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Implications of ecological data constraints for integrated policy and livelihoods modelling: An example from East Kalimantan, Indonesia

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ABSTRACT

Policy and human livelihoods modelling increasingly demands integrated research which requires ecological expertise. However, contributions from ecologists are often based on sparse data. Rather than discounting such data, in this paper we demonstrate how ecological modelling can effectively contribute to the development of policy recommendations in spite of data constraints. In a petrol subsidy analysis in East Kalimantan, Indonesia, we accounted for ecological data uncertainty by (a) assuming large parameter value ranges and (b) conducting a robustness test for policy recommendations. In addition to data scarcity, counter-intuitive results emerged emphasising the need for model validation. These counter-intuitive results indicated that decreasing petrol prices led to increased poverty. This informed a policy recommendation to prevent the reduction of petrol prices below IDR 5500 per litre. Using two key livelihood resources (fish and honey), we found that while a traditional sensitivity analysis suggested highly robust results, a robustness test indicated that policy recommendations would change if the incorrectness of parameter values approached 50%. The results show that ecological modelling can contribute effectively in spite of sparse data to guide policy, as well as identifying future research priorities.

1. Introduction

Research is increasingly expected to provide guidance in applied situations which integrate multi-dimensional social and biophysical indicators (Parker et al., 2002; Smajgl et al., 2009c). Crossing disciplinary boundaries from a modelling perspective often involves the explicit consideration of links between ecological, economic, social, and physical variables. However, model developers rarely face situations in which comprehensive data exists across all these disciplinary domains. In particular, ecological data can often be sparse or absent. Consequently, two options arise for ecological modelling: either to disregard the request for a contribution unless acceptable data exists, or to provide best-possible contributions based on data availability (Sutherland and Watkinson, 2001).

Where ecological modellers seek to contribute to applied integrated modelling efforts, methods need to be employed for quantifying parameters. Deterministic methods such as agent-based modelling or system dynamics modelling require data for informing assumptions on initial states of variables and their likely response to changes in other variables, which we refer to as response functions. In most cases such deterministic models deal with increasing levels of data scarcity by a combination of (a) expert knowledge, (b) inference from secondary data for supposedly akin cases, and (c) increased aggregation of system variables (Robinson et al., 2007; Smajgl, 2010c; Smajgl et al., In Print). Probabilistic methods such as Bayesian Belief Networks (e.g. Martin et al., 2005; Crome et al., 1996) require specification of states and quantification of underlying probability distributions. Similar approaches as listed for deterministic models dominate the parameterisation of uncertainty distributions in probabilistic models. In most cases the aggregation of system variables implies an increased range of parameter values initiating variable states (Robinson et al., 2007; Smajgl, 2010c).

In addition to responding effectively to data scarcity, appropriate approaches for specifying model uncertainty need development. Arguably, traditional methodologies such as sensitivity analysis can be misleading in complex systems modelling (Moss, 2008; Ascough et al., 2008).

This paper describes challenges encountered in a participatory policy modelling process in Indonesia under such sub-optimal conditions. An applied agent-based model was developed for the province of East Kalimantan to simulate potential impacts of energy price changes on poverty. Agent-based modelling was identified as the most suitable methodology as it allows integration of human behavioural, ecological and physical variables (Parker et al., 2003; Grimm et al., 2006; Gilbert, 2008; Heckbert et al., 2010). In the context of East Kalimantan, fishing and the collection of honey

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are key components of livelihood strategies. Thus, ecological processes supporting these resources are highly relevant for integrated modelling. Data availability, however, was extremely limited.

The first challenge was the development of ecological response functions for two key livelihood resources, fish and honey, in a situation of data scarcity. The second was the problem of model validation, and the testing of the robustness of ecological modelling in an applied policy context. The emergence of counter-intuitive results indicating that poverty increased following petrol price reductions put an additional emphasis on model validation. Here we describe the context for the participatory modelling, the challenge for ecological modelling and the assumptions implemented for fish and honey-related variables. Then we present the agent-based model and provide results for the robustness test, and consider the implications for integrated policy and livelihood analysis in Indonesia and other contexts.

2. Materials and methods

2.1. Case study

In 2008, increasing oil prices put severe pressure on the national budget of Indonesia as consumer prices for fossil fuels are fixed and highly subsidised. Consequently the Indonesian Government considered cutting back subsidies (Smajgl, 2010b). As rising fuel prices are likely to affect poor people disproportionately, poverty cash payments were added to the policy design. During 2009 the Government discussed reducing the petrol price, since the world price for oil was declining. The goal of this research was to analyse poverty implications of fuel price reductions (Smajgl et al., 2009b). Stakeholders' predictions of impacts on poverty levels varied widely due to the diversity of livelihoods across the Indonesian archipelago. East Kalimantan Province was selected as a case study to test these predictions.

East Kalimantan is the second largest province in Indonesia, located in the east of Borneo (Fig. 1), and is rich in natural resources such as timber, gold, coal, and oil. Illegal logging is rampant (Fwi/Gwi, 2002), placing increasing pressure on the rural population's traditional livelihoods (Sunderlin et al., 2001; Pambudhi et al., 2004).

Consequentially, increasing numbers of rural people are moving into urban and peri-urban areas. In 2006 about 47% of the population (~3 million people) lived in urban areas, which account for only 1% of the provincial area. However, as a result rural poverty has declined from 18.1% of the population in 2005 to 13.9% in 2009, while urban poverty only decreased from 6.0% to 4.0% (BPS Kalimantan Timur, 2007, 2008, 2009).

In order to understand how such regional poverty reductions would be affected by central government policy decisions, integrated models were developed (Smajgl et al., 2009b). Agent-based modelling (or individual-based modelling) was chosen as the most appropriate methodology, as the analysis required the spatially explicit integration of diverse social–ecological variables including human behaviour (see Bousquet and Le Page, 2004, for an overview on agent-based modelling).

Poverty was defined as household income with an official poverty line of IDR 41,500 per capita per week (BPS, 2009). In the mostly rural context of East Kalimantan livelihood strategies are based on the harvest of a range of natural resources, including fish, honey, timber, rattan, and rubber. Modelling therefore needed to consider these ecological variables and the impacts of them on household incomes, since livelihoods are characterised by a high natural resource dependency.

2.2. Agent-based model implementation

Simulation results suggested that fishing and honey collection are the two livelihood strategies that fluctuate the most in response to fuel prices changes (Smajgl et al., 2009b). While assumptions for household livelihood strategies are informed by primary data collected from 3500 households (Bohensky et al., 2007), the actual data available for modelling fish growth and honey yield in East

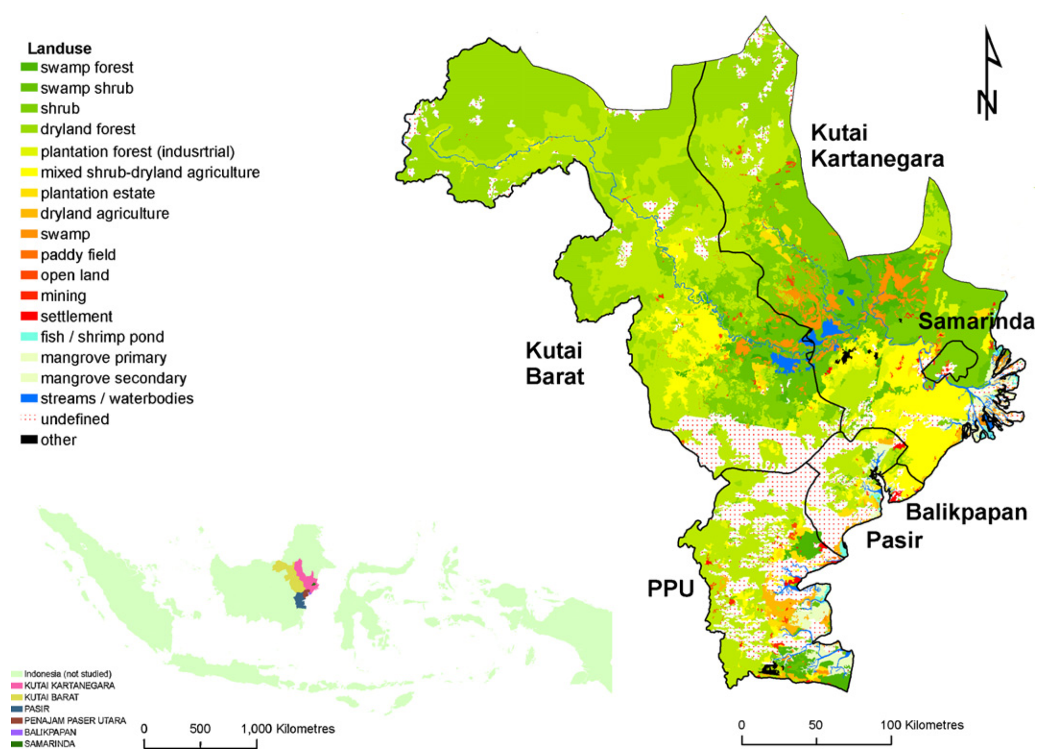

Fig. 1. East Kalimantan Province, Indonesia.