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Reusser, D. E.; Lissner, Tabea; Lutz, Raphael; Siabatto, Flavio Augusto Pinto; and Kropp, Jürgen, "Collaborative modelling of the interdependence of mitigation, adaptation and development" (2012). International Congress on Environmental Modelling and Software. 84.
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Collaborative modelling of the interdependence of mitigation, adaptation and development

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Abstract: Managing the interdependence of climate mitigation, adaptation and sustainable development requires a good understanding of the dominant socio-ecological processes that have determined the pathways in the past. In a collaborative modelling exercise with the environmental administration from Mexico and the spatial planning centre from Indonesia, we are developing two country-specific system dynamic models to describe the most relevant processes with respect to balancing mitigation, adaptation and development. In a first workshop in November 2011 interested stakeholders from the ministries were introduced to the method and relevant sectors have been identified. In an iterative process, key variables, the interdependencies between the variables and the resulting dynamics will be discussed and tested with respect to the ability to reproduce past dynamics. We will report about the experience in this ongoing process and present the current state of the resulting dynamic model along with first, preliminary results. We will also present some of the feedback from the participants in the Ministries with respect to the applicability of the resulting model.

Keywords: country level model; system dynamics; historical transitions; Mexico; Indonesia

1 Introduction

Climate change is a major challenge for human society, as mitigation and adaptation strategies will both require and trigger changes in society and technology [WBGU, 2011]. Managing the climate related changes is difficult because normal development, climate mitigation and climate adaptation are interacting [Klein et al., 2005]. We can understand these changes as transition processes, which interconnect two sides, environmental innovation and related societal changes including new institutions [van den Bergh et al., 2011]. This helps us to broaden the view from narrow, economical and technological solutions to a broader view related to a societal path towards sustainability.

Research on socio-technical transition is an evolving field [for a recent overview see e.g. van den Bergh et al., 2011; Holtz, 2011] and models may be used to better understand policy options for transition processes. Examples of existing models on transition processes include a climate change related study by Köhler et al. [2009], who present an agent based model on a transition to sustainable transportation, while Chappin [2011] presents a number of models in the field of energy transitions and discusses transition management. Both these topics are closely related to climate mitigation.

Adaptation on the other hand is currently represented in models in a very simplistic way
[Patt et al., 2009; Dickinson, 2007], assuming for example optimal and immediate adaptation, which does not reflect many characteristics of actual adaptation processes [Moser and Ekstrom, 2010]. Models are missing that integrate adaptation, mitigation and development processes at the country level. Therefore further model development is required to support the management of climate related transition processes.

Collaborative modelling may support the sharing of knowledge and understanding of a system and its dynamics under various conditions between modelling experts and domain experts. Further it aids the identification and clarification of the impacts of policies directed at solving a given problem, which helps the decision making process [Wassen et al., 2011; Voinov and Bousquet, 2010]. Within the scope of a joint project with the German Agency for International Cooperation (GIZ) we collaborate with partners from Mexico and Indonesia on the development of country scale models that integrate adaptation, mitigation and development processes in order to better understand pathways towards sustainability. We present more details on this process in Section 3.

While collaborative processes are one way of building model credibility, testing it on past observations is a further technique for model validation. Thus we are interested to see how other studies have used historical societal transitions to give support to their model and review these studies in Section 2. As the number of transitions related modelling studies is limited, we extend our review to the broader set of studies, that look at historical transitions, not necessarily modelling them. The studies we found are mostly about transitions related to infrastructure and agriculture.

We have structured this manuscript the following way. In Section 2 we review which past transitions have been described in the literature and how usage of resources have been described and modelled. In Section 3 we outline the process that we have started together with GIZ to build the country scale model in collaboration with partners from Mexico and Indonesia. In Section 4 we briefly present model components that are required to integrate adaptation, mitigation and development processes. We intend to transfer best the experience from existing literature to our research. We conclude in Section 5.

2 Review past transitions

As pointed out in the introduction and requested in the literature [Holtz, 2011], models on societal transitions should use multiple indicators from observation for model validation. However, it is not immediately apparent what indicators are best suited and readily available for such a validation exercise. Therefore, in this section we review existing literature, asking which transition processes have been analysed and how natural resources have been addressed in these studies. The goals of this review is to find literature where model based understanding of past transitions is exemplified and to identify those case studies and related data that may help a model validation. We started from documents in the newly established journal “Environmental Innovation and Societal Transitions” and publications cited therein. We then broadened the search by looking for related manuscripts within the web of science and on google scholar. We found that our search results can be roughly split into two parts, one addressing changes in infrastructure (Table 1, top), the other addressing societal transitions related to agriculture (bottom). A large fraction of the infrastructure related case studies uses the multi level perspective (MLP) [e.g. Geels, 2011]. The MLP describes a dominating configuration of societal networks, institutions and technologies as a regime. Alternative configurations are called niches which are forming due to societal changes and technological innovations. The regime and niches compete in the so-called landscape, that involves higher order policies, values and environmental constraints, such as scarce resources and emission limits. MLP based studies
Generally do not attempt to quantify resources and environmental implications. A second conceptual framework is often used to describe historical case studies. Socioeconomic metabolism uses a combination of the systems approach and mass balance to quantifying flows and stocks of materials or substances in a society [e.g. Fischer-Kowalski, 2011]. This framework is applied to several case studies related to agriculture and infrastructure and results in more quantitative results compared to the MLP based studies. From the identified studies, quite a number will be relevant sources for our model validation, because transitions in energy related infrastructure is very relevant for climate mitigation, while changes in agricultural practise are relevant for both, mitigation and adaptation.

3 Collaborative process

To ensure that the model addresses the needs of stakeholders, that it reflects their reality and - most importantly - that the developed model is useful and can be applied, we develop the model in close collaboration with experts from relevant target groups in the two case study countries Mexico and Indonesia. Stakeholders will be involved at all stages of the model development process. Figure 1 outlines the most important steps of model development, specifying the role of science and practice at each step. Collaborative modeling processes make broad acceptance more likely and increase the probability, that the achieved results will enter the decision-making process [Wassen et al., 2011].

Collaborative and participatory approaches aim at increasing and sharing of knowledge.
<table>
<thead>
<tr>
<th>Reference</th>
<th>System described</th>
<th>Ressources Affected</th>
<th>Quantified</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geels [2002]</td>
<td>Sailing to steam boat</td>
<td>coal and time saving</td>
<td>No</td>
<td>MLP</td>
</tr>
<tr>
<td>Geels [2005b]</td>
<td>horse carriage to automobile</td>
<td>energy and time saving</td>
<td>No</td>
<td>MLP</td>
</tr>
<tr>
<td>Geels [2005a]</td>
<td>Open water supply to close pipes</td>
<td>Water</td>
<td>No</td>
<td>MLP and Co-evolution</td>
</tr>
<tr>
<td>Verbong and Geels [2007]</td>
<td>Carbon based economy to renewables</td>
<td>Energy supply system</td>
<td>No</td>
<td>MLP</td>
</tr>
<tr>
<td>Raven [2004]</td>
<td>Transition of energy system: manure digestion</td>
<td>Energy</td>
<td>No</td>
<td>MLP</td>
</tr>
<tr>
<td>Geels [2006]</td>
<td>Cesspools to sewer systems</td>
<td>Waste water</td>
<td>No</td>
<td>regime transformation technology push</td>
</tr>
<tr>
<td>Van den Ende and Kemp [1999]</td>
<td>Mechanical calculator to computer</td>
<td>Energy and commodities</td>
<td>No</td>
<td>technology push</td>
</tr>
<tr>
<td>Krausmann and Haberl [2002]</td>
<td>Transition of energy system</td>
<td>Energy resources, emissions</td>
<td>Energy</td>
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</tr>
<tr>
<td>Belz [2002]</td>
<td>Industrial to sustainable agriculture</td>
<td>Land use and agricultural input</td>
<td>No</td>
<td>MLP</td>
</tr>
<tr>
<td>Krausmann [2004]</td>
<td>Preindustrial to industrial agriculture</td>
<td>Land use and agricultural input</td>
<td>No</td>
<td>Socio-ecological metabolism</td>
</tr>
<tr>
<td>Krausmann et al. [2008]</td>
<td>Agrarian to industrialized societies</td>
<td>Energy and land use</td>
<td>Energy and land use</td>
<td>Socio-ecological metabolism</td>
</tr>
<tr>
<td>Krausmann [2011]</td>
<td>Agrarian to industrialized societies (Japan/ USA/ India)</td>
<td>Energy, material flow and metabolic rate</td>
<td>Energy and material flow (DMC)</td>
<td>Socio-economic metabolism</td>
</tr>
</tbody>
</table>

**Table 1.** Past transitions described in the literature
to enhance the understanding of the system under analysis. Participatory modeling is founded in the realization, that system behavior is governed by numerous unstated assumptions and thus often contains gaps and inconsistencies.

Participatory approaches can help in illuminating such gaps and potential points of conflicts to produce more accurate system descriptions [Langsdale et al., 2007]. They can help in clarifying and identifying the solutions space and ensure that developed strategies take the decision-making reality into account [Voinov and Bousquet, 2010]. Depending on the anticipated outcome, the degree of involvement of stakeholders and actual modeling methods will vary [Brugnach, 2010].

For the clarification of the essential system elements and the relations between them, causal loop diagrams are often used [Vennix, 1996]. They can be regarded as directed graphs, where the nodes represent the system elements and edges are used when the receiving element increases (positive dependency) or decreases (negative dependency) with an increase in the outgoing element. Within a graph describing a system, positive and negative feedback loops can be found by identifying cycles in the graph.

As outlined in Figure 1, the concept of causal loop diagrams plays an important role in obtaining the view of our country partners on how climate change may affect society. Each step of the collaboration includes a literature-based recommendation of possible model components and processes. Before proceeding to the next level of model development, interaction between science and practice ensures the applicability of the proposed model components. In a first step, we will ask for relevant variables or system elements and in the next step, we will also ask for the interrelations between these variables. The approach aims at validating the elements in our model representation, while at the same time enhancing our partners’ understanding of the model.

Collaborative processes require knowledge management. One form is the emerging concept of Communities of Practice (CoP), defined as groups of people informally bound together by common interests and shared expertise [Wenger and Snyder, 2000]. It differs from a network by having a specific topic that it is built around and is defined by the practice and common knowledge of its members [Wenger, 1998]. To initiate the collaborative process for the preparation of the proposed model, a CoP, built around common knowledge on the management of climate change, is in the process of developing. An initial workshop was held in Durban, South Africa, in November 2011. A common internet platform that allows for interaction between participants on a regular basis has been set-up. Further workshops will be held on a regular basis, bringing together the full group of practitioners. Smaller groups get together for specific topics. Members of the CoP include representatives from local and regional governments, as well as research institutes and partners from local NGOs. Specifically, partners for the collaboration on the present models include the National Development Planning Agency (BAPPENAS), the Institut Teknologi Bandung (ITB) as well as Bogor Agricultural University in Indonesia. Partners from Mexico are the Secretariat of Environmental Sustainability and Land-Use Planning, State of Puebla, and the Ministry of Environment and Natural Resources (SEMARNAT). Additionally, national representatives of GIZ in the partner countries contribute to the model development. While most of the interactions are planned to occur through the CoP-internet platform, there will be two subsequent meetings planned.

4 MODEL COMPONENTS

Our basic assumption is that, in order to explore pathways for sustainable development at the country level, models of economic and social transformation have to be coupled
with the dynamics of natural resources. For example, forest for Indonesia or Brazil, water for Egypt or south Africa, land and water regimes for India or Pakistan. Coupling sector economic models with natural resources provides a means to explore pathways of transformations towards sustainability. We then look at how mitigation and adaptation processes will interact with a countries development. To achieve this goal, model components describing resources will include the atmosphere-ocean-system (e.g. results from global circulation models) and the eco-hydrosphere (e.g. results from global dynamic vegetation models). On the socioeconomic side, we expect to include model components on demography, technology related to energy supply, agricultural production and trade including land use change and an economic model [see Reusser et al. this issue for more details on model components]. For the economic model we consider alternative and complementary approaches. While Computable General Equilibrium (CGE) models help analyze sector performance, stochastic models help analyze economic consequences of shocks. Upon CGE models we also might analyze the costs of of adaptation and mitigation.

The type of development for developing countries is at the core of the discussion on transitions to sustainable development. It has been shown that if the economic aspirations of developing countries are to reach economic trends of most developed countries, it would require resources equivalent to five Earth planets. Of course, the discussion about sustainability refers to North-South equity, and the standards of developed countries are to be discussed. Yet, the important message is that the discussion of what kind of development is feasible and desirable is also on the table. In this regard we consider development pathways under the perspective of regional growth theories, but also the insights opened by new approaches like 'economic de-growth'.

5 Discussion and Conclusion

Managing climate related changes in the socio-technical system requires a good understanding of mitigation, adaptation and development. Models may be used to project related resource usage and emission trajectories into the future to support management decisions. We are using collaborative model building and validation on historical data as tools to increase model credibility.

We outlined the collaborative process with partners from Mexico and Indonesia that has just started. We expect the process to help better addressing policy relevant questions, to refine the model and to increased mutual understanding.

For the validation with historical data we analyzed how existing studies represented changes in resource usage during societal transition processes. We find that the number of studies closely rooted in the transitions literature and at the same time quantitatively describing resource usage and emissions is fairly limited. This is consistent with the demand to better relate results from transition models to observations [Holtz, 2011]. Studies linking to quantitative data are most often based on the socio-economic metabolism framework.

More quantitative model results can for example be found in the field of climate change, where many assessment models make projections of greenhouse gas emissions into the future and attempt to estimate climate change impacts. However, these models represent societal transitions in a quite simplified way, for example as emission limiting and technology restricting policies. In this way Patt et al. [2009] state from their review on adaptation in integrated assessment models that current approaches are likely to be over-optimistic about the net benefits from adaptation and have a number of suggestions to improve the
simplified representations. Therefore, we argue that understanding climate related societal transitions requires simultaneous and interlinked modelling of mitigation and adaptation – especially if we attempt to go beyond purely cost-based assessment [see Reusser et al. this issue].

For the purpose of model development we will focus on two countries; the end-product, however, should be transferable for application on other countries. The proposed model has the potential to increase communication between science and practice, both during the development phase of the model and the application by stakeholders. By providing an applicable and understandable tool, mutual understanding can be increased to contribute towards knowledge-based decision making. By linking adaptation and mitigation, we contribute to identifying trade-offs and win-win-situations for a transition towards sustainability.

We would like to stress, that here we are able to present not more than the first findings from an ongoing process, which lay foundations for future work. Like all collaborative processes, the quality of the model output in part depends on the input from our partner countries; insufficient contributions may reduce the applicability and credibility of the model. The parallel process of validating the model using documented transition processes ensures that an adequate level of quality will be ensured nonetheless.

With our modelling exercise, we intend to contribute to the ongoing international process on improving our management of climate related transitions. Using historical observations to validate models is a crucial step. To our knowledge, this is the first review of the usage of historical observations for the validation of transition models. Our review indicates that it is possible and necessary to closer connect our understanding of societal transitions with the resulting changes in resource usage and emissions.

ACKNOWLEDGMENTS

Funding from the PROGRESS project (BMBF 03IS2191B), Inventory of methods (BMU-IKI 10.9062.0) made the work presented possible.

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