

The Impact of Recent and Future Land-Use and Climate on the Global Carbon Cycle

SUPERVISORS:

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The land biosphere plays an important role in the carbon cycle and climate system: uptake reduces the rate of atmospheric CO₂ build-up and associated climate warming; conversely deforestation releases CO₂ to the atmosphere. Future changes in climate and land-use will affect land-atmosphere exchange and vegetation and soil dynamics, and hence the ability of the land-surface to sequester carbon. Previous modelling studies have revealed large uncertainty as to future projections of global net carbon uptake, indeed as to whether the land biosphere remains a carbon sink or becomes a source in the late 21st century. However, very few studies to date have examined how multiple sources of uncertainty such as climate and land-use affect future global and regional projections of terrestrial carbon storage.

In this project we will quantify the uncertainty in terrestrial carbon storage associated with recent and future scenarios of climate and land-use, using a state-of-the-art land surface model (JULES) developed at the Met Office Hadley Centre.

The project will involve three stages: building a representation of temporally varying land-use into JULES and evaluating its performance against observations of the global carbon cycle, to explore different land-use strategies and help build scenarios of future land cover change on a global scale, and to evaluate the impact of future land cover scenarios on the global carbon cycle.

1) Represent land-use in JULES

Temporally varying land-use and cover change representation will be built for the JULES model. This will involve creating maps of land-cover from existing land-cover/use datasets and using other Earth Observation (EO) datasets to produce annually varying datasets of land use for JULES over the 20th Century. JULES will be developed to utilise such information by enabling the model to simulate deforestation, land abandonment, follow the wood product pool, and incorporate simple schemes of land management (e.g. forest rotation times etc). New generalised plant types to represent agricultural and pastoral land-use will be created for JULES by obtaining relevant biophysical parameters from the literature and utilising EO data (e.g. from AVHRR, MODIS) where possible.

2) Develop land-use strategies and scenarios of future land cover change on a global scale

Land cover maps will be created to represent the effect of different land management and future climate policy scenarios on land cover globally. These scenarios will be based on methodologies used in the European ATEAM project to produce future land cover datasets based on scenarios of global trading policies and on the SRES family of scenarios. A key development is the construction of plausible land use scenarios and land cover maps for the tropics and other developing World regions. The effect of climate-related policies such as reforestation initiatives proposed under the Clean Development Mechanism of the Kyoto Protocol on regional land cover will also be investigated.

3) Implications of future changes in land-use

By incorporating land cover changes into a state-of-the-art land surface model, and conducting an evaluation of the impact of land use and cover changes on the global carbon cycle over the 20th Century, utilising carbon cycle data and Earth Observation. An important advance compared to previous studies is the inclusion of pastureland, an important land cover type especially in tropical ecosystems. The project will also collaborate with CarboEurope activities which aim to quantify the impact of present-day and land-use changes on the European carbon balance. The combined effect of different future land use and climate scenarios on the global carbon cycle and on regional carbon balances will then be simulated with JULES. These model simulations will yield uncertainty estimates for future net primary productivity and net land uptake associated with changes in land use as well as provide insight into key ecosystem responses to climate and land-use change.

Supervision and collaborations

The student will benefit from supervisory expertise in climate and ecosystem/land-use modelling and remote sensing in Edinburgh and Aberdeen and at the Hadley Centre, and will have the opportunity to work with state-of-the-art models and interact with major multi-disciplinary national and international research networks e.g. JULES (<http://www.jchmr.org/jules>), the Scottish Alliance for Geoscience, Environment and Society (SAGES) (www.sages.ac.uk) QUEST (QUERCC) (<http://quest.bris.ac.uk/>) and CLIP(www.clip.msu.edu). They will learn transferable and communication skills from training courses and appropriate MSc. Modules (e.g. global environmental change, environmental sustainability, remote sensing) within the University and attendance at the NERC Earth Systems Science summer school and relevant conferences. Links to the Hadley Centre and SAGES will provide valuable involvement in world-leading science with a strong policy focus, and will provide opportunities to see the science applied directly to UK and international policy via the Hadley Centre's government research programme and the Intergovernmental Panel on Climate Change (IPCC).

Existing Facilities:

The necessary computing resources are available within the School. The external supervisor at the Met Office will provide the Hadley Centre climate-carbon-cycle model code. The student will also have the opportunity to obtain to interact with colleagues in the School of Biological Science at the University of Aberdeen (<http://www.abdn.ac.uk/biologicalsci/>), at the Hadley Centre and in the NERC funded Centre of excellence for Terrestrial Carbon Dynamics <http://ctcd.group.shef.ac.uk/ctcd.html>).

Project summary:

The role of the terrestrial biosphere whether as a carbon source or sink in the 21st century is highly uncertain. This modelling project will investigate the influence of current and future scenarios of changes in land-use on the carbon cycle and associated feedbacks on climate.