Sensing Data

The most well-known and widely used agricultural and rural land use data comes from various remote sensing sources. The two most widely recognized remote sensing sources are the USGS National Land Cover Dataset (NLCD) and the USDA Cropland Data Layer (CDL).

The National Land Cover Dataset (NLCD) is a component of the USGS Land Cover Characterization Program and includes data products from 1992 and 2002. The seamless NLCD contains 21 categories of land cover information suitable for a variety of State and regional applications, including landscape analysis, land management, and modeling nutrient and pesticide runoff. The NLCD is distributed as a 30-meter resolution raster image.

The USDA, NASS Cropland Data Layer (CDL) is a raster, geo-referenced, crop-specific land cover data layer with a ground resolution of 56 meters. The CDL is produced using satellite imagery from the Indian Remote Sensing RESOURCESAT-1 (IRS-P6) Advanced Wide Field Sensor (AWiFS) collected during the current growing season, with several ancillary inputs. The strength and emphasis of the CDL is agricultural land cover.

Dr Nicolas Dendoncker – Session 2 Presenter

Centre for the Study of Environmental Change and Sustainability (CECS), University of Edinburgh, UK

Email: n.dendoncker@ed.ac.uk

Research Area/Discipline: Agents Based Models of Land Use Change

Extended Abstract:

A first aspect of my research is related to the spatial downscaling of pan-European land use change scenarios. This has lead to several publications in which I showed that data issues largely influence the outcome of integrated land use and environmental models (Dendoncker et al. 2006, 2007, 2008a, 2008b).

My current research is being undertaken in the context of the EU-funded ECOCHANGE project and, indirectly, within the Belgian government funded MULTIMODE project.

The general objective of this research is to develop an integrated sustainability assessment (ISA) of the impacts of environmental change on ecosystem goods and services. This framework, using agent based models (ABM), will be applied at the regional scale within three selected case study areas (located in Belgium, Switzerland and Romania), for which different sustainability issues have been identified.

The main focus of my research is related to the Belgian case study that I will briefly describe here. I will stress the issues that arise when combining different data sources of various types (from GIS to outputs from social survey) and scales (from parcel level data to aggregate statistics) in a single integrated modelling framework.

The core of the ISA framework is an integrated ABM which will simulate land use and land cover change based on the decision processes of individual land use agents underpinned by theories of cognitive strategies and social interaction.

This ABM consists of three main sub-modules (Human behaviour module – Habitat module – Species distribution module) that influence each other with feedbacks. In the human behaviour module, the behaviour of farmer agents will be modelled. In particular, we will focus on how farmers implement agricultural practices that have an impact on ecosystem services (e.g. the application of agri-environmental measures to maintain or restore biodiversity, prevent erosion, maintain the landscape…). Agent profiles will be determined from a social survey and in-depth interviews. A typology of agents will then be made using PCA and cluster analysis. The baseline land use map will be at the parcel level. However, agri-environmental measures are often applied at the sub-parcel level

(e.g. an improved grass strip at a field margin). This means that issues of data representation in a GIS will arise.

The outcome of the human behaviour module (i.e. choice of land use and (non-) application of agri-environmental measures) will impact on the habitat module (land use and cover change). This module will be coupled to a model of crop yields and plant functional types (PFT). Model and data integration will be of concern. Indeed, the yield and PFT model produce outputs at different spatial and temporal resolutions from those of the habitat module.

The habitat module will in turn influence the species distribution module. For example, agricultural birds such as Skylarks or Yellowhammers will be affected by the changes in habitat, determined by human actions. The behaviour of species will again be modelled using an ABM approach with rules defined by their known ecology. Species distribution data for birds are typically provided on a grid basis. This grid has a coarser resolution than that of the parcel level used. Can we simply affect the grid cell value to all the parcels that it comprises or should we implement some downscaling algorithm that would take account of local heterogeneities? This is another data compatibility issue that will need to be addressed.

Feedbacks from the Species Distribution Module to the Habitat Module and from the Habitat Module to the Human Behaviour module will raise issues of temporal compatibility.

Finally, scenarios of climate, economy and policy changes, representing a range of possible futures, will be constructed and implemented as exogenous drivers of changes affecting the three sub-modules. These scenarios will largely be based on statistical data that are generally only available at relatively coarse scale and do not necessarily unequivocally translate to local conditions.

The outputs of the ABM will be translated into indicators of ecosystems services and this will be the basis for the last stage of the ISA (learning, evaluating and monitoring phase). Integration and generalization across case studies is a final issue that is worth mentioning.

This research is still at an early stage (we are about to start the farmer interviews, which will be complete and the data will be analysed by the time of the workshop.) However, as the above description clearly shows, we expect great challenges in relation to data issues; in terms of merging data sources, extents and resolutions.

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Dr Karlheinz Erb – Session 4 Presenter

Institute of Social Ecology, Klagenfurt University, Austria

Email: karlheinz.erb@uni.klu.ac.at

Research Area/Discipline: Integrated land science

Extended Abstract:

Land use data: Integrating socio-economic and ecological data within the HANPP framework

Karlheinz Erb, Veronika Gaube, Fridolin Krausmann, Helmut Haberl
Institute of Social Ecology, Klagenfurt University
Schottenfeldgasse 29, 1070 Vienna, Austria

Improving our understanding of the intricate interplay of natural and socioeconomic factors in generating patterns and dynamics of the Earth system is essential for sustainability. The development of integrated models capable of simulating socio-economic processes, land use and socio-ecological material and substance flows plays a central role in this context. The integration of social and socio-economic data with ecological information is a prerequisite for such integrated models and a major challenge of integrated land science.

In particular, spatially explicit, consistent and comprehensive land use data are high on the agenda of integrated land system science. Land use has created human-dominated ecosystems on the majority of the Earth's surface. These systems are driven by socioeconomic factors such as production and consumption at least as much as by natural factors such as climate and soil. As both ecosystems and human activities are extremely diverse across the Earth's surface, maps are particularly valuable for a better understanding of the links between human systems, drivers of change, and their ecological consequences.

Yet, despite the plethora of data, statistics and spatially explicit information available to the scientific community, accurate, consistent, and spatially explicit information on land use has been frequently identified as a major data gap. Data integration is hampered by the fact that most (global) spatially explicit datasets refer to land cover and not to land use. Land cover refers to biophysical characteristics of the Earth's surface – information indispensable for assessing the state of terrestrial ecosystems – and these data are not directly linkable to socio-economic information. Land use data, on the other hand, can be unambiguously linked to socioeconomic data. However, as the possibility to infer land use information from land cover data is limited, approaches which rely on land cover information alone lack consistency and are thus of limited practicability for integrated assessments. Furthermore, most readily available spatially explicit datasets lack

information on settlement and infrastructure areas associated with agricultural production, livestock herding and forestry. Nevertheless, despite their small extent, settlement and infrastructure areas play a decisive role within the land use context, because this type of land use results in far-reaching alterations of ecosystem patterns and dynamics. And lastly, there is a lack of reliable data on the extent, distribution and land use intensity of grazing land. This land use category is characterized by a very loose relation of land use and land cover, which renders the establishment of reliable datasets on basis of remote sensing particularly difficult: livestock grazing may occur in a wide range of ecosystems, natural and artificial grasslands as well as deserts, semi-deserts, scrublands and woodlands and forest-like savannah associations. This limits the applicability of remote sensing techniques in identifying grazing land. On the other hand, available census data are limited in scope, very heterogeneously defined, and are known to be highly inaccurate. Difficulties in producing grazing land inventories and sometimes leads to the decision to omit this land use type in global assessments of land use and land cover change, despite its importance in land use research: Livestock grazing is one of the largest fractions of the global biomass harvest and a major driver of the human transformation of terrestrial ecosystems.

The prevailing divergence of spatially explicit data and land use statistics (such as derived from e.g. national census statistics), together with the lack of comprehensive data on settlement and infrastructure area and especially data related to livestock grazing, can be regarded as major obstacles to advancements in our understanding on the interrelation of human drivers of global environmental change and their ecological impacts.

In our presentation, we will elaborate on data requirements and applications of land use data in the context of integrated land science. We will present the accounting framework "human appropriation of net primary production" (HANPP) as an example for the systematic integration of ecological and socio-economic data. HANPP is a measure for land use intensity; it assesses changes in the availability of trophic energy in ecosystems due to human activities, integrating land use effects such as changes in productivity caused by land conversions and biomass withdrawals during biomass harvest. HANPP can be unambiguously attributed to specific societal activities, which makes it particularly valuable as a framework for linking socio-economic and ecological dimensions of global/regional environmental change.

Based on the HANPP approach, we will present empirical examples of integrating socioeconomic data such as income, municipal budget, time use or the number of farms with socio-ecological/ecological information, such as land use, land cover, plant growth and harvest or fossil fuel consumption on the local scale, and the application of such data in agent based models. Further, we will elaborate on requirements for global land use datasets which allow for consistently integrating data on socio-economic material and energy flows, in particular biomass harvest on croplands, forests and due to grazing. On basis of these examples, spanning from the local to the global scale, we will discuss issues of data consistency (e.g. land use data and data on socioeconomic material and energy flows), data comprehensiveness, and data accuracy.

The presentation will draw conclusions from these examples on requirements and necessities for data organization and integration and elaborate on the intricate relationship of land use and land cover. It will present insights gained from attempts to integrate knowledge from different scientific disciplines in a coherent model system and will elaborate on current shortcomings, different requirements and future applications of land use data in the context of integrated land science.

Ir. Kees Klein Goldewijk – Session 3 Presenter

Senior coordinator International Datalogistics, Global Sustainability and Climate Unit, Netherlands Environmental Assessment Agency (PBL), The Netherlands

E-mail: kees.klein.goldewijk@mnp.nl

Research Area/Discipline: International Data Logistics, Global Sustainability and Climate

Company profile Netherlands Environmental Assessment Agency

The Netherlands Environmental Assessment Agency in Bilthoven, the Netherlands, is a government organization with legally guaranteed scientific independence. It is a scientific organisation and the key advisory body to the national ministries that deal with public health, the environment and nature. It carries out its legal assessment tasks regarding environment and nature. Total staff is approximately 200 staff members. Since the late 1980s, a core task has been to perform integrated assessments in environment and public health, on the basis of extensive monitoring, modelling, scenario analysis and an active dialogue with the scientific community and uses the assessment results in policy making. Currently the Agency is developing a system of Sustainable Development Outlooks in support of the Dutch government.
The Agency fulfils specific roles in its relationship with various international organizations. It hosts the European Topic Centre (ETC) on Air and Climate Change, the European Coordination Centre for Effects of Transboundary Emissions and the Technical Support Unit for Working Group III of Intergovernmental Panel on Climate Change (IPCC) and is also a Collaborating Centre to UNEP for Reporting Assessment and Forecasting.

Examples of internationally oriented activities are:

International developments related to environmental matters in the context of sustainable development

- Millennium Ecosystem Assessment; co-chair and scientific support WG on responses; contribution to development of scenario's
- Biodiversity Indicators for OECD and CBD (Natural Capital Indices)
- Analyses for the Global Environment Outlook, including global and separate pan-European scenario analysis as well as a supporting role in the design of the global network of collaborating centres in all regions of the world; initiating role in the GEO Core Data process
- Scenario analysis for IPCC SRES and related contributions to the IPCC
- Scenario-based policy-science dialogue, in particular, in the COOL project (Climate Options Over the Long term), at a national, European, and global level

Knowledge and understanding of environmental information activities at the European level

- Initiative and co-organisation of a workshop in Rome (September 2003) on improving current methods for assessing sustainable development in Europe and thus strengthening governance in this area
- Lead role in the Sustainability Advanced Test project (2004-2006)
- Support to the mechanisms for prospective analysis under the Convention on Long-Range Transboundary Air Pollution
- ETC/ACC; Design and implementation of Climate Change Indicators.

Kees Klein Goldewijk Profile

Kees Klein Goldewijk graduated at the Wageningen University in Integrated Pest Managment (MsC). He has nearly 16 years of experience in environmental research, with particular emphasis on integrated environment assessments, (meta-)data handling, specializing in GIS and datalogistic processes. His main expertise lies in the management and organization of international environmental data, co-ordination and harmonization of global datasets, partly with other international partner institutes. He was involved in the recent establishment of a new geoinformation system at the Agency. His research activities include integrated assessments such as the Global Environmental Outlook (GEO) of UNEP, contributions to the IMAGE model as input for the reports of the Intergovernmental Panel on Climate Change (IPCC), the Millenium Ecosystem Assessment and several Dutch environmental Outlooks and Balances.

He is the developer of the History Database of the Global Environment (HYDE). This database is a compilation of historical time series and geo-referenced data on land use and population for the Holocene, and economic/industrial indicators for the last 300 years and may serve as input for integrated models of global change. See also http://www.mnp.nl/hyde.

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Abdul Husaini

Assistant Chief Town Planning Officer
Niger State Urban Development Board, Minna, Nigeria and The Federal University of Technology Department of Geography

E.mail: abdulhusaini@yahoo.com

Research area/Discipline: Remote Sensing and urban and regional planning. The unplanned expansion of fringe areas of urban centres.

The growth of satellite towns around the federal capital of Nigeria, Abuja: the need for data and model integration

One focus of integrated land use /land cover research is to understand the forces/factors behind the current environmental situation and to be able to project the implications of the action or inaction of administrators or policy makers. The outcome of any such research is better presented through models that put all factors together.

In Nigeria, the modelling of land use and land cover change that includes socio economic and political factors and variations in population is in its infancy. Scientists in Nigeria that have heard of such modelling have done so through close contact with the Global Land Project. Therefore, there is the need for us to have a better understanding of the principles behind data and model integration for coupled model of land use.

The environmental changes we are currently experiencing in Nigeria are far too great and poorly understood. We have changes occurring in our environment due to both anthropogenic and natural factors yet we do not have access to accurate information knowledge of where relevant information can be found or the know-how to present information in a clearly understood manner. This calls for a deliberate effort to popularise data usage, integration and modelling. According to the GLP Science Plan, one of the aims of GLP is to improve the understanding and modelling of the effects of human actions on natural processes in the terrestrial biosphere. This knowledge is urgently needed in the third world where the impact of man on the environment is high, the state of science and mitigation techniques is low, poverty is high and the rate of corruption is also high. These factors in combination, lead to environmental degradation. Therefore any techniques that can be used to couple human and environmental factors by utilising a variety of data sources such as remote sensing, vegetation maps, rainfall, crop yield etc. would help us visualise the situation and present a pictorial story to policy makers. Such techniques also allow for projection, showing the implications of action and inaction.

My area of interest is in what happens when urban growth occurs without adequate planning. I believe this to be a very serious problem considering the rate of rapid changes which are affecting the morphology of our urban centres. This growth is taking place in the cities of most developing countries, with little or no planning. Government efforts are inadequate and do not address the problem and the magnitude of these problems has wider implication for the overall environment.

My specific area of interest is Abuja, the Federal Capital of Nigeria. The problem is that Abuja is surrounded by settlements that are rural in nature but due to proximity to the capital are attracting a massive in-migration of people which has a negative impact on the natural resources of the area. There is no coordination of planning policy between Abuja and the neighbouring settlements. The strict urban planning laws and land policy in Abuja is forcing people to move to the satellite settlements for housing. This has a detrimental effect on the ecosystem services of the satellite towns which have little or no ability to cope with the transport, pollution, crime and other problems which arise as a result of this in-migration.

The implication of this is that even though the city of Abuja may look like any other modern city in Africa or the world, the growth of the satellite towns around the capital means that a large area of the city is operating outside of the law. This has implications for the security, survival and efficiency of Abuja. By conducting a comprehensive study of the impact of Abuja on its surrounding settlements and applying data integration and modelling using the various data that is available, we could draw the attention of the federal government to the dangers ahead and make informed projections for the next 15 to 20 years under a business as usual scenario.

I strongly feel we need to start applying modelling techniques to make our point clearer to policy makers and politicians. Ultimately the actions and decisions that can save or improve our environment lie with the politicians who are currently poorly informed on the advancement in such fields and the interdependency of cities with their satellite towns.

Dr Suzi Kerr – Session 3 Presenter

Director, Motu Economic and Public Policy Research, New Zealand

Email: suzi.kerr@motu.org.nz

Research Area/Discipline: Economics

Previous member of GLP SSC

Extended Abstract:

I am currently involved in two major land-use related integrated modelling projects. One relates to climate change and land use. We have built a spatially explicit, dynamic model of land use for the whole of New Zealand and linked it to a model of agricultural emissions and forestry sequestration so we can simulate a variety of policies. The land-use model is based on econometrically estimated land use relationships. We are still developing this model (we have a new five-year grant that started last October) and are currently using it to inform the development of the agricultural component of the New Zealand emissions trading system in which we are heavily involved.

The other project uses the same basic land use model (with additional local scale data) but links it to a catchment scale model of surface and ground water, and a simulated regulatory/market infrastructure to simulate the effects of a nutrient trading system for controlling water quality problems from diffuse sources (primarily agricultural run-off but also some urban and geothermal sources) in Lake Rotorua. This modelling effort is directly linked to a dialogue group process that has been developing a prototype nutrient trading system (funded by the local government who is interested in implementing such a system as well as central government).

Both projects are collaborative between Motu, who provide the economic expertise, and a number of Crown Research institutes who provide the relevant scientific input. We are in the process of developing data and modelling platforms and processes that will allow strengthening and extensions of our existing model (essentially generated as a proof of concept) and expand the range of simulations we can run.

Information on both projects is available at www.motu.org.nz under the 'research' section.

Natasha Macbean

PhD Student, Department of Geography, University College London, UK

Email: n.macbean@ucl.ac.uk

Research Area/Discipline: Remote Sensing of the Environment

Extended Abstract:

Monitoring and modelling vegetation response under catchment-scale treatment regimes using Earth Observation (EO) data

N. MacBean[a], M. Disney[a], P. Lewis[a], P. Ineson[b]
[a] *Department of Geography, University College London*
[b] *Department of Biology, University of York*

The aim of my PhD project is to examine the possibilities for using Earth Observation (EO) data in monitoring and modelling vegetation state and dynamics under catchment-scale treatment regimes in an upland peat ecosystem. This project is an ideal opportunity to link quantitative measurement of ecosystem response to the socio-economic implications of policy decisions regarding land use management.

Peatlands are widespread areas of accumulated organic matter that occur beneath a living plant layer as a result of the waterlogged nature of the soil restricting complete decay of the biomass [1]. Peatlands are important ecosystems; while only covering 3% of the land and freshwater surface, they store between one-third and one-half of the global pool of carbon [2]. Peat-covered landscapes are highly sensitive to changes in land management, climate and pollution [3]. Many have suffered degradation due to afforestation, encroachment by alien species, over-grazing, artificial drainage, and either deliberate or accidental burning, (www[1]), resulting in erosion, flooding, poor water quality and loss of ecological biodiversity [4]. Such damage is causing peatlands to be converted from net sinks to net sources of carbon [2]. As a result understanding the impact of changing management, land use and climate on peatlands is of great importance. This is particularly true in areas where efforts aimed at restoring peatlands to their 'natural' state are currently underway.

My research involves investigating the utility of remotely sensed data to monitor and model the impacts of changing land management practices in an upland peat site in North Wales; both in the recent past (last ~30 years) and as a result of new policies that are currently being implemented as part of a unique catchment-scale controlled experiment. Five separate catchments within the site have been divided into two treated and untreated (control) halves, with the treated halves undergoing blocking of artificial drainage channels (grips) to facilitate the restoration of the catchment hydrology. I am using a combination of moderate- and high-resolution satellite data, ground-based measurements of spectral reflectance taken in the field and historical land use information to explore the changes in the vegetation cover and dynamics. Such data are particularly useful when considering the effect of changing land management practices on the carbon gas fluxes over the site, which biologists at the University of York are currently trying to quantify.

We aim to develop a model that can predict carbon gas fluxes over the site in North Wales under a range of conditions. Particularly, it is important to understand how blocking of the artificial drainage channels, hypothesised to result in a raised water table, will impact on methane fluxes dependent on competing processes of aerobic and anaerobic respiration. Remote sensing data is uniquely capable of monitoring land surface characteristics relevant to modelling, including vegetation type, percentage cover and height, biomass, stand age, phenology and leaf area index [5], over large spatial scales with high temporal frequency. I will aid development of the model through the incorporation of remote sensing data.

Several issues have to be considered when building the model. The first is how best to incorporate remote sensing data. Ecosystem models have been developed which are specifically designed to assimilate remotely sensed observations, [e.g. 6], however this is an ongoing area of research. The second issue is one of characterising the scale of spatial heterogeneity over the site. Remotely sensed data also is a useful tool in the analysis of spatial autocorrelation. Taking this into account is imperative when designing the model, especially with a view to using the model to scale-up ground-based flux measurements. This will enable a better estimate of the net carbon flux for an upland peat ecosystem to be derived.

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Menno Mandemaker

PhD Reseracher, Wageningen University and Research Centre, P.O. Box 47, 6700 AA Wageningen , The Netherlands

Email: menno.mandemaker@wur.nl

Research Area/Discipline: Landscape Dynamics

Extended Abstract:

Understanding factors that drive agricultural production changes is fundamental and crucial in relation to a rising global population and the current tensions on global food markets. Governance networks and institutions concerned with global food production and trade (EU, national governments, FAO, WTO etc.) rely strongly on projections of future agricultural production by macro-economic models. Macro-economic models, however, generally do not consider the gap between microscopic scale and macroscopic scale phenomena in a realistic way, as they generally do not consider (to any extent) the transitions and processes endemic to levels in between these lower and upper limits. As a result, only coarse and unreliable projections can be obtained for macroscopic applications. Consequently, the inability to bridge the aforementioned gap and the strong dependence of governance structures on projections of these macro-economic models have given rise to the need for a complementary research approach that does address the numerous scale and aggregation issues that arise when making global production projections.

For the purpose of contributing to an improved understanding of where, when and how agricultural production is expected to increase or decrease in the future, a quantitative multi-level analysis of observed past changes in the production of wheat and maize is proposed. At various levels (i.e. field, farm, regional, national and global), biophysical and socio-economic factors associated to production changes (be they stimulating or hindering factors) will be identified. The primary aim of this investigation is to improve understanding of temporal and spatial dynamics of agricultural production changes characteristic of these levels of observation. Focus will be on identifying driving factors of production changes, as well as their relationship to the different components of production changes (i.e. changes in yield and/or area). Furthermore, the spatial and temporal relationships between these two components will be studied. A secondary aim of this multi-level investigation is to study whether, and if so how, the dynamics of different levels influence each other (possibly revealing general principles).

Thus, on the one hand, this research seeks to identify functional relationships between changes in agricultural production and environmental factors, and on the other hand how to minimize unexplained variance encountered in the (inter)relationships between these components and the various biophysical and socio-economic factors considered. Moreover, this research seeks to identify factors to which the remainder of unexplained variance can be attributed, by observing which variables do not (yet) allow for

quantification. Methods of quantification will be developed and/or elaborated for the purpose of meaningfully associating measurable quantities to these variables. In light of the aforementioned, the development of a hybrid spatial model is anticipated to follow from this research. This model would be a hybrid in the sense of combining empirical statistical modeling with process based modeling in an integral way, through an improved understanding of level specific agricultural production changes and their driving factors.

Dr Odunuga Shakirudeen – Session 3 Presenter

Department of Geography, University of Lagos, Lagos. Nigeria

Email: odushak@yahoo.co.uk

Research Area/Discipline: Hydrological and land use change modelling

Extended Abstract:

Integrating Urban Land use Dynamics and Precipitation for Flood Analysis in Lagos

In Lagos, one of the two megacities in Africa, the need to meet infrastructural developments (especially for real estate development) has resulted in policy change in land use within and around the city. For instance, agriculture and other land uses at the inter-state areas, purposely zoned to break development, protect the flood plains of the River Ogun and keep away flooding, have been subjected to intense invasion by residential developers. Similar conversions of wetlands, floodplains as well as continuous increase in the housing stock and density within the greater Lagos has resulted in phenomenal flooding that is now associated with the wet season destroying properties worth millions of dollars and turning the residents into refugees in their own home land. Consequently, this research focuses on the generation of urban land use land cover changes using remote sensing and GIS techniques. As well as developing models that synthesize hydrological processes on urban surface dynamism while simulating the impact of climate and landuse changes on sustainable livelihood of urban populace.

Initial broader studies examined the immediate and future consequences of land use change in the ecologically fragile coastal flood plain of the Lower Ogun River basin in the north east and south eastern parts of Lagos. The statistic landcover of the lower Ogun floodplain in 1965 was 38.01×10^6 ha. The ecologically fragile wetland covered 82.45% of the total area. This figure decreased to 13×10^6 ha. or 36.31% in 2005 at an average rate of 0.439×10^6 ha. per annum. The functional nature of changes is in favour of residential development. Based on a detailed examination of the Lower Ogun studies, an investigation on the urban land use change and the flooding in Ashimowu watershed, situated in central part of Lagos metropolis was conducted. Using hierarchical classification scheme, the land use situation of Ashimowu watershed for 1965, 1975 and 1987 were generated from mosaics of sheets of aerial photograph while an IKONOS 2 image was used to map the 2003 land use. The analyses include area data of the land use / land covers classes for the four scenarios (1965, 1975, 1987 and 2003) to generate trends, rate of change (1965-2003) and overlay analysis of the generated land use of different years (1965-1975, 1975-1987 and 1987-2003), thus providing information in matrix format on specific point by point change detection procedure that generated data on the nature, location and magnitude of the changes. The rainfall characteristics between August and November 2005 were studied and eleven storm rainfall events were recorded. The Precipitation Water Inundation Model (PWIM) was developed. PWIM is land system

model that synthesis hydrological processes on digitally generated urban surface characteristics and simulates runoff and peak flow from precipitated water. It has four major components which include: Rainfall-Runoff, Infiltration, Digital Surface and Stochastic. PWIM was used to analyse the flooding patterns of the land use scenario as well as climate change connection in intra-urban watershed flooding. The future flooding pattern was based on the change in precipitation and urbanization (land use change) drivers. Predictions were made for 25 years, 50 years and 100 years. However, the activities described reveal that of the 13.46 km^2 Ashimowu watershed, the built up area progressively increased from about 166.88 hectares (12.40%) in 1965 to 1231.00 hectares (91.46%) in 2003 at an average rate of 28 hectares per annum. The correlation coefficient (r) of land use of the four scenarios with PWIM simulated peak flow shows an average of 0.96 while the coefficient of determination (r^2) reveals an average of 0.92 (92%). This indicates a high linear and positive relationship between urban development and flood generation. The area inundated by a particular storm event was found to be largely determined by the rainfall intensity. Four levels of vulnerability were determined; these are very high, high, medium and moderate risk zones. The very high and the high are limited to the LUTH-Idi Araba sub-watershed due to the urban land spatial arrangement which makes the area more vulnerable than the down stream of the watershed.

On the impact of climate change, the study reveals that urban flooding will be more severe in the first 20 to 30 years, using the year 2003 urbanization drivers as the base year. Similarly, the peak flow and other related velocity for the 25 years high climate change will increase by an average of 16.1% while inundation areas will increase by an average of 2.46%. Policy implementations that 1) embrace the use of the PWIM for design and urban renewal purposes, 2) use incorporation of estimated future floods resulting from present global climate change phenomena in current interventions, 3) encourage public campaigns/awareness raising and 4) improve the socio-economic status of vulnerable individuals are recommended.

Prof. Tom Veldkamp – Session 2 Presenter

Wageningen University and Research Centre, P.O. Box 47, 6700 AA Wageningen, The Netherlands

Email: tom.veldkamp@wur.nl

Research Area/Discipline: Landscape Dynamics

GLP Scientific Steering Committee Member

Extended Abstract:

The influence of scale on the analysis of key drivers of land-use/cover change processes

A. Veldkamp

Wageningen University and Research Centre, P.O. Box 47, 6700 AA Wageningen, The Netherlands

Introduction

Interpretations of how multi-dimensional land use/cover driving forces act and interact is still controversial, especially with respect to the assessment of the relative importance of the different forces underlying land use decisions in specific cases. Insights in the functioning of this complex system of driving forces can be gained by studying these processes in comparative studies. Unfortunately, relative few regional comparative studies have addressed the role of these combined driving forces in agro-ecosystems in a spatially and temporally explicit way.

Researchers in the field of the social sciences have a long tradition in studying individual behaviour in human-environment interactions at the micro-scale, mostly by narrative approaches. At higher levels of aggregation, geographers and ecologists have studied land use change either by direct observation using remote sensing and GIS. Other studies have applied the systems/structures perspective to find understanding in the organisation and institutions of society and landscapes that establish opportunities and constraints on decision making. Direct up-scaling of processes and understandings of land use driving factors to higher aggregation levels is not possible, because these relations are often not valid through to scale dependency of the relations. Through non-linearity, complexity, feedback's and interactions the behaviour of a large group of people is different from the sum of the behaviour of the individual actors. New theories on land use drivers and processes at higher aggregation levels are needed to understand this behaviour.

System's theory, however, is not yet very well developed for the land use system. Fortunately, the properties of a land use system are comparable to those of an ecosystem and the way it functions in many ways, and ecosystem theory does have a long history. Especially the concept of the system's complexity is well evolved. Ecologists discern two types of complexity that both apply to land use systems as well. Firstly, land use systems are functionally complex, i.e. many factors influence the manner the land is used. Biophysical, climatic, demographic, economic, and political variables all directly or indirectly influence land use practices. Moreover, factors do not act independently, but form a web of interactions and feedbacks. A second, probably more important type of complexity is structural complexity, indicating that factors act on different temporal and spatial scales. For ecosystems, the so-called hierarchy theory has been developed that states that to understand any complex system, one needs study at least three levels in the spatio-temporal hierarchy. There is a growing body of evidence of the importance of the scale effect in many scientific disciplines.

A scale can be defined as a range of spatial and temporal frequencies. This range of frequencies is defined by resolution below which faster and smaller frequencies are noise, and the extent above which slower and larger frequencies are background. Actors and processes that operate at the same scale interact strongly with another, but the organisation and context of these interactions are determined by the cross-scale organisation of the system. In general, processes operate at characteristic periodicity's and spatial scales. All these processes produce scale-specific patterns, which are self-organising in nature.

Data Source and Issues

Land use systems have been analysed at different spatial scales through multiple statistical methods for many different countries and regional all over the world (see: www.cluemodel.nl). Multiple regression techniques were used, checked for their significance and spatial auto correlation. With these methods the most important bio-geophysical and socio-economic drivers of land use are being determined, as well as the quantitative relations between these drivers and the surface area of different land use types. This analysis is repeated for various aggregation levels in order to determine spatial scale effects.

For all executed land change studies both biophysical and socio-economic factors proved to be important. So, land use is more than the product of human behaviour, for it is intimately tied to the physical environment. Similar social, political, and economic conditions of decision making in dissimilar physical environments usually yields different land uses. We therefore strongly agree with that the environment mediates and conditions land use. Consequently, all analysis of land use should always integrate biophysical and socio-economic conditions. We can therefore safely conclude that interdisciplinary approaches and theories are needed to analyse land use successfully.

Using data sets of different scales, merging, scaling and aggregation issues

Resolution of data affects the results of a land system analysis. Different processes determine the land use pattern at their own dominant scale level. For the system as a whole there is not one optimal scale level. Concerning with land use systems we are dealing with a scale continuum with no simple predetermined aggregation levels. Therefore, explicit attention should be given to the question at which scale of analysis the driving factors of land use change should be studied. A multi-scale approach, comprising the study of the system at different levels of integration, should be followed to analyse the system and variety in processes in a more complete way. The above mentioned case studies clearly illustrate the need for more scale sensitive approaches in land use system analysis.

Collecting data for modelling

Land use data generally records the production or provision of a certain commodity within a certain (administrative) area, and is mostly obtained from census or survey data. Agricultural land use data report harvested areas or the harvested areas are inferred from total produced quantities divided by reported or estimated yields; Forestry land use data report the amount of wood or other forest-products extracted from a forested area. Land use data are generally only spatially explicit at the level of specific administrative units, such as provinces, counties or municipalities.

Land cover data are commonly more spatially explicit with high levels of spatial resolution, varying from less than a meter to approximately 1 km, depending on the source data (satellite images, aerial photography etc). Land cover records that which is observed on the earth's surface and does not report information concerning any activity. In many cases it is possible to distinguish land cover that is associated to a specific land use (i.e. where a commodity is produced or provided) and land cover that is not (e.g. scrublands, wetlands, abandoned agricultural land).

Land use and/or land cover modelling approaches have often treated land use and land cover as if they were interchangeable. This may be because monitoring past and/or present land use / cover does not necessarily require a distinction between use and cover: the presence of any land cover is often directly categorically associated to a land use and vice versa. For modelling land change, however, often one has to be derived from the other, which is not always a straightforward task.

Currently there are different modelling approaches for modelling future land change. Models that aim at predicting land change need to address two separate questions: 1) at what rates will different types of change occur: i.e. the quantity of change; and 2) where will land changes likely take place: i.e. the location of change. The first question is usually derived from changes in the demand for land-based commodities. Models typically addressing quantity and rate of land use are process-oriented economic and/or (multi) agent-based models. At wider scale levels these models focus on production, demand and trade, whereas at finer scales the land owner decision-making is the main topic of interest.

The second question requires the natural and socio-economic landscape attributes that determine the spatial location of change to be identified - i.e. local proximate causes directly linked to land changes. Models inferring the location of land change usually obtain their allocation rules from the spatial association between land cover data and certain environmental characteristics. These - generally empirical - models link the cover pattern information to potential spatial determinants by means of statistical analyses combined with assumed spatial behaviour as mimicked by cellular automata (CA). The hence obtained land change patterns are often described in terms of land cover change. Thus, the answer to the ‘how much’ question takes the form of a land use commodity quantity, while the answer to the ‘where’ question takes the form of a land cover pattern.

Interchangeable use of land use and land cover is limiting the quality of future land change projections. Research should pay more attention to investigating the nature of the land use – land cover relationship. The observed mismatch between land use statistics and land cover observations needs to be identified in terms of data-errors and spatial variability in the land use/cover. Spatial land cover allocation should take into account the requirements for secondary land use in terms of minimal spatial extent, connectivity, and the compatibility with neighbouring land cover types.

Prof. Guangsheng ZHOU

PI of 'Global Change and Terrestrial Ecosystems' Research Group, State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, the Chinese Academy of Sciences, China

Email: gszhou@ibcas.ac.cn

Research Area/Discipline: Integration and modelling on the interaction between global change and terrestrial ecosystems / Ecology

Extended Abstract:

Simulating water vapor, sensible heat and carbon dioxide fluxes over typical terrestrial ecosystems in northeast China based on modified integrated biosphere simulator (IBIS)

Guangsheng Zhou[a,b], Li Zhou[a], Xinhua Sui[a], Yuhui Wang[a]

[a] *State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, the Chinese Academy of Sciences, 20 Nanxincun, Xiangshan, Haidian District, Beijing 100093, China*

[b] *Institute of Atmospheric Environment; China Meteorological Administration; Shenyang 110016, China*

Terrestrial ecosystems affect climate through exchanges of energy, water, momentum, CO_2, trace gases, and mineral aerosols. Changes in community composition and ecosystem structure alter the fluxes and in doing so alter climate. It is essential to improve our understanding of the terrestrial biosphere, not only in terms of the possible impacts of climate change, but also in terms of the interactive role that biospheric processes play in the functioning of the Earth system as a whole. A wide variety of numerical models have emerged in the last decade in an attempt to elucidate global biogeophysical processes related to energy and water. The integrated biopshere simulator (IBIS) of Foley et al. (1996) is designed to simulate such processes. It is designed to integrate a variety of terrestrial ecosystem phenomena within a single, physically consistent model that can be directly incorporated within atmospheric general circulation models (AGCMs). To facilitate this integration, the model is designed around a hierarchical, modular structure and uses a common state description throughout. However, the accuracy of flux estimations from IBIS is restricted due to the constants of maximum capacity of Ribisco to perform the carboxylase function and carbon allocation. Here, we propose a modified IBIS model from the effects of soil nutrients on photosynthesis and the carbon allocation, in order to understand and improve estimates of water vapour, sensible heat and carbon dioxide fluxes over typical terrestrial ecosystems in northeast China.

The effects of soil carbon and nitrogen on leaf photosynthesis are described by the maximum rate of carboxylation V_{cmax} based on a biochemical processes developed by woodward et al.(1995). For a given availability of light (L), water (W), and nitrogen (N), the allocations of carbon to roots (ρ), stem (σ), and leaves (λ) are modified from the allocation scheme for global terrestrial carbon models given by Friedlingstein (1999). In order to validate the performance of modified IBIS, long term observation data of aboveground biomass in meadow steppe from Grassland Research Station of Northeast Normal University (1981-1990), typical steppe from Inner Mongolia Grassland Ecosystem Research Station, the Chinese Academy of Sciences (CAS) (1981-1994), and alpine meadow steppe from Haibei Research Station of Alpine Meadow Ecosystem, CAS (1981-1994), as well as flux observation from Inner Mongolia Typical Grassland Ecosystem Field Observation Station, Jinzhou Agricultural Ecosystem Field Observation Station, Panjin Wetland Ecosystem Field Observation Station, and Changbai Mountains Temperate Forest Ecosystem Field Observation Station from August 2004 to December 2006.

The resulted indicated that the modified IBIS could greatly improve the estimate of aboveground grassland biomass in China, and also simulated the dynamic fluxes of water, heat and carbon fluxes over grassland ecosystems very well.

The results indicated that the accuracy of aboveground biomass and flux estimations from IBIS is serious affected due to the constants of maximum capacity of Ribisco to perform the carboxylase function and carbon allocation. The modified IBIS could greatly improve the estimate of aboveground grassland biomass and fluxes of water, heat and carbon fluxes over typical terrestrial ecosystems in northeast China, including temperate grassland, maize farmland, reed wetland and forest ecosystems. This study provides a key tool for carbon cycle studies and evaluations of terrestrial ecosystems as it represents processes and provides detailed information as to the workings of the terrestrial carbon system.

Key words: Water vapour flux, sensible heat flux, Carbon dioxide flux, Terrestrial ecosystems, China modified integrated biosphere simulator (IBIS)

Participant List

Email

Prof. Richard Aspinall r.aspinall@macaulay.ac.uk
Chief Executive
The Macaulay Institute,
Craigiebuckler,
Aberdeen,
AB158QH
UK

Dr Innocent Bakam i.bakam@macaulay.ac.uk
Complex Systems Modeller,
The Macaulay Institute,
Craigiebuckler,
Aberdeen,
AB158QH
UK

Prof. Heiko Balzter hb91@le.ac.uk
Centre for Environmental Research, Department of Geography, University of Leicester,
University Rd,
Leicester,
LE17RH,
UK

Dr Randall Boone rboone@nrel.colostate.edu
Natural Resource Ecology Laboratory,
Colorado State University,
Fort Collins
Colorado
80523
USA

Mr Shawn Bucholtz Shawn.Bucholtz@wdc.usda.gov
PhD Student,
Department of Computational Social Science,
Center for Social Complexity,
George Mason University,
4400 University Drive,
Fairfax,
Virginia 22030
USA

Dr Nicolas Dendoncker n.dendoncker@ed.ac.uk
Centre for the Study of Environmental Change and Sustainability (CECS),
University of Edinburgh,

Dr Karlheinz Erb karlheinz.erb@uni.klu.ac.at
Institute of Social Ecology,
Klagenfurt University
Schottenfeldgasse 29,
1070 Vienna,
Austria

Dr Kees Klein Goldewijk kees.klein.goldewijk@mnp.nl
Senior Coordinator International Datalogistics,
Global Sustainability and Climate Unit,
Netherlands Environmental Assessment Agency (PBL),
Global Sustainability and Climate (KMD),
P.O. Box 303,
NL-3720 AH BILTHOVEN,
The Netherlands

Mr Abdul Husaini abdulhusaini@yahoo.com
Assistant Chief Town Planning Officer,
Niger State Urban Development Board,
Minna,
Nigeria

Prof. Suzi Kerr suzi.kerr@motu.org.nz
Director,
Motu Economic and Public Policy Research,
Level 1, 93 Cuba Mall,
P.O. Box 24390,
Wellington,
New Zealand

Ms Natasha MacBean n.macbean@ucl.ac.uk
PhD Student,
Department of Geography,
University College London,
Pearson Building,
Gower Street,
London,
WC1E 6BT
UK

Mr Menno Mandemaker menno.mandemaker@wur.nl
PhD Reseracher,
Wageningen University and Research Centre, P.O. Box 47,
6700 AA Wageningen,
The Netherlands

Dr Eleanor Milne e.milne@macaulay.ac.uk
Executive Officer for the Global Land Project
Nodal Office for Integration and Modelling
The Macaulay Institute,
Craigiebuckler,
Aberdeen,
AB158QH
UK

Dr Odunuga Shakirudeen odushak@yahoo.co.uk
Department of Geography
University of Lagos,
Lagos,
Nigeria

Prof. Tom Veldkamp Tom.Veldkamp@wur.nl
Land Dynamics group
Wageningen University,
P.O. Box 47,
6700 AA Wageningen,
The Netherlands

Prof. Guangsheng Zhou gszhou@ibcas.ac.cn
PI of Global Change and Terrestrial Ecosystems Research Group,
State Key Laboratory of Vegetation,
Environmental Change,
Institute of Botany,
The Chinese Academy of Sciences,
China