Overview of proposed papers

#### **Paper 1: Structural patterns of economic development and environmental sustainability co-authors: Jørgensen**

Objectives

Assess the extent to which the patterns of association between economic development and environmental impact at the country-level, fit the so-called ‘modernization theory’, and the extent to which deviations from this theoretical patterns can be accounted for using variables from alternative theories of human-environment relationships, as well as other from the development economics literature.

Research question

How does change in the key social and economic (macro/aggregate) variables associated with development (urbanization, growing share of industry and service sectors), relate with the change in key selected (macro/aggregate) environmental impacts (domestic forest area and material throughput)?

Justification

‘Modernization theories’ pose that beyond a certain level of economic development, countries start to reduce their environmental impact. However, empirical evidence suggests this is not the case for most types of environmental impacts. Building a link to the rich literature on development economics, to identify specific mechanisms that can account for expected and observed patterns of association between economic development and environmental impact. We see that, although research has focused “structural change of inter-linked social and natural systems” (Fischer-Kowalski & Haberl 2007:8) is not new, and researchers working from an ecosystem services and social-ecological systems perspective are also addressing related questions (Cumming et al. 2014; Seppelt & Cumming, 2016), both this framings seem to have ignored the development economics literature (e.g. Reardon et al. 2015; Berdegué et al. 2015; Barrett et al. 2010) . We think that this literature offers a wealth of ‘process’ understanding, that could be used to enrich our understanding of unsustainable socio-ecological patterns and potential sustainability transitions.

Academic context

* Big narratives/theories of the relation between social and economic development and environmental impacts (York et al. 2003; vanWey et al. 2005)
  + Forest transition as a specific ‘modernization theory’ (environmental Kuznets curve)
* Socio-ecological transitions (Fischer-Kowalski & Haberl 2007)
* Development economics, mainly on rural development and structural change (e.g. Reardon et al. 2015; Berdegué et al. 2015; Barrett et al. 2010).
* The environmentalist's paradox (Raudsepp-Hearne et al. 2010, 2011)

Methods

* Statistical analysis using aggregate data on national economic change (World Bank 2016), material throughput (Wiedmann et al. 2013), and forest cover (FAO 2015). Two possible strategies we are currently trying out:
  + Explorative: Categorization of countries based on economic ‘state’ and ‘trend’, on one hand and environmental impact (also ‘state’ and ‘trend’). Followed by analysing the how consistently these categories mirror each other.
  + Separating in 3-4 groups all the countries based on their current development state, identify the socially and environmentally ‘desirable’ and ‘undesirable’ deviations from a theoretically-informed model of the relationship between development and environmental impact. Using cluster analysis, factor analysis and PCA, explore if there are cohesive groups among these countries, and whether these groupings can be explained by any of the variables suggested by other big theories, as well additional variables derived from the development economics literature.

Relation with other papers

* This is the bigger picture: long-term development trends and the possibilities for a sustainability transition (Kates & Parris 2003). One of this trends is rural out-migration and urbanization, that papers 1 and 4 analyse beyond the aggregate patterns and into the specific processes.

Progress

* We have downloaded and cleaned the data, and completed the first exploratory analysis of the aggregate patterns.
* We have advanced conceptually on the methods to use.

Next steps

* Concretize the methods and try them out.
* Identify key variables to might help to explain what can be expected to be large deviations from a EKC.

#### **Paper 2: Archetypes of land use change (co-authors: Rocha, Baraibar, de Bremond, Alpizar?)**

Objectives

* Propose an approach to operationalize resilience analysis for land systems, based on existing tools, and useful for settings with low data availability.

Research question

* How can a resilience perspective by operationalised for the analysis of land use change?

Justification

* For some years now, there has been a recognition of the potential gains of bringing resilience thinking into land change science, both for theoretical development and for policy purposes. This is illustrated by recent advances within this research community to analyze land use regime shifts. The increasing attention and concern about the vulnerability of local and regional landscapes, livelihoods, and rural economies to global changes also contributes to the growing appeal of a resilience perspective to land use policy. However, operationalization of resilience analysis remains limited, and the existing methods tend to impose high data demands. Our point of entry to this challenge, is to build on the long tradition of system dynamics, and particularly to pick-up on an approach to identify surrogates of resilience.

Academic context

* Applications of system dynamics archetypes, a formal way of classifying system structures responsible for generic dynamical patterns (Meadows and Wright 2009, Wolstenholme 2003, Senge 1990), to the study of socio-ecological phenomena:
  + Syndromes of global environmental change (Schellnhuber *et al* 1997, Petschel-Held *et al* 1999), and recent attempt to revisit the approach (Eisenack 2012).
  + Identifying surrogates of resilience through system dynamics archetypes (Bennett et al 2005)
* Current work on land system archetypes, which follow a very different approach (Václavík et al 2013; Levers et al 2015), together with similar land classification schemes and maps that are not explicitly labelled as ‘land systems archetypes’ (Ellis and Ramankutty 2008, Letourneau et al 2012, Asselen and Verburg 2012).

Other important links to make:

* Land use regime shifts (Coomes & Ramankutty 2016; Müller et al. 2014)
* Process-based models and theory development in land change science (Meyfroidt 2015)

Methods

For this paper we revisit different existing methodological approaches for analysing system dynamics and resilience, to suggest their application on the field of land system science:

* Building on the experience of the regime shifts database (Biggs et al. 2015), for synthesizing case study insights, we develop a *template* to systematically characterize land system change case studies.
* Based on these insights we develop CLD following established guidelines (Sterman, 2000), and identify the archetypical system dynamics (Meadows and Wright 2009; Senge 1990) as well as more recently develop *resilience-oriented* archetypes (Bennett et al 2005).
* These archetypes are then the units of analysis for a qualitative exploration of alternative scenarios focused on key global and regional drivers of land use change

Relation with other papers

* Part of the regional drivers to consider in the ‘resilience to what’ part of this paper, will be the trends that constitute the so-called *structural transformation* underlying economic development (guiding point of paper 1). Hence, some of the archetypes to be proposed here should represent processes linking changes in the land system to those macro trends of social and economic change.
* One of the case studies used will involve rural out-migration and forest regrowth in a Latin American country, therefore informing the mechanisms explored and tested in papers 3 and 4.

Progress

* Template has been developed and refined through two applications.
* Two case studies have been characterized.
* The general approach is beginning to take form.

Next steps

* Characterize 2-3 additional case studies, which will be used as ‘prove of concept’ for the approach.
* Use the case studies analyses to build land system archetypes.
* Concretize the second part of the approach (i.e. from archetypes to resilience-oriented analysis).

#### **Paper 3: Migra-LUCC model co-authors: Crépin, Peterson**

Objectives

Develop a theoretical model to explore the conditions under which rural out-migration can lead to significant farmland abandonment, and potential forest regrowth. These conditions refer to both structural socioeconomic factors (prices of agricultural commodities, urban employment opportunities and wage differentials), as well as endogenous socio-ecological processes (ecosystem services from forests to agriculture, and investment of remittances on new land management).

Research question

* Under what conditions *can* rural out-migration lead to farmland abandonment and secondary forest regrowth?
* Is this basic mechanism underlying the ‘economic development’ pathway of forest transition enough to drive farmland abandonment and forest regrowth under structural conditions observed in different developing regions?
* How does the inclusion of additional hypothesized socio-ecological processes shape the effects of this mechanism?

Justification

The forest transition as an empirical regularity, observed at national and subnational scales, has substantial supporting evidence. Yet, many different mechanisms have been suggested, and the evidence on this regard is mixed. That is the case of one of the main causal pathways that has been proposed, namely the ‘economic pathway of forest transition’ which highlights the role of rural out-migration characterizing structural change of economies as they develop, and the drive for ‘agricultural adjustment’ in response to the resulting labor scarcity.

This causal pathway is of particular importance, as it clearly links economic development with an important dimension of global environmental change, namely land systems change. A planetary boundary for land-system change has been put forward (Steffen 2015), drawing attention to the need for reducing agricultural expansion into forests, but also to the potentially very significant role of secondary forest (Chazdon et al. 2016) for keeping societies within a safe operating space.

While the effects of these processes (and in some cases the processes themselves) are still to take place in developing countries in Asia and Africa, this phenomenon can be expected to have occurred to a large extent in Latin America already. Hence, studying how this has played out in Latin America might offer useful insights for Asia and Africa.

Academic context

* Mechanisms underlying the forest transition (Lambin & Meyfroidt 2010)
* Migration and farmland abandonment as underlying processes of a generic socio-ecological regime shift (Figueiredo & Pereira 2011)
* Agricultural livelihoods transitions (Magliocca et al. 2013; Cumming et al. 2014)

Methods

* Pattern-oriented agent-based modeling (Grimm et al. 2005; Magliocca et al. 2013a)
* System-level and agent-based model comparison

Relation with other papers

* Will guide the development of paper 4
* A specific process in the context of the patterns explored for paper 1

Progress

* System-level implementation of the base model (Figueiredo & Pereira 2011) on excel and Vensim.
* A first version of the agent-based implementation is working.

Next steps

* Implement a migration threshold effect on ABM version.
* Create artificial landscapes on ABM to explicitly experiment and debug.
* Clearly state a set multiple hypotheses regarding other possible underlying mechanisms linking out-migration to farmland abandonment and forest regrowth

#### **Paper 4: Assessing the effect of rural out-migration on forest regrowth possible co-authors: a) Etter, b) Rocha, Ruíz**

Objectives

Empirically test hypotheses derived from model of paper 1. One way of doing this could be to reanalyse available tree cover data at the municipal level, but focusing on key selected mechanisms identified through the theoretical work of paper 3.

Research question

1. Do municipalities (or households) with high rates of out-migration exhibit higher rates of farmland abandonment and/or forest regrowth?
2. ?

Justification

(same as for paper 1)

Academic context

* Mechanisms underlying forest transition (Lambin & Meyfroidt 2010).
* Empirical analysis of the effect of rural out-migration on land cover/use, agricultural practices, and off-farm economic activities: Latin American case studies (Davis & Lopez-Carr 2014; Gray & Bilsborrow 2014; Gray 2009a,b)

Methods

* Following approach used by Rueda et al. (2015) to assess the effect of coffee eco-certification on Colombian Andean landscapes:
  + Random forest (Breiman 2001) using Landsat imagery to derive variables based on vegetation indices, spectral, topographic, and textural data (possibly also some landscape pattern indices). And reference data from high resolution aerial or satellite data.
  + Pair-matched control method (Blackman and Naranjo 2010)using data from the recent Censo Nacional Agropecuario, to try to create a robust counterfactual.

Relation with other papers

* Will be shaped by first results obtained working on paper 1
* A specific process in the context of the patterns explored for paper 3

Progress

* (not started yet)

Next steps

* Assess the availability of key migration data (Bell et al. 2014) or indirect estimations (Sorichetta et al 2016; Stillwell et al 2014), and possibly remittances (?)