Impacts World 2013, International Conference on Climate Change Effects,
Potsdam, May 27-30

Framework for multi-scale integrated impact analyses of climate change mitigation options

Marta Pérez-Soba, Terry Parr, Laure Roupioz, Manuel Winograd, Marielos Peña Claros, Consuelo Varela-Ortega, Nataly Ascarrunz, Patty Balvanera, Pradeepa Bholanath, Miguel Equihua, Lucieta Guerreiro Martorano, Laurence Jones, Manuel Maass and Kirsten Thonicke

Abstract— Tropical forest ecosystems are hotspots for biodiversity and represent one of the largest terrestrial carbon stocks, making their role in climate change mitigation (CCM) programmes increasingly important (e.g. REDD+). In Latin America these ecosystems suffer from high land use pressures that have resulted in a dramatic biodiversity loss. Little is known about how CCM options may impact on biodiversity and how this in turn may affect ecosystem carbon storage. Within this context, the FP7 ROBIN (Role Of Biodiversity In climate change mitigatioN) project developed a framework for multi-scale integrated analysis of the impacts that land use change may have on the ecological and social-economic processes of these ecosystems. The framework represents a continuous feedback loop in which changes in CCM options modify land use, that results in biodiversity change, affecting ecosystem functions, leading to changes in ecosystem services that affect human outcomes and societal behaviour, and which then affect the main drivers and pressures on biodiversity and ecosystems, and so on. We have constructed an indicator framework that allows to quantify, link and assess these interactions at three spatial scales: regional (Central and South America), national (Bolivia, Brazil, Guyana and Mexico) and sub-national (study sites representing multifunctional landscapes). Indicators are selected through a demand-driven approach, by directing modelling and assessment efforts towards end-user relevant issues using stakeholder participatory processes. Indicator values are grounded on field data, statistics and model outputs. The framework provides a basis for understanding potential tipping points and unexpected consequences that may arise from the implementation of climate change mitigation policies, or management options (e.g. reducing deforestation and burning, or expansion of areas of biofuel crops in illegal areas). An illustrative example, showing how the framework helps to identify the appropriate indicators to synthesise the impacts of afforestation (one of the CCM options) across the ecological and socio-ecological processes and regions is presented.

Index Terms—Biodiversity, climate change mitigation (CCM), framework for multi-scale integrated impact analysis, tropical forest ecosystems, social-ecological systems.

———————————————————

1 Introduction

Tropical forest ecosystems are hotspots for biodiversity and represent one of the largest terrestrial carbon stocks (IPCC 2007), making their role in climate change mitigation (CCM) programmes increasingly important (e.g. REDD+). In Latin America these ecosystems suffer from high land use pressures that have resulted in a dramatic biodiversity loss (Higgins, 2007). Little is known about how CCM options may impact on biodiversity and how this in turn may affect ecosystem carbon storage. Furthermore, it is also unknown how these changes in the ecological system will affect the underpinned ecosystem services, their benefits to human beings and finally result in changes in human behaviour and societies (mitigation and adaptation measures). The assessment of this complex social-ecological process requires analytical frameworks that are able to deal with the multi-scale, multi-sectoral interactions. Within this context, the FP7 ROBIN (Role Of Biodiversity In climate change mitigatioN) project has developed a framework for multi-scale integrated analyses of the impacts that land use change may have on the social-ecological processes of these systems. The objective of this paper is to contribute to the conference discussions on "Can we integrate our existing knowledge across sectors?" by introducing the ROBIN framework for multi-scale integrated impact analyses of climate change mitigation options, and illustrating how it can be applied.

2 Analytical framework for multi-scale integrated impact analyses

The ROBIN analytical framework (Fig. 1) is based on the Integrative Science for Society and Science ISSE framework (Collins et al. 2010). It has been designed to address the following key research questions:

1. **Q1**: How do changes in biodiversity affect key ecosystem processes that then affect the capacity of ecosystems and multi-functional landscapes to mitigate climate change?
2. **Q2a** and **Q2b**: How do changes in biodiversity and linked ecosystem structure and functions affect (Q2a) climate change mitigation capacity and (Q2b) other key ecosystem services?
3. **Q3**: How do changes in climate mitigation capacity affect human outcomes (i.e. benefits to society) and what is the effect of taking into account other ecosystem services in this evaluation process?
4. **Q4**: How do changes in human outcomes affect societal behaviour?
5. **Q5**: How do changes inglobal drivers, policies and management options affect climate change and land use change?
6. **Q6**: How do changes in climate and land use affect the biodiversity and ecosystem functions?

The framework represents a continuous feedback loop in which changes in CCM options modify land use that result in biodiversity changes, affecting ecosystem functions, leading to changes in the provision of ecosystem services that affect human outcomes and societal behaviour, and which then affect the main drivers and pressures on biodiversity and ecosystems and so on.

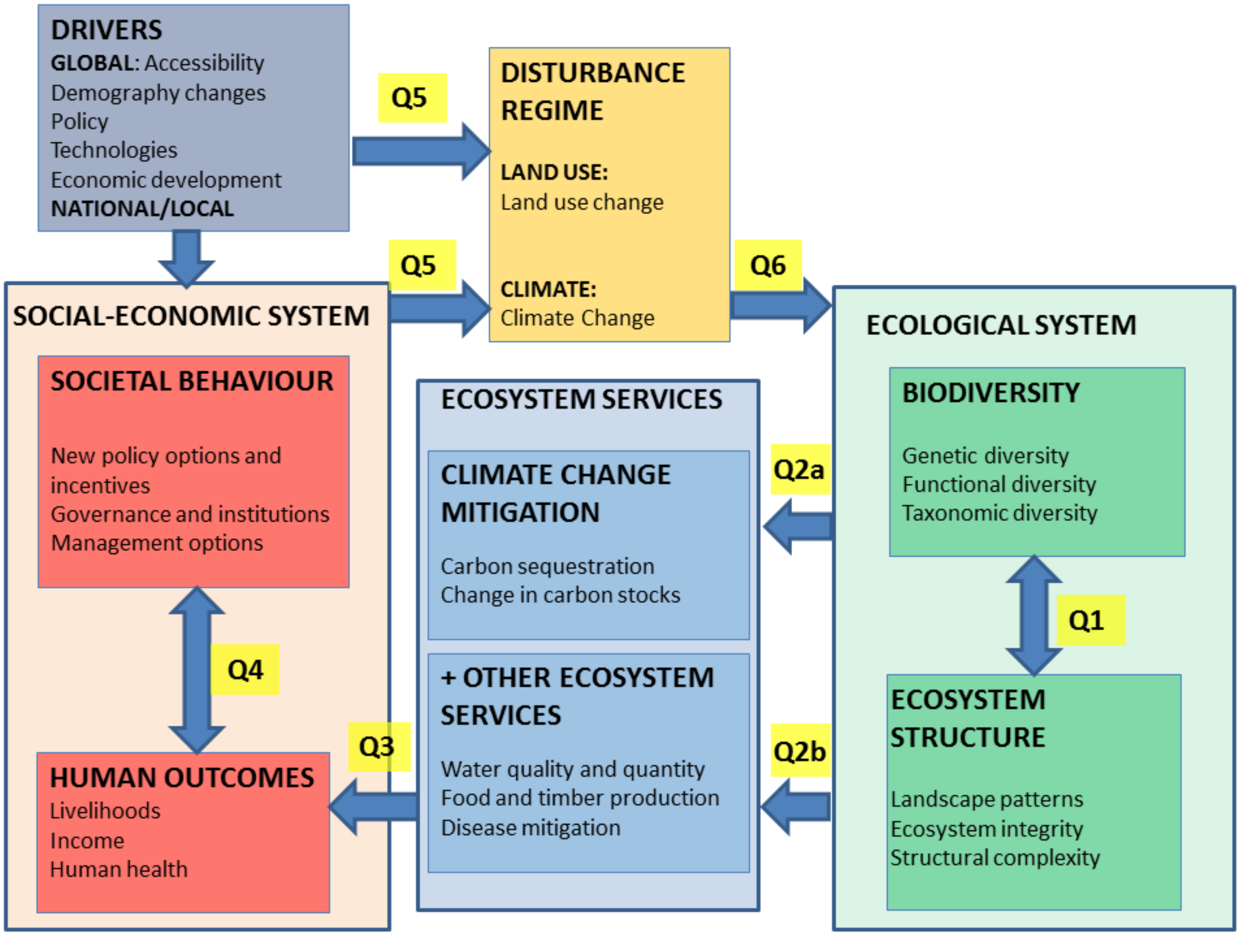

Figure 1. ROBIN analytical framework showing the main *Categories* as coloured boxes (e.g. DISTURBANCE REGIME), *Themes* within the boxes (e.g. LAND USE) and *Variables* (e.g. Land use change).

3 Indicator framework

The analytical framework is connected to an indicator framework for quantifying the interactions at three spatial scales: regional (Central and South America), national (having as example countries Bolivia, Brazil, Guyana and Mexico) and sub-national (study sites representing multifunctional landscapes). Indicators are selected ensuring a demand-driven approach, by directing modelling and assessment efforts towards end-user relevant issues, using stakeholder participatory processes. Indicator values are grounded on field data, statistics and model outputs. The framework provides a basis for understanding potential tipping points and unexpected consequences that may arise from the implementation of climate change mitigation policies, or management options (e.g. reducing deforestation and burning, expansion of areas of biofuel crops in illegal areas).

3.1 Structure of the indicator framework

The indicators selected for the ROBIN indicator framework are linked to the ‘boxes’ in the analytical framework presented in Figure 1. The indicator framework is structured into four divisions: categories, themes, variables and indicators, defined as follows:

- CATEGORIES: Broad group of issues to be assessed and analysed in the context of the ROBIN indicator framework. These issues are linked to the continuous flow between the ecological and social-economic systems, i.e. global and national drivers cause changes in land use and climate that affect eco-systems and particularly their biodiversity, which in turn impact their provision of ecosystem services, with direct and indirect impacts on the social-economic system (human outcomes affecting societal be-haviour) that drive changes, etc. They can be identified as the ‘boxes’ with different colours in Figure 1.

- THEMES: Main particular issues to be tackled within each category in order to assess and analyse the key research questions. For example, within the category ecosystem services, there are two themes: climate change mitigation (main focus of ROBIN) and other ecosystem services.

- VARIABLES: topics under each theme which value varies in time and/or space according to their current state, dynamics and trends. An operational variable is a representation of an attribute (quality characteristic, property) of a system. The pragmatic interpretation of a particular variable as an indicator is usually made on the basis that this variable carries information about the condition and/or trends of the considered system attribute.

- INDICATORS/INDEXES: They help to characterise the state, dynamics and trends of variables to be monitored, assessed and analysed. Overall, an indicator is an empirical observation or statistical esti-mation that synthesizes aspects of one or more events that are important to one or more analytical or user requirements purposes over time.

3.2 Selection of indicators

In ROBIN the selection of indicators follows a stepwise approach. In the first step, a preliminary selection is based on an extensive review of available and relevant datasets and frameworks in Latin America, which are linked to impact assessment of land use change, climate change and the sustainability of so-cial-ecological systems, particularly biodiversity, using international, regional, national and local sources. Indicators are selected 1) considering the different spatial and temporal aspects of ecosystem dynamics in climate change mitigation; 2) ensuring that both the socio-economic and environmental dimensions of land-use are covered; 3) helping to relate main policy questions to diagnostic criteria on system sustainability.

Once the data sources are reviewed and potential indicators identified, a consistent selection of the indicators is done by a few key criteria. 1) A maximum of three key indicators are selected per VARIABLE (e.g. land use change) for the regional and national scales; the number of key indicators for the local scale is not fixed since it will be regularly updated throughout the project based on the input from the local stakeholders and the participants in the project as it evolves. 2) The key indicators are ideally the same for the three spatial scales. 3) Data are available in international, national and local data sources, and if possible at different time periods.

Applying these criteria, tables were produced for the six main categories in the analytical framework, i.e. drivers, disturbance regime, ecosystem, ecosystem services, human benefits and human behaviour. The tables are structured according to categories, themes, variables and indicators/indexes, as defined above. See Table 1 as an example of the current selection of indicators for the Category “DISTURBANCE REGIME”.

In a second step, end users will revise the preliminary list ensuring a demand driven approach. By end-users we mean scientists within and outside the project, and policy and decision makers at different decision levels: government officers (national, sub-national and local authorities), land use managers (national and local), NGO’s, cooperatives, farmers, wood producers, etc. Then the revised indicator list will be operationalised by using the framework to assess the impact of some climate change mitigation options in case studies. This activity will test and improve the validity of the established framework.

Table 1. Indexes and Indicators for the DISTURBANCE REGIME category

CATEGORY	THEME	VARIABLE	INDICATOR/INDEX		
			REGIONAL (Meso-America and South-America)	**NATIONAL (Bolivia, Brazil, Guyana and Mexico)**	**SUB-NATIONAL (case studies:Tapajos, Guarayos, Cuitzmala)**
DISTURB-ANCE REGIME	LAND USE	1. Land use change (including land management)	1a. Forest risk index	1a. Forest cover change (by type) 1a. Deforestation rate (%, has, by type of forest)	1a. Forest degradation index 1a. Phenology/ disturbance index (derived from Remote Sensing)
			1b. Land use index	1b. Land Use Land Cover Change 1b. Land use potential	1b. Land degradation index 1b. Carrying capacity index (Animal Units/ha) 1b. Fraction of functional crop types 1b. Harvested biomass 1b. Residual biomass after harvesting 1b. Land use carbon change in soils 1b. Land use carbon change in biomass
			1c. Crops affected by pest and diseases	1c. Use of pesticides per ha	1c. Location of crops diseases 1c. Location of livestock diseases 1c. Location of forest diseases 1c. Location of human diseases
			1d. Invasive species	1d. # of alien plants species	1d. Location of alien plants species
	CLIMATE	2. Climate change	2a. Climatic risk index	2a. Precipitation/ temperature change 2a. Drought events (#, areas affected, economic losses) 2a. Flood events ((#, areas affected, economic losses)	2a. Economic impact of ENSO[1] 2a. Evapo- transpiration change 2a. Precipitation/ temperature change 2a. Area affected by drought 2a. Area affected by flood
			2b. Fires location/extension	2b. CO_2 emissions by land use change 2b. Fire location 2b. Fires risk	2b. Area affected by fires 2b. CO_2 emissions by land use change 2b. CH_4 emissions by land use change

4 Example illustrating the analytical framework application

The example in Figure 2 shows how the ROBIN framework (see Fig. 1) helps to identify the appropriate indicators to synthesise the impacts of afforestation (one of the CCM options) across the ecological and socio-ecological processes and regions. The framework can be consistently applied to address the key research questions (see section 2 above) at three different scales (regional, national and sub-national, and provides a logical and functional link between the different conceptual compartments and integration between the three spatial scales. It is interesting to see how the different indexes and indicators are used at different scales depending on their relevance and availability.

[1] ENSO = El Niño-Southern Oscillation

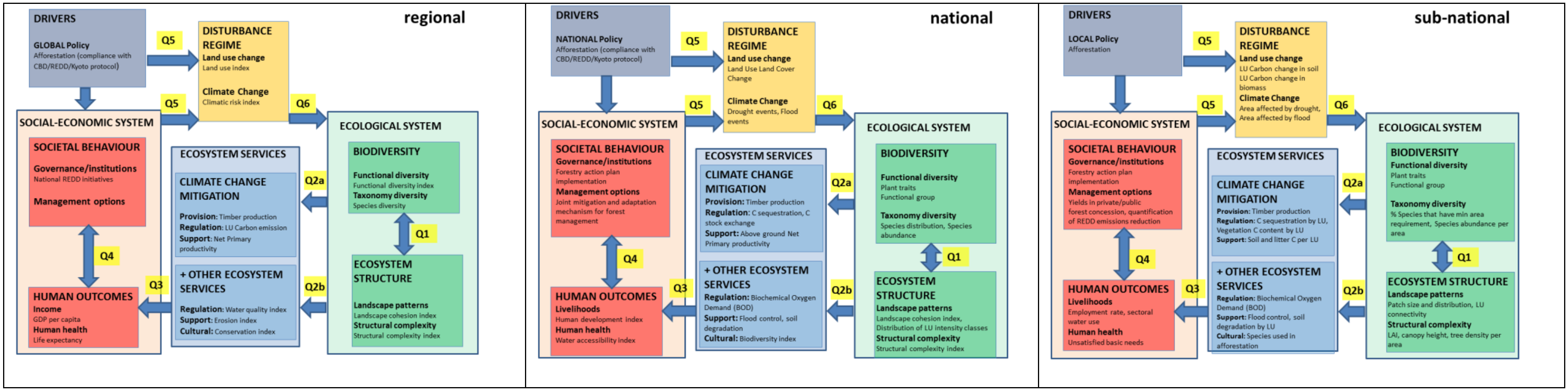

Figure 2. Example illustrating the application of the analytical framework integrating the different conceptual compartments at three scale levels: regional, national and sub-national.

5 Conclusions

One of the biggest challenges to define efficient and effective climate change mitigation options is to integrate our existing knowledge across sectors and scales. Achieving understanding on the interactions and feedbacks between sectors at different spatial levels as well as across ecological and social structures, could have a profound influence on the global mitigation capacity. We introduce here a generic analytical framework based on a circular model, where the links between the sectors within the social-ecological system are made explicit and measurable through a set of key indicators. This framework can be applied at different spatial levels in a consistent and flexible manner, allowing a multi-scale integrated assessment. The framework can also provide an understanding of the potential effects of changes in other 'land-use-related' policies than climate change, such as environmental and agricultural policies. Our framework thus provides the basic building blocks for a better understanding of the feed-back loops in the system, the interaction between scales and the testing of mitigation options.

6 References

Collins, S.L. et al, 2010. An integrated conceptual framework for long term social-ecological research. Front. Ecol. Environ. doi:10.1890/100068.

Higgins, P.A.T., 2007. Biodiversity loss under existing land use and climate change: an illustration using northern South America. Global Ecology and Biogeography, 16, pp.197–204.

IPCC, 2007. IPCC Fourth Assessment Report.