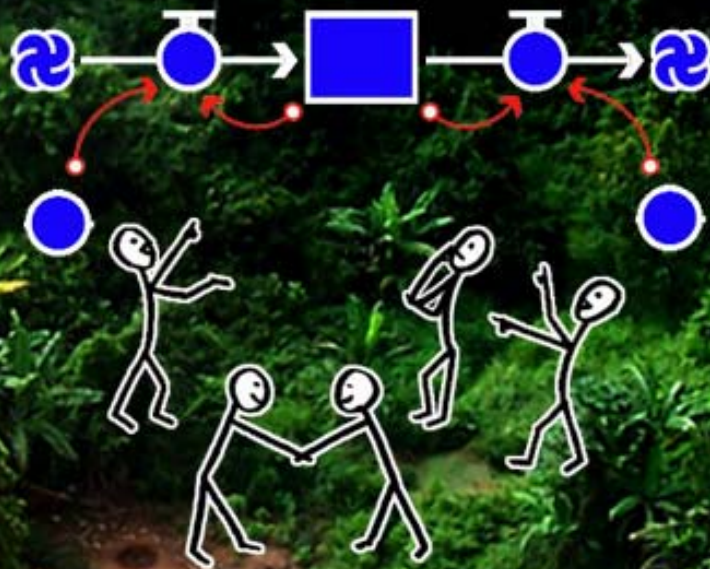


# Scenarios for Conservation and Development

Participatory Modelling to support Decision Making  
in Tropical Forest Landscapes



Marieke Sandker

2010

# **Scenarios for Conservation and Development**

## **Participatory Modelling to support Decision Making in Tropical Forest Landscapes**

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# Contents

<b>Acknowledgements</b>	<u>VII</u>
<b>Summary</b>	<u>IX</u>
Resumen	<u>XI</u>
<b>Thesis outline</b>	<u>XIII</u>
<b>Introduction</b>	
Chapter 1 <b>Participatory System Dynamics Modelling to understand Conservation and Development trade-offs in Tropical Forest Landscapes</b>	<u>1</u>
Conservation and development; a historical overview of paradigm shifts	<u>3</u>
System dynamics modelling to understand conservation and development interactions	<u>7</u>
System dynamics; a brief history	<u>8</u>
Scenario planning; how it evolved	<u>9</u>
Models in policy making	<u>10</u>
Participatory modelling, a state-of-the-art	<u>12</u>
Objectives of this thesis	<u>15</u>
<b>Methodology</b>	
Chapter 2 <b>Science for action: The use of scoping models in conservation and development</b> Collier, N., B.M. Campbell, M. Sandker, S.T. Garnett, and J.A. Sayer. <i>Under review Global Environmental Change</i>	<u>23</u>
Chapter 3 <b>What are participatory scoping models?</b> Sandker, M., B.M. Campbell, and A. Suwarno. 2008. <i>Ecology and Society</i> 13:r2	<u>41</u>
Chapter 4 <b>Spatial Projections of Participatory System Dynamics Modelling Outcomes: Exploring Oil Palm and REDD consequences for Local Livelihoods in Papua, Indonesia</b> Sandker, M., A. Puntodewo, F. Sitorus, H. Purnomo, Y. Yumte, M. Ruiz-Pérez and B.M. Campbell. 2010 <i>Proceedings LandMod Conference, Montpellier, France</i>	<u>47</u>

## Case studies

- Chapter 5     **Will Forests Remain in the Face of Oil Palm Expansion? Simulating Change in Malinau, Indonesia**     61  
Sandker, M., A. Suwarno, and B.M. Campbell. 2007. *Ecology and Society* **12**:37
- Chapter 6     **Exploring the effectiveness of integrated conservation and development interventions in a Central African forest landscape**     81  
Sandker, M., B.M. Campbell, Z. Nzooh, T. Sunderland, V. Amougou, L. Defo, and J. Sayer. 2009. *Biodiversity and Conservation* **18**: 2875-2892
- Chapter 7     **REDD payments as incentive for reducing forest loss: A case from Ghana**     101  
Sandker, M., S.K. Nyame, J. Förster, N. Collier, G. Shepherd, D. Yeboah, D. Ezzine-de Blas, M. Machwitz, S. Vaatainen, E. Garedew, G. Etoga, C. Ehrlinghaus, J. Anati, O.D.K. Quarm, and B.M. Campbell. 2010. *Conservation letters* **3**:114-121
- Chapter 8     **Logging or conservation concession: Exploring conservation and development outcomes in Dzanga-Sangha, Central African Republic**     127  
Sandker, M., B. Bokoto-de Semboli, P. Roth, C. Pellisier, M. Ruiz-Pérez, J. Sayer, A.K. Turkalo, F. Omoze, and B.M. Campbell. *Under review* *Conservation and Society*

## Synthesis

- Chapter 9     **The role of participatory modeling in landscape approaches to reconcile conservation and development**     151  
Sandker, M., B.M. Campbell, M. Ruiz-Pérez, J. Sayer, R. Cowling, H. Kassa, A. Knight. 2010. *Ecology and Society* **15**:13
- Chapter 10     **Trade-offs between Biodiversity Conservation and Economic Development in five Tropical Forest Landscapes**     169  
Sandker, M., B.M. Campbell and M. Ruiz-Pérez. *Manuscript*



*'Quand tu veux construire un bateau, ne commence pas par rassembler du bois, couper des planches et distribuer du travail, mais réveille au sein des hommes le désir de la mer grande et large.'*

[If you want to build a ship, don't drum up the men to gather wood, saw planks and divide the work. Instead, teach them to yearn for the vast and endless sea.]

**Antoine de Saint-Exupéry**

*"Il semble que la perfection soit atteinte non quand il n'y a plus rien à ajouter, mais quand il n'y a plus rien à retrancher."*

[Perfection is attained not when there is nothing more to add, but when there is nothing left to take away.]

**Antoine de Saint-Exupéry**

*"Essentially, all models are wrong, but some are useful."*

**George E. P. Box**

*"Life can be pulled by goals just as surely as it can be pushed by drives."*

**Viktor Frankl**



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**Marieke Sandker**



## Summary

Worldwide, biodiversity keeps declining while many people, especially in rural and forest areas, still live in (extreme) poverty. The landscapes in this thesis concern sites of exceptional biodiversity, partially protected in national parks or reserves with the surrounding unprotected area housing people living in great poverty. Interventions in these landscapes often aim at conserving nature and/or lifting people out of poverty e.g. through *integrated conservation and development projects* (ICDPs). Booking progress on both conservation and development outcomes appears a great challenge and worldwide ICDPs have had scarce success.

I hypothesise conservation and development interventions in the landscapes are obstructed by a limited understanding of complex systems' behaviour and a failure to recognise trade-offs occurring between conservation and development outcomes. Without this understanding and trade-off recognition, conservation interventions can negatively influence development outcomes and vice versa, buffering each others effectiveness. I consequently hypothesise that to get best outcomes in the landscapes, stakeholders should exchange more, look beyond their discipline at the landscape system and formulate strategies together, combining top-down planning and bottom-up approaches, i.e. they should take a *landscape approach*. I propose participatory modelling as a tool to implement a landscape approach.

Participatory modelling is the act of building a model with a group of non-modellers under the guidance of a model expert facilitator. The modelling platform used here, is system dynamics using the icon-based interface software STELLA. The model building participants are stakeholders working in the landscape, often local decision makers, mainly government officials and personnel of conservation and development organisations. A model of the landscape is built with the participants capturing all socio-economic, ecological and political aspects which according to them are relevant to conservation and development. A set of plausible scenarios is jointly defined and its implications are explored with the landscape model. Conservation and development indicators are plotted on graphs allowing us to quantify trade-offs between conservation and development outcomes under different scenarios. In this way, the model is used to test specific policies (e.g. implementing a REDD strategy), interventions (e.g. anti-poaching) or investments (e.g. in eco-tourism), and get an idea of their likely intended and unintended effects, and the scope of impact. Building the model together reveals how all elements in the landscape are connected. It encourages stakeholders to exchange knowledge and visions and make their assumptions explicit. In this thesis, participatory modelling is applied in a number of African and Asian conservation landscapes. The modelling outcomes for five of those landscapes are described in greater detail under the case studies section of this thesis.

Participatory modelling as a tool to promote a landscape approach is evaluated and a trade-off analysis between conservation and development outcomes in different landscapes is presented.

## **Overall conclusions**

### **...concerning participatory modelling**

Overall, participatory modelling contributes to the implementation of a landscape approach. Participants confirmed cross-sector strategic thinking was stimulated by the modelling, and it helped to confront the real drivers of change and recognize trade-offs. The modelling was generally considered to be successful in building shared understanding of issues. This understanding was mainly gained in the discussions held in the process of building the model, rather than in the model outputs. Different stakeholders valued the modelling exercise differently. Noteworthy was the difference between scientists and stakeholders connected to the policy process; the first were most critical of participatory modelling and the presence of the latter in the modelling activities is key to achieving policy impacts. Problems emerged when models became too complex. Key lessons for participatory modelling are the need for good facilitation in order to maintain a balance between 'models as stories' and technical modelling, and the importance of inviting the appropriate stakeholders to achieve impact.

### **...concerning conservation and development**

The alleviation of poverty coincided in several scenarios with great biodiversity loss, while in others it gave best conservation outcomes. On the other side, in all cases sustained poverty resulted in unsustainable long-term pressure on the natural resources. In most cases trade-offs occur between conservation and development outcomes and are not easily overcome. Under none of the explored scenarios, payments for environmental services (PES) sufficed in cash terms to turn them into synergies. I therefore suggest PES can reinforce landscape decisions resulting in a 'conservation scenario' only when this is already supported by intrinsic motivation spawned by non-cash benefits. Conservation and development outcomes in landscapes can be determined by external factors, making local interventions obsolete.

## Resumen

En el mundo, la biodiversidad sigue disminuyendo mientras muchas personas, especialmente en zonas rurales y forestales, siguen viviendo en pobreza (extrema). Los paisajes analizados en esta tesis son zonas de gran diversidad biológica, parcialmente protegidas por parques nacionales o reservas, rodeadas por áreas no protegidas en las que habitan poblaciones en condiciones de grave pobreza. Las intervenciones en estos paisajes suelen tener el objetivo de conservar la naturaleza y/o disminuir la pobreza, por ejemplo a través de proyectos integrados de conservación y desarrollo (PICDs). La obtención de avances tanto en conservación como en desarrollo, parece constituir un gran reto y a nivel global los PICDs, hasta el momento, han tenido escaso éxito.

En la tesis se plantea la hipótesis de que las intervenciones de conservación y desarrollo en los paisajes son dificultadas por una comprensión limitada del comportamiento de los sistemas complejos, así como por la falta de reconocimiento de los *trade-offs* (fenómenos por los cuales para ganar en unos aspectos se pierde en otros) que tienen lugar entre las consecuencias de la conservación y las del desarrollo. Sin esta comprensión y reconocimiento de los *trade-offs*, las intervenciones de conservación pueden impactar negativamente sobre el desarrollo y viceversa, disminuyendo así la efectividad de ambos. Como consecuencia planteo la hipótesis de que para obtener mejores resultados en el paisaje, los actores sociales deben intercambiar más, mirar al sistema desde una perspectiva más allá de su propia disciplina y formular estrategias conjuntas, combinando la planificación dirigida desde lo alto con enfoques de tipo abajo-arriba, es decir aplicando un *enfoque de paisaje*. Propongo la modelización participativa como herramienta para implementar el enfoque de paisaje.

La modelización participativa es el acto de construir un modelo con un grupo de personas no expertas en modelización, bajo la orientación de un facilitador experto. La plataforma de modelización utilizada en esta tesis es la de las dinámicas de sistemas, utilizando el software STELLA con su interfaz de iconos. Los participantes en el proceso de construcción del modelo son actores sociales que actúan en el paisaje, a menudo tomadores de decisiones locales, que trabajan para el gobierno o para organizaciones de desarrollo o conservación. Los participantes construyen un modelo del paisaje incluyendo los aspectos socio-económicos, ecológicos y políticos, que consideran relevantes para la conservación y el desarrollo. Colectivamente se define un conjunto de escenarios plausibles y se exploran sus implicaciones en el modelo del paisaje. Indicadores de conservación y desarrollo son visualizados en gráficos, permitiendo la cuantificación de los *trade-offs* entre resultados de conservación y desarrollo bajo los distintos escenarios. De esta forma, se usa el modelo para evaluar políticas específicas (por ejemplo la implementación de una estrategia de REDD), intervenciones (por ejemplo la lucha contra la caza furtiva) o inversiones (por ejemplo en ecoturismo), y visualizar sus efectos deseados e imprevistos, así como el alcance del

impacto. La construcción colectiva del modelo revela cómo todos los elementos del paisaje están interconectados. Asimismo, este mecanismo fomenta el intercambio de conocimientos y visiones e incentiva a explicitar sus asunciones. En esta tesis, la modelización participativa se ha aplicado en varios paisajes africanos y asiáticos. En la sección correspondiente a los casos de estudio se discuten en mayor detalle los resultados de la modelización en cinco de estos paisajes.

Se ha evaluado el uso de la modelización como herramienta para promover un enfoque de paisaje y se presenta un análisis de *trade-offs* entre conservación y desarrollo en los diferentes paisajes.

## **Conclusiones generales**

### **...acerca de la modelización participativa**

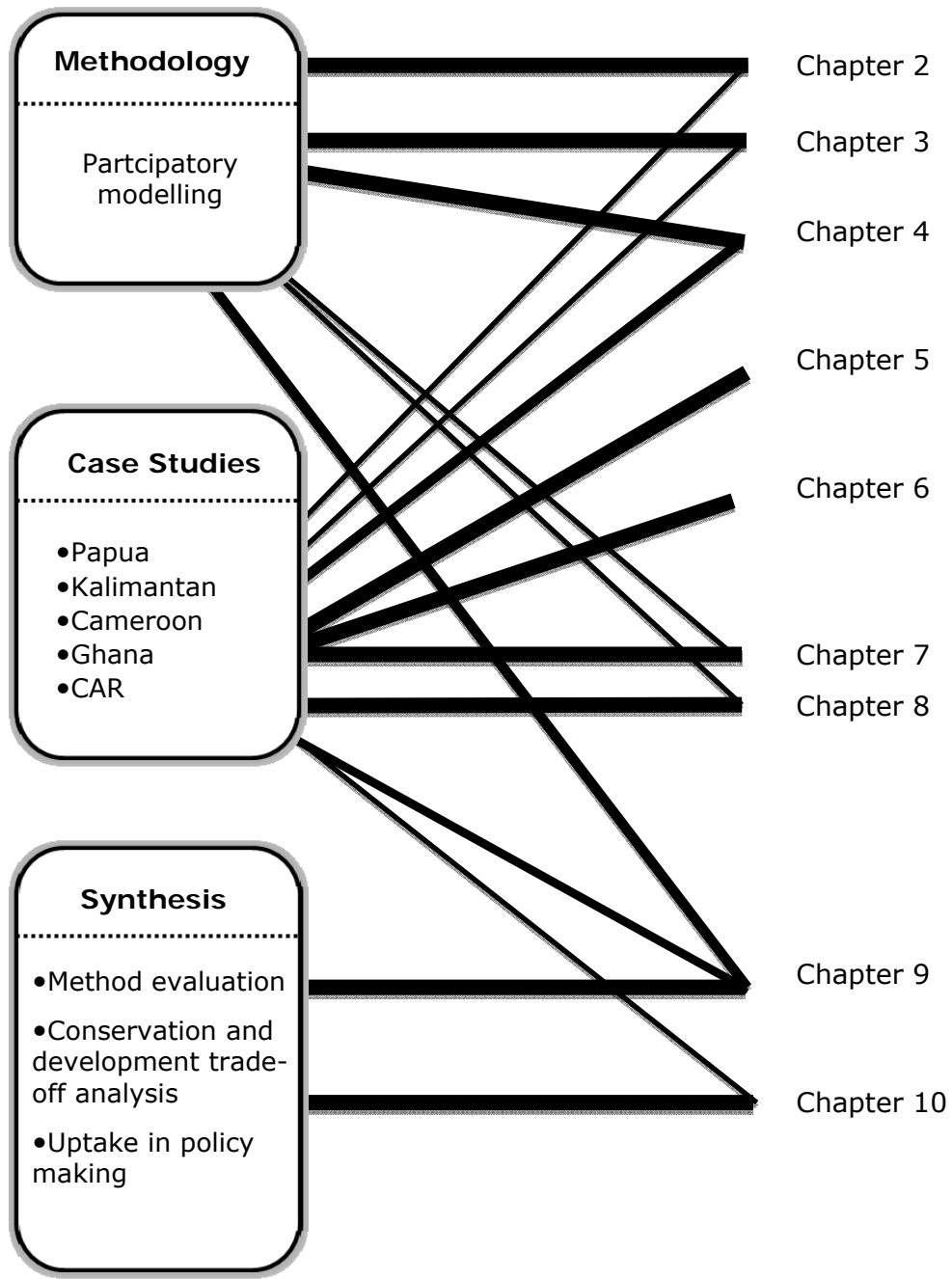
Por lo general, la modelización participativa contribuye a la implementación de un enfoque de paisaje. Los participantes confirmaron que la modelización estimuló a pensar de forma estratégica y transdisciplinar. Asimismo ayudó a confrontar motores reales de cambio y reconocer *trade-offs*. En general la modelización fue considerada un éxito en la creación de una comprensión compartida de los problemas. Esta comprensión se obtuvo sobre todo durante el proceso de construcción del modelo más que por las simulaciones generadas. Diferentes actores valoraban de modo distinto el ejercicio de modelización. La diferencia entre científicos y actores sociales vinculados a la política fue especialmente notable. Mientras los primeros fueron los más críticos con la modelización participativa, la presencia de los últimos fue determinante para lograr acciones políticas concretas. Por otro lado, surgieron problemas cuando los modelos fueron demasiados complejos. Lecciones claves para la modelización participativa son la necesidad de una buena facilitación para mantener el equilibrio entre 'modelos como historias' y la modelización técnica, así como la importancia de invitar a los actores apropiados para lograr impacto.

### **...acerca de la conservación y el desarrollo**

En varios escenarios, el alivio de la pobreza coincidió con grandes pérdidas de biodiversidad, mientras en otros se obtuvieron mejores resultados para la conservación. Por otro lado, en todos los casos la pobreza sostenida dio lugar a una presión insostenible a largo plazo sobre los recursos naturales. En la mayoría de los casos se dan *trade-offs* entre las consecuencias de la conservación y las del desarrollo, que no son fáciles de superar. Bajo ninguno de los escenarios explorados, los pagos por servicios ambientales (PSA) fueron suficientes en términos de efectivos monetarios para convertir los *trade-offs* en sinergias. Por esto propongo que los PSA pueden reforzar decisiones a nivel del paisaje resultando en 'escenarios de conservación' sólo cuando éstos ya están apoyados por motivaciones intrínsecas alimentadas por beneficios no monetarios. Por último, resultados de desarrollo y

conservación en paisajes pueden verse determinados por factores externos, dejando así obsoletas las intervenciones locales.

## Thesis outline





**Chapter 1** shortly discusses global trends in biodiversity and poverty, followed by a historical overview of paradigm changes in conservation and the integration of development concerns in conservation approaches. It gives some hypotheses for the limited success in conservation and development interventions so far, and suggests that to reach best outcomes one should take a landscape approach: integrating top-down planning and bottom-up approaches, getting stakeholders to exchange and look beyond their discipline to the landscape system and formulate strategies together. A landscape approach can be implemented through participatory modelling with landscape stakeholders. A historical overview is given of system dynamics modelling and its applications, and a state-of-the-art of participatory modelling is provided. The challenge of mainstreaming conceptual changes with changes on the ground is briefly discussed. The advantages described in the participatory modelling literature clarify why participatory modelling is a good candidate to take up this challenge.

**Chapter 2** (Collier *et al. under review*) explores the use of system dynamics modelling to investigate trade-offs and synergies in conservation and development. The use of 'scoping models' is advocated because of their ability to incorporate complexity and promote social-learning in a participatory environment, whilst increasing the capacity of local actors to manage complex social-ecological systems. We demonstrate their positive role in facilitating change in three landscapes in the tropics, particularly for policy.

**Chapter 3** (Sandker *et al.* 2008) explains the concept of participatory modelling, and our position on the continuum from a predictive model to an explorative/scoping model helping shape plausible scenarios. The article sets out how multi-stakeholder platforms are perhaps ideal but not always feasible and when aiming to inform the decision making process one primarily works with decision makers, where in some landscapes like in East-Kalimantan power is shared among few. This article is a response to Dudley *et al.* 2008 which again is a response to Chapter 6.

**Chapter 4** (Sandker *et al.* 2010a) reports on the spatial projection on maps of forest cover changes under different scenarios from participatory modelling. It combines the system dynamics software STELLA with the spatial simulation software GEOMOD (IDRISI) and reports on the advantages and shortcomings of this combination. The participatory model was built for Kaimana district, Papua, Indonesia, and explores environmental and social impacts of large scale plantation investments and payments for Reducing Emissions from Deforestation and Forest Degradation (REDD).

**Chapter 5** (Sandker *et al.* 2007) concerns a case study of participatory modelling used in East-Kalimantan, Indonesia. The model was built with district officials and explores scenarios of large scale plantation investments versus conservation. Impacts of the scenarios on the environment (mainly forest cover) and livelihoods (approximated by household income) are envisioned. The results show how such large scale investments would trigger massive immigration changing daily life in Malinau dramatically. It shows potential negative (long-term) impacts of such a development but also shows the enormous economic potential which might be appealing to local leaders with development aspirations. Ecotourism cannot provide economic incentives comparable to oil palm plantations, new mechanisms have to be put in place to provide more competitive alternatives like REDD payments.

**Chapter 6** (Sandker *et al.* 2009) concerns a case study of participatory modelling used in South-East Cameroon. The model was built with personnel from conservation NGOs, government officials, donors and development NGOs with the objective of formulating a strategy with best outcomes for conservation and development. The results reveal win-win situations are rare for conservation and development outcomes in tropical forest landscapes in Central Africa. In the South-East Cameroon landscape, initiatives holding the potential of creating these synergies are severely obstructed by the poor governance situation.

**Chapter 7** (Sandker *et al.* 2010b) concerns a case study of participatory modelling used in South-West Ghana. The model was built with the objective of exploring REDD strategies. The results suggest REDD payments would struggle to compete with forest conversion for cocoa production. In landscapes like the Ghanaian with high population pressure and highly lucrative cash crops a REDD payment scheme will likely result in money being spend without achieving long term emission reduction.

**Chapter 8** (Sandker *et al. under review*) concerns a case study of participatory modelling used in South-East Central African Republic. The model was built with personnel from conservation and development NGOs with the objective of exploring different management options for the landscape's production forest and its implications on wildlife and local livelihoods. The resulting model revealed that economic investments in- and outside the landscape strongly determine conservation and development outcomes, more than conservation interventions. It also explored the scenario of turning the production forest into a conservation concession and concludes this doesn't hold the potential of promoting either conservation or development given current investment levels.

**Chapter 9** (Sandker *et al.* 2010c) evaluates participatory modelling as perceived by the model building participants. In specific it investigates whether participatory modelling helps to take a landscape approach and compares its application in six conservation landscapes in Africa and Asia to answer this question. The study gives an overview of the thresholds and advantages of participatory modelling, reports on some proven qualities of participatory modelling, and illustrates some cases of impact. The article touches on discrepancies between what projects claim to do and what they really do, e.g. an ICDP in Cameroon was doing 'conservation and some development' rather than integrating the concepts. The results suggest a distinct difference in view between scientists and policy makers concerning the methods usefulness, which might illustrate a disconnection between the two and explain in part why there is often little uptake of scientific model results by policy makers.

**Chapter 10** (Sandker *et al. manuscript*) compares the conservation and development outcomes under different scenarios in the five landscapes where participatory modelling took place. The study finds that development trajectories can either be at the cost of conservation or can benefit conservation, but in all cases sustained poverty negatively affects conservation in the long term. It quantifies trade-offs between conservation and development and finds that in cash terms all Reducing Emissions from Deforestation and forest Degradation (REDD) implementation scenarios come at a cost for development and payments for environmental services (PES) are not sufficient to make up for lost opportunities to earn cash. However, environmental service benefits and subsistence income enhance the attractiveness of conservation scenarios to local people and PES may provide the extra cash incentive to tip the balance for such a scenario. The paper identifies interventions which hold a promise to improve both conservation and development outcomes. It also stresses the importance of external factors (like industrial investments and the development of the national economy) in largely determining landscape scale outcomes, and suggests a negotiating and visioning role for conservation agencies.

## Chapter 1

### Participatory System Dynamics Modelling to understand Conservation and Development trade-offs in Tropical Forest Landscapes

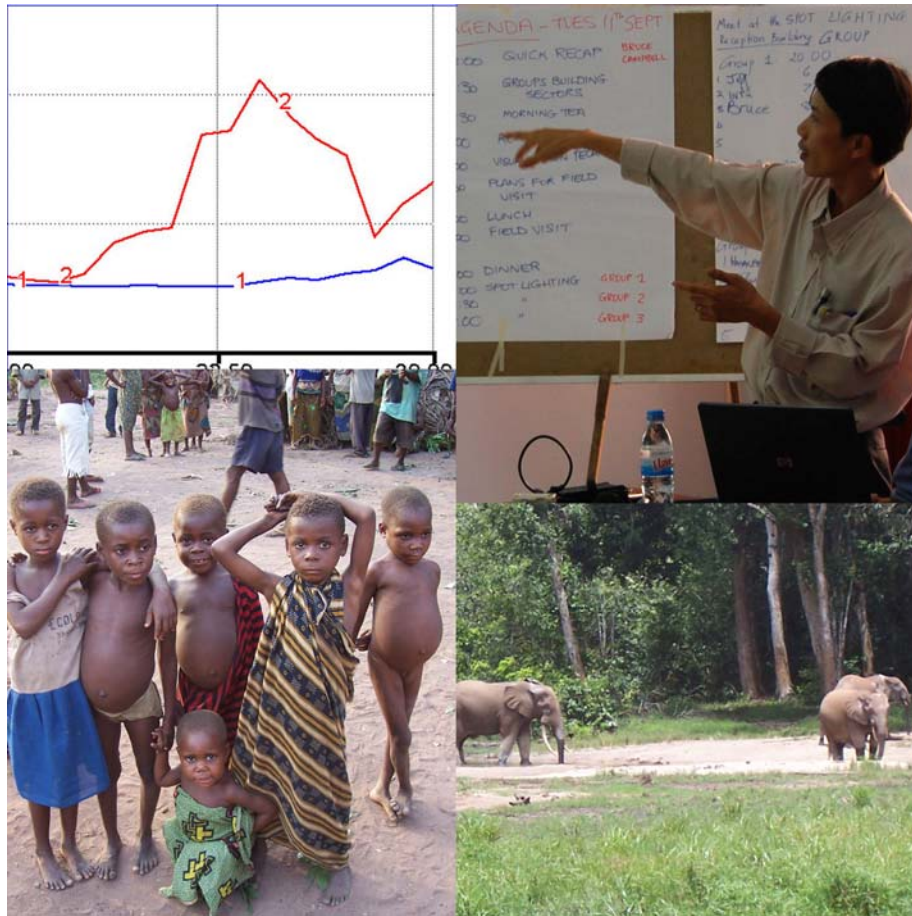


Photo right upper corner: Courtesy of Neil Collier

## **Participatory System Dynamics Modelling to understand Conservation and Development trade-offs in Tropical Forest Landscapes**

Following the definition of the FAO, 31% of the earth's land surface is covered with forest, of which more than 10% is legally protected in national parks or reserves (FAO 2010). The last decade, an alarmingly high amount of around 13 million hectares of forest were replaced worldwide (FAO 2010). Optimists might proclaim global deforestation is declining but global biodiversity keeps declining without significant reduction of rates (Butchart *et al.* 2010). The stagnating forest loss is largely explained by increased reforestation, especially in Asia and Europe, consisting of a biodiversity-poor replacement of the species-rich natural forests. At the same time, there is great concern for the extinction of many animal species, disappearing as a consequence of human activities, especially in Central Africa. Some conservationists warn for 'empty forests' where impressive tropical trees remain while most of the larger fauna is depleted (Redford 1992).

A more positive global trend is seen in poverty, which is declining at a fast pace. The percentage of people living in extreme economic poverty has halved between 1981 and 2005 (WB 2010). However, these global statistics mask great regional disparity; in sub-Saharan Africa the 50% poverty rate has remained roughly unchanged between 1981 and 2005. Furthermore, though the share of people living in extreme economic poverty worldwide has decreased, the absolute number has largely remained unchanged and the number of hungry people in the world is increasing sharply (FAO 2009). High poverty rates are concentrated in rural and forest areas (Sunderlin *et al.* 2008).

The landscapes in this thesis concern sites of exceptional biodiversity, often decreasing at a fast pace, which are partially protected in national parks or reserves. The areas surrounding the protected zones house people suffering high levels of poverty and relying largely on natural resources for their subsistence and income. Interventions often aim at conserving nature and/or lifting people out of poverty, e.g. in several of the landscapes *integrated conservation and development projects* are active. We define landscapes as: *mosaics of landcover types providing environmental services and development opportunities for the multiple needs of diverse stakeholders*. Conservation and development are strongly related in these landscapes and therefore a strategy to develop the local economy will affect conservation outcomes (e.g. through forest conversion) and a strategy to conserve natural resources will affect local livelihoods (e.g. through restricted access).

This dissertation attempts to shed light on how conservation and development outcomes in tropical forest landscapes are interlinked and to identify strategies that can manipulate these outcomes into desired directions. The method used to understand conservation and development



interactions is participatory modelling (defined later on), using system dynamics as modelling platform. Models representing the conservation-development interactions taking place in the landscape are built with actors implementing conservation and development interventions. Plausible future scenarios are explored with the landscape model, and the impacts of interventions and policies on conservation and development outcomes are tested.

## **Conservation and development; a historical overview of paradigm shifts**

### *The roots of twentieth century conservation*

The first conservation efforts date back far over a thousand years ago, with areas being protected for spiritual reasons (sacred groves) and for hunting interests enforced by royal and other elites all over the world (Perlin 1989). Modern conservation starts with the endorsement of national parks, the first of which were established late nineteenth century in the United States. In the tropics the first national parks date back to the beginning of the twentieth century, starting with game parks in the Democratic Republic of Congo (Albert National Park in 1925, later to be renamed Virunga National Park) and South Africa (Kruger National Park in 1926). They were typically implemented by colonial powers without taking into account local people using and living in these areas. These conservation efforts were based on the exclusion of people from protected areas and occasionally came at a high price for local people, being displaced to make way for national parks and losing access to natural resources (Cernea & Schmidt-Soltau 2006; Schmidt-Soltau & Brockington 2007).

### *Paradigm shift in natural resource management*

In the seventies there was a shift in the conception of how to manage natural resources largely triggered by the introduction of the concept called *adaptive environmental management* (Holling 1978; Walters 1986). Adaptive environmental management suggests a structured, iterative process to gain a better understanding of the systems' functioning in the face of uncertainty, with the aim of optimizing decision making. It suggested moving away from single discipline interventions to a multi-disciplinary approach. Adaptive environmental management is characterized as 'learning by doing' and was meant to replace top-down or command-and-control natural resource management (Holling & Meffe 1996). Holling unified ecology with simulation modelling and policy analysis to develop integrative theories of change with practical utility.

The approach integrating the various disciplines in natural resource management became widely known as *integrated natural resource management* (INRM). Sayer (2007) defines INRM as "a process of

incorporating the multiple aspects of natural resource use (biophysical, socio-political, or economic) into a system of sustainable management to meet production goals of producers and other direct users (e.g., food security, profitability, risk aversion) as well as goals of the wider community (e.g., poverty alleviation, welfare of future generations, environmental conservation).” This paradigm shift towards multi-disciplinary and cyclical as opposed to linear thinking resulted in the parallel emergence of a range of more or less similar concepts. Many of these concepts differ slightly in origin and philosophy, e.g. *integrated water resource management* (Calder 1999) was developed as a multi-disciplinary approach to manage water resources, *sustainable forest management* was developed by forestry professionals with a primary focus on production, and the *ecosystem approach* was proposed by a more heterogeneous group concerned primarily with conservation (Sayer *et al.* 2007).

### *Including people in conservation*

Following the INRM philosophy, the conviction people that should be central in nature conservation emerged. A notion arose that the situation where rural poor are compelled to absorb the opportunity costs and suffer the restrictions from conservation was unfair and that this situation asked for a new approach to conservation which should end social conflicts resulting from protectionism (Sunderland *et al.* 2008). This new people-centred approach became functional with the introduction of *integrated conservation and development projects* (ICDPs) (Hughes & Flintan 2001). Despite practically no field testing, ICDPs were broadly adopted and generated enormous money flows because of the appealing combination of two major concerns, alleviating poverty while safeguarding biodiversity, and the promise of ‘win-win’ solutions (Sunderland *et al.* 2008). It became a widely accepted approach in the eighties, with the launching of some ICDPs by the World Wide Fund for Nature (WWF), and the standard of aims of many international organizations in the nineties (Garnett *et al.* 2007) following the Caracas World Parks Congress in 1992. The paradigm shift in conservation toward more concern with local people was given an extra impulse by the 1987 Brundtland report (Brundtland Commission 1987) stressing an overriding priority should be given to the world’s poor and by the Rio declaration from the 1992 Earth Summit which included a principle suggesting environmental issues are best handled with the participation of all citizens concerned. ICDPs embodied a promise of addressing these growing concerns with local people.

### *The failure of ICDPs and polarized positions*

However promising the ICDP concept seemed, various studies reviewing their implementation on the ground revealed in most cases they have not prevented biodiversity from declining, and they didn’t do much to alleviate poverty either (Alpert 1996; Kremen *et al.* 1994; Wells *et al.* 1999) provoking the notion of ‘win-win illusions’ (Christensen 2004). Why ICDPs

didn't live up to their promise has become subject to a polarized debate (see introduction Chapter 6).

On one side you have those subscribing this failure to the ICDP concept being a contradiction in terms. They believe economic development inherently goes at the cost of nature conservation and therefore advocate the exclusion of local people from conservation efforts (so-called 'fortress conservation' or 'protectionist-approach') (Loche & Dearden 2005; Oates 1999; Terborgh 1999). According to Oates (1999) p189): "An emphasis on large projects, linking conservation with rural development and relying on large amounts of foreign money, leads to the neglect of relatively simple, low-cost, and more sustainable conservation solutions."

On the other side are those who believe goals of eradicating poverty, attaining food security, and conserving the environment are highly interdependent and that conservation efforts are doomed if they do not integrate local people and aim to enhance their livelihoods simultaneously (Martino 2005; McShane *et al.* 2004; Wilshusen *et al.* 2002). They believe it was not the concept of the ICDP being responsible for their failure, but rather conventional conservation programmes auto-proclaiming themselves as ICDP while their approach on the ground was still driven by conservation agendas with inequitable outcomes for local people (Chapin 2004; Malleon 2002). They blame a limited understanding of how conservation and development are interlinked and ICDP projects not recognizing the importance of external factors in determining conservation and development outcomes at the project scale (McShane *et al.* 2004). Authors on this side of the debate underline the unequal cost-benefit distribution, where benefits from conservation are captured at national and global levels but the costs are borne by (poor) local communities mainly through restrictions in access to natural resources (Balmford & Whitten 2003). Guha (1997) goes as far as describing protectionist conservation in the tropics as 'anti-human neo-colonialism'.

### *Conservation concessions*

In 1992 Richard Rice of Conservation International came up with yet another concept seeking to reconcile resource protection with development in the form of *conservation concessions* (Hardner & Rice 2002; Rice 2003) (Chapter 8 includes the conservation concession as one of the scenarios explored). Under this concept the resource owner is compensated for conserving the area. However, especially in Africa where most of the forest is state-owned this entails money flows to national governments leaving the local population largely uncompensated for lost access to natural resources and foregone income from jobs from other uses (e.g. logging, mining). Karsenty (2007) criticizes conservation concessions for their compensation being much lower than actual opportunity costs, for which reason they would obstruct development in locations of severe poverty. Rice proposed the idea of conservation concessions as an intermediate step for such an area to become

an officially protected area so even though the concern for development is raised, ultimately the concept is in line with fortress conservation. Furthermore, even without providing a full compensation of opportunity costs imposed by conservation, in Cameroon (The Economist 2008) and Peru (Hardner & Rice 2002) conservationists were unable to provide the funds to secure a conservation concession.

### *Payments for Environmental Services*

Pagiola (2008) does report on poverty alleviation going alongside environmental protection in Costa Rica through successful implementation of *payment for environmental services* (PES) schemes. Wunder (2005) outlines how emerging scarcity of environmental services can make them subject to trade. Though Kremen *et al.* (2000) and Ferraro and Kiss (2002) made a notion of economic incentives and direct payments for conservation, Wunder (2005 p3) was the first to define PES as: "*a voluntary transaction where a well-defined environmental service (or a land-use likely to secure that service) is being 'bought' by a (minimum one) buyer from a (minimum one) provider, if and only if the provider secures the environmental service provision (conditionality).*" The concept holds (again) the promise to reconcile conservation with development, though some difficulties have been outlined. Sommerville *et al.* (2010), evaluating a PES scheme in Madagascar, mention poor governance as a major pitfall and individuals experiencing high opportunity costs losing under such a scheme. Wunder *et al.* (2008) describe how local Dayaks in Indonesia failed to auction off their forest to a set of international donors, where the donors were not attracted to 'pay for doing nothing'. Börner *et al.* (2010), exploring potential carbon payments in Brazil, add unclear and insecure tenure over land or environmental services to the list of difficulties for PES implementation. And Fisher *et al.* (2010) evaluating PES in Tanzania bring up uncertainty around the causal link between the ecological functioning, services delivered, and land-use as a difficulty in establishing a PES scheme. E.g. even in the successful PES scheme mentioned by Pagiola (2008) the conditionality of PES actually being responsible for additional service gains couldn't be confirmed. Chapters 4, 5 and 7 discuss the potential of PES in the respective landscapes to reconcile conservation and development.

### *Landscape approach*

The unsatisfactory success of ICDPs and the notion they are imposed by conservationists on the remaining stakeholders without involving them in the design of interventions resulted in the continued definition of more promising concepts. The ecosystem approach defined as "*a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way*" (CBD 2000) largely concurs with the ICDP concept adding that outcomes of conservation and development need to be equitable. The ecosystem approach was perceived by some to be too biophysical, lacking a reference to e.g. institutions, which is why shortly

after its definition, the term *landscape approach* was launched by WWF and IUCN (Bowling 2002; Sayer 2009). In reality the two approaches are not really different though. *The landscape approach is a framework for taking landscape level-decisions and seeks to integrate top-down planning and bottom-up approaches. Key in a landscape approach is to get all different stakeholders in the landscape to exchange, to look beyond their discipline to the landscape system and formulate strategies together.* Chapter 9 evaluates whether participatory modelling attributes in taking a landscape approach.

## **System dynamics modelling to understand conservation and development interactions**

The historical overview given of conservation and development illustrates how challenging it has been and still is to reform conservation approaches on the ground in accordance with the conceptual changes in natural resource management over the past decades. The importance of integrating disciplines and of cyclical top-down and bottom-up information flows in decision making was already outlined in the 70ies and yet we are still continuously defining new approaches to successfully implement this concept on the ground. Though often proclaimed differently in project descriptions, on the ground projects are often still accused of being top-down (Holling & Meffe 1996) and mainly single-discipline conservation biology driven (Chapin 2004). This apparent challenge of synchronizing conceptual changes in how natural resources should be managed with actual changes in management is probably related to the complexity project leaders are faced with on the ground. Landscapes are highly complex systems with many non-linearities, delayed responses and uncertainties. In fact, the failure in reconciling conservation and development goals is attributed by some to the failure of conservation biologists to fully understand dynamics and relationships in complex landscapes and recognize trade-offs occurring between conservation and development (Malleson 2002; Salafsky & Wollenberg 2000). On a similar note, Agrawal and Redford (2006) analysing 37 peer-reviewed writings on the poverty-biodiversity link, found that 34 out of 37 reviewed studies gave “drastic simplifications of the complex concepts of poverty and biodiversity and focused on processes and outcomes in a single case and single time period without taking into account the relations between outcomes and contextual features of programmatic interventions” (pii).

Sterman (2000 p´preface'), a leading figure in system dynamics, comments: “Effective decision-making and learning in a world of growing dynamic complexity requires us to become systems thinkers—to expand the boundaries of our mental models and develop tools to understand how the structure of complex systems creates their behavior.” We hypothesise the use of participatory system dynamics modelling will increase understanding of complex landscapes, enable the quantification of trade-offs occurring between conservation and development and stimulate discussion between stakeholders with different, often conflicting, objectives. This in turn will



promote the negotiation of a joint strategy with best possible outcomes for conservation and development.

### **System dynamics; a brief history**

*"System dynamics is an approach to understanding the behaviour of complex systems over time. ... What makes using system dynamics different from other approaches to studying complex systems is the use of feedback loops and stocks and flows. These elements help describe how even seemingly simple systems display baffling nonlinearity."* (Wikipedia 2009)

As this definition suggests, the system dynamics approach discarded linear thinking to embrace closed-loop or iterative thinking in science that supports decision making. Iteration is the act of repeating a process, where the result from one iteration is used as a starting point for the next. It refers to a cyclical, not a linear process. The change from linear thinking to an iterative mental model in research planning was introduced shortly before system dynamics was developed with the concept of *action research* launched in 1944 by Kurt Lewin. He defined action research as "*comparative research on the conditions and effects of various forms of social action and research leading to social action*" that uses "*a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action*" (Lewin 1946). Another important conceptual change, which might have helped to set the scene for system dynamics, came with the introduction of *systems theory*. This trans-disciplinary approach sees a system as a compilation of a set of independent but interacting parts. It was developed by Ludwig von Bertalanffy and others just before the 1950s.

System dynamics was first developed by Jay Forrester during the 1950s at the Massachusetts Institute of Technology (MIT). Forrester previously worked as an engineer involved in the creation of an aircraft flight simulator for military purposes and the testing of computerized combat information systems before being appointed to manage a laboratory at MIT. This experience made him conclude that the largest impediment to progress comes from the management side of understanding social systems rather than the engineering side of understanding physical processes (Radzicki 1997). Forrester believed social systems contain many feedback loops and for understanding these systems' behaviour one has to abandon linear thinking. Discussions with managers of General Electric puzzled by a three-year employment cycle lead him to do his first hand simulations including existing hiring and lay-off decision making structures. Forrester was able to show the cycle was due to the internal structure of the firm and not to an external force such as the business cycle (Radzicki 1997). He named these simulations to understand corporate issues 'Industrial Dynamics' (Forrester 1958, 1961). He soon needed a computerized approach to realize these complex simulations. The first computer based modelling language was created in 1958 by Richard Bennett and named SIMPLE (Simulation of

Industrial Management Problems with Lots of Equations). Immediately after, in 1959, an improved version of SIMPLE called DYNAMO (DYNAMIC MODELS) was launched by Phyllis Fox and Alexander Pugh which became the standard modelling language for the following three decades.

From the late 50s to the late 60s, system dynamics was mainly applied to managerial problems in the industrial sector. Its application was broadened to the urban sector in 1968 following the appointment of John Collins, the former mayor of Boston, as visiting professor of Urban Affairs at Forrester's institute. With their offices neighbouring, the two men exchanged in daily discussions resulting in problems in cities being studied with system dynamics, published in 'Urban Dynamics' (Forrester 1969). In 1970, Jay Forrester was invited by the Club of Rome to a meeting in Bern, Switzerland. He was asked to create a model exploring future problems of a growing world population's demand on the earth's carrying capacity. This resulted in a model for the world linking model sectors 'world population', 'industrial production', 'pollution', 'resources', and 'food'. He published his findings in 'World dynamics' (Forrester 1971) but continued work on this by his PhD student became better known as 'The limits to growth' (Meadows *et al.* 1972).

From the seventies till this moment, important publications in the field of system dynamics encompass Roberts (1978), Randers (1980), Senge (1990), Ford (1999), Sterman (2000) and Morecroft (2007). Costanza *et al.* (1993) linked the natural and socioeconomic system in a system dynamics model. In 1985 High Performance Systems (now ISEE systems) developed STELLA; an icon based modelling software, being highly user-friendly and making system dynamics available to a broader public. This is the model-building platform used in this thesis. Similar modelling software are VENSIM (developed by Ventana Systems), POWERSIM and SIMILE (developed by Simulistics).

## **Scenario planning; how it evolved**

Scenario planning was developed simultaneously in the United States and France in the 1950s and 1960s. Herman Kahn working for the US Military came up with a range of stories of the future based on different key assumptions to formulate strategies (Kahn & Wiener 1969) while Gaston Berger working for a French research centre invented future scenarios to help formulate public policy (Berger 1964). In the 1970s the method was adopted by some private companies, notably General Electrics and Royal Dutch Shell.

Shell greatly benefited from the planning method which helped them to forecast the beginning of the energy crisis in 1973 and the shock in oil prices, which had been stable since World War II. Being prepared for this, they advanced from one of the weakest of the seven largest global oil companies to one of the two largest (Schwartz 1991). As the methodology was further developed by Shell, the first objective of scenario planning became "the

generation of projects and decisions that are more robust under a variety of alternative futures" (Van der Heijden 1996) p17). Scenario planning became all about collective learning, reframing perceptions, analyzing causal relationships, envisioning multiple features influencing the future and dealing with uncertainty. Peterson *et al.* (2003) emphasize scenario planning to be specifically appropriate for systems where there is a lot of uncertainty that is not controllable, where they propose other methods if a system doesn't display this specific combination.

Another major advance in the use of scenario planning came with the launching of the Millennium Ecosystem Assessment (MA) in 2001, called for by the United Nations Secretary-General Kofi Annan in 2000. It rose out of a demand from both scientists and policy makers and had the objective "to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being" (MA 2005). Raskin *et al.* (2005 p36) define scenarios as "*plausible, challenging, and relevant stories about how the future might unfold, which can be told in both words and numbers.*" The storytelling in words refers to qualitative narrative, while storytelling in numbers refers to quantitative modelling. The history sketched so far concerns qualitative scenario building. The first global scenarios from quantitative modelling were the earlier mentioned limits-to-growth scenarios forecasting a collapse in natural resources with increasing demands from a growing population (Forrester 1971; Meadows *et al.* 1972). Kahn *et al.* (1967) challenged the limits-to-growth perceptions and sketched more optimistic future scenarios with increasing economic growth and wellbeing for all, assuming current problems of over-demand from a growing population and pollution will either soon solve themselves or have "rather straightforward and practical solutions" (Kahn *et al.* 1967 p20).

## **Models in policy making**

System dynamics and scenario planning are used with the ultimate goal of informing the decision-making process and to formulate more effective and robust policies. Though logical reasoning suggests modelling and scenario planning provide information and improve understanding of system's functioning, and better information leads to better decisions, actual uses of models in policy making have fallen short of expectations (Meadows & Robinson 1985; Vennix 1996).

### *Disconnection between scientists and policy makers*

King & Kraemer (1993) mention it are especially 'scientific' models (read predictive models) being disconnected from the policy making process. The lack of uptake of results from 'scientific' models by policy makers according to them relates to the policy process going further into the social realm where "the word 'science' is something of a euphemism" (King & Kraemer

1993 p357). On a similar note Kraemer and King (1986 p501) state “‘Pure’ approaches to modeling require formal expression and rigor in every aspect of model building. The models that result are so abstract and removed from the realities of fuzzy political problems that they are almost certain to fail as tools for public policy-making.” Both papers report on the unwillingness of scientists to deal with uncertainties leading to the creation of highly correct and highly useless models. Chapter 9 reports further on different perceptions of scientists and policy makers.

#### *Action doesn't follow logically from a 'good' model*

However, even in Shell's earlier mentioned success story, policy uptake didn't follow directly from scenario planning which didn't avoid uncertainty or stop when the problem moved further into the 'social realm'. When Pierre Wack presented the different scenarios to Shell's directors he made it very clear that the Arabs could demand higher prices for their oil and there was all reason to believe they would, the only unknown being when. The directors understood the implications, realised they might have to change their business drastically but didn't do anything until the scenario actually came true. When Pierre saw his outlined scenarios didn't result in direct change in the company's policy, he realized that to be truly effective, scenarios had to “change our manager's view of reality” (Schwartz 1991 p8). Schwartz (1991 p9) mentions the comparative advantage of Shell was them being 'emotionally prepared' for the change and therefore responding quickly, not them having altered their way of doing business beforehand. This implies that apparently, though the managers hadn't changed their way of working before the price shock, something did change in their minds or mental models that gave them a comparative advantage when dealing with the crisis.

#### *Conceptual insights gained from modelling*

Meadows and Robinson (1985) analysing the practise and impact of computer models as applied to policy, found most insights gained from models are conceptual rather than instrumental. However Pala and Vennix (2005) and Vosniadou (1994) report that changing conceptual mind models through system dynamics shouldn't be taken for granted. Pala and Vennix studied whether system dynamics improved task performance of students and discuss the possibility their students only “enrich (i.e. add information to existing conceptual structures) their ideas rather than revising (i.e. changing their beliefs or presuppositions) them” (p 169). So, models hold the potential of changing the way people think about a system or problem but it is a challenge to modellers to actually realize this conceptual change. Achieving conceptual change in people's minds, as the Shell example taught us, can have major impacts on the ground.

### *How to assure action follows*

In accordance with the Shell experience Vennix *et al.* (1996) argue the real challenge is not identifying the best strategic decisions or robust policy, but getting managers (or other stakeholders) to back it up. To get managers (or policy makers or other model clients) to take the next step of actually using newly gained information and perceptions in their business or policy formulation, they propose the creation of a 'platform for change'. This platform for change implies the encouragement of team learning, the fostering of consensus, and the creation of commitment to the resulting decision especially when divergent opinions are involved (Vennix *et al.* 1996). Such a platform for change could be created by involving the client in the model building process as is done in participatory modelling. Another strong motivation for doing participatory modelling to increase impact on policy formulation is given by Greenberger *et al.* (1976 p321) who found "most insights of models exploring policy effectiveness are gained during the model building process rather than after." Similar conclusions from systematic research on models in policy making are that the way a structure is used is more critical than the nature of the structure (Den Butter & Morgan 2000) and the desire of politicians to use model-generated information to be more important than the means to do modelling (Kraemer & King 1986).

## **Participatory modelling, a state-of-the-art**

### *Definition and origins*

There are quite a number of synonyms which all refer to a more or less similar approach: group model building (Andersen & Richardson 1997; Stave 2002; Vennix 1996), mediated modelling (Van den Belt 2004; Videira *et al.* 2006), cooperative modelling (Cockerill *et al.* 2006), companion modelling (Barreteau *et al.* 2003; Bousquet *et al.* 2007) and participatory modelling (Beall 2007; Standa-Gunda *et al.* 2003). In the remainder of this article we will use participatory modelling to refer to any of the approaches mentioned above. We define participatory modelling as: *the act of building a model with a group of non-modeller 'clients' under the guidance of a model expert facilitator*. Standa-Gunda *et al.* (2003) describe participatory modelling as a process through which members of a community identify a problem, collect and analyze data, and act upon the problem to find solutions and to promote social and political transformations in which a model is the medium for representing and communicating ideas. It is said that participatory modelling and modelling for learning was shaped by Donella Meadows and Jennifer Robinson's book 'The electronic oracle: Computer models and social decisions' (1985). The book investigates the impact of computer models as applied to social policy and stresses the importance of exposing hidden assumptions and biases to make them discussable which would happen if all stakeholders involved have a full comprehension of the model.

### *Different modelling platforms*

Different modelling platforms have been used in participatory modelling. The author found cases where agent based modelling, Bayesian networks, fuzzy cognitive mapping, geographical information systems (GIS) and system dynamics modelling is used in participatory modelling. Agent based modelling, also referred to as multi-agent simulations, usually comprise spatial models. The models run simulations in which autonomous agents act and interact determining the behaviour of the whole system. Their actions may change as a result of events and interactions and simple rules may result in complex dynamics. Examples of participatory agent based modelling are Becu *et al.* (2008) and Bousquet and Le Page (2004). A Bayesian or belief network is a probabilistic static representation of conditional interdependencies between input variable states and the states of variables of interest. It is an accumulation of logical, intuitively easy conditional relations and can answer questions like 'what is the probability of Y happening given X has happened?'. Lynam *et al.* (2002) and Mendoza and Prabhu (2006) evaluate their use in participatory modelling. Fuzzy cognitive mapping is a way to represent complex decision problems composed of interrelated dynamic entities within which the relationships between these entities can be used to approximate the strength of impact of these entities. The complex entities are represented as nodes and the causal links are represented by arrows with the direction of the arrow representing the direction of influence. An example of it's use in forest management is given by Mendoza and Prabhu (2006). GIS is any system that presents data that are linked to location. Examples of participatory modelling or participatory mapping using GIS as platform are Castella *et al.* (2005), Brown and Reed (2009) and Robiglio *et al.* (2003).

The most frequently used platform in participatory modelling is system dynamics modelling (see earlier paragraph for definition and background). Participatory system dynamics modelling has been used in a wide variety of situations:

- In formulating business strategies (Akkermans & Vennix 1997; Vennix 1996)
- To improve understanding of oil market behaviour (Morecroft & Van der Heijden 1992)
- To explore air quality problems in the city (Stave 2002)
- To increase profit and reduce risk in agricultural production systems (Meinke *et al.* 2001)
- In community based watershed planning (Cockerill *et al.* 2006; Tidwell *et al.* 2004) and river basin planning and management (Videira *et al.* 2009)
- To formulate water management strategies taking into account expected climate change effects on future water supplies (Langsdale *et al.* 2005)

- As negotiation and consensus building tool in coastal management, including model-sectors like tourism and pollution (Van den Belt *et al.* 1998)
- To explore policy impacts in the fishing industry (Otto & Struben 2004)
- To ensure the protection of endangered species in land-use planning (Beall & Zeoli 2008)
- To support environmental decision making (Cockerill *et al.* 2007; Van den Belt 2004; Videira *et al.* 2003)
- To promote multi-stakeholder involvement in public decision making (Van den Belt *et al.* 2010)
- To explore adaptation strategies to macro-economic changes for rural communities in woodland areas (Standa-Gunda *et al.* 2003)
- In community based forest management (Kassa *et al.* 2009; Suwarno *et al.* 2009)
- To explore the effect of policies and interventions on conservation and development outcomes in tropical forest landscapes and negotiate a commonly accepted strategy (this thesis)

### *Complex versus scoping models*

Some modellers try to capture the underlying system as accurate as they can in an attempt to avoid uncertainty. The resulting models are very detailed and highly complex. Hisschemöller *et al.* (2001) note such a model is not necessarily as accurate as needed, particularly not for complex environmental issues on large spatial and temporal scales. Another downside of such complexity is that it is quite incompatible with participation thus leading to a lack of understanding of the internal model structure and a lack of trust in its outcomes. Such models have their value, especially when its aim doesn't include those of participatory modelling like increased understanding and consensus building, but the models build in this thesis do not belong to this category and are better described as 'scoping models' (Costanza & Ruth 1998).

### *Importance of stakeholder involvement in model building process*

Beall (2007) and Beall and Ford (2007) describe how participatory modelling often occurs at changing positions on what they call the 'hands-on continuum'. On the one side of this continuum, models are built by experts using input from participants and perhaps reporting back the simulation outcomes, while on the other side of the continuum, software is used at workshops to assist with problem mapping. As suggested by Beall our positioning changes, but in general we locate ourselves more on the latter side of the continuum, where participants build model-sectors largely on their own later to integrate the sectors revealing linkages in the landscape system. Beall (2007) claims advantages of this side of the continuum to be that participants will trust the model more and get a better understanding of non-linear system thinking. The process of building a model helps participants see important causal relationships in complex systems. On a similar note, Vennix

(1996) reports on the importance of involving clients in the model building process to increase their sense of ownership of the model without which the model results are not likely to be used. Policy makers are unlikely to trust a model they don't understand, which is quite likely to happen if they have not been involved in its building (SME 2010). As described earlier, building a 'good' model doesn't necessarily result in uptake in the decision making process of its results but involvement in the model building process does increase its probability. Akkermans and Vennix (1997) evaluated six case studies using participatory modelling and found that five of those cases were successful in creating insight and building consensus and commitment.

### *Participatory modelling as negotiation tool*

Several authors have used participatory modelling as a negotiation tool to build consensus among a range of stakeholders with different interests (Cockerill *et al.* 2006; Costanza & Ruth 1998; Van den Belt 2004) (this thesis). Participatory modelling can help to gain a shared vision among stakeholders and according to Costanza (2000) a shared vision is key to change in the desired direction. Features of participatory modelling which make them particularly suitable as consensus building tool are that assumptions have to be made explicit and knowledge from a range of stakeholders is solicited increasing exchange and common understanding (Costanza & Ruth 1998). Videira *et al.* (2006 p9) describe 'shared language', 'openness', 'team learning' and 'knowledge integration' as features proven to be promoted by participatory modelling.

### **Objectives of this thesis**

The objectives of using participatory modelling in this thesis go further than creating better understanding only. We use participatory modelling to let stakeholders step away from their disciplinary paradigm to take a more overall systems view. This should foster understanding of different viewpoint and objectives. The modelling enables the quantification of trade-offs occurring between conservation and development and promotes exchange and collaboration between different stakeholders. The ultimate goal of the modelling is to create consensus among stakeholders with diverging and often conflicting interests and define a commonly accepted strategy to achieve satisfactory outcomes for all. Participatory modelling helps to get a grip on complex systems and understand its behaviour; it promotes a multi-disciplinary approach, reveals how conservation and development are interlinked and stimulates strategic thinking. The concepts of multi-disciplinarity, integrated conservation and development and strategic thinking are not new in the area of biodiversity conservation, but they have been notoriously difficult to integrate in our way of managing natural resources on the ground. We believe participatory modelling is one efficient tool, in a large toolbox of different approaches, which can help to implement a landscape approach.



## REFERENCES

- Agrawal, A., and K. Redford. 2006. *Poverty, Development, And Biodiversity Conservation: Shooting in the Dark?* Page 58. Working paper. WCS.
- Akkermans, H. A., and J. A. M. Vennix. 1997. Clients' opinions on group model-building: an exploratory study. *System Dynamics Review* **13**:3-31.
- Alpert, P. 1996. Intergrated Conservation and Development Projects. *Bioscience* **46**:845-855.
- Andersen, D. F., and G. P. Richardson. 1997. Scripts for group model building. *System Dynamics Review* **13**:107-129.
- Balmford, A., and T. Whitten. 2003. Who should pay for tropical conservation, and how could the costs be met? *Oryx* **37**:238-250.
- Barreteau, O. *et al.* 2003. Our Companion Modelling Approach. *Journal of Artificial Societies and Social Simulation* **6**:6.
- Beall, A., and A. Ford. 2007. Participatory Modeling for Adaptive Management: Reports from the Field II. *Unpublished report*
- Beall, A., and L. Zeoli. 2008. Participatory modeling of endangered wildlife systems: Simulating the sage-grouse and land use in Central Washington. *Ecological Economics* **68**:24-33.
- Beall, A. M. 2007. *Participatory Environmental Modeling and System Dynamics: Integrating Natural Resource Science and Social Concerns*. PhD thesis, Washington State University.
- Becu, N., A. Neef, P. Schreinemachers, and C. Sangkapitux. 2008. Participatory computer simulation to support collective decisionmaking: Potential and limits of stakeholder involvement. *Land Use Policy* **25**:498-509.
- Berger, G. 1964. *Phénoménologies du Temps et Prospectives*. Presse Universitaires de France.
- Börner, J., S. Wunder, S. Wertz-Kanounnikoff, M. R. Tito, L. Pereira, and N. Nascimento. 2010. Direct conservation payments in the Brazilian Amazon: Scope and equity implications. *Ecological Economics* **69**:1272-1282.
- Bousquet, F., J.-C. Castella, G. Trébuil, C. Barnaud, S. Boissau, and S. P. Kam. 2007. Using multi-agent systems in a companion modelling approach for agroecosystem management in South-east Asia. *Outlook on Agriculture* **36**:57-62.
- Bousquet, F., and C. Le Page. 2004. Multi-agent simulations and ecosystem management: a review. *Ecological Modelling* **176**:313-332.
- Bowling, J. 2002. *The Landscape Approach*. Position Paper. WWF.
- Brown, G. G., and P. Reed. 2009. Public Participation GIS: A New Method for Use in National Forest Planning. *Forest Science* **55**(117):166-182.
- Brundtland Comission. 1987. *Our Common Future*. Report of the Brundtland Commission on Environment and Development. Oxford University Press, Oxford, UK.
- Butchart, S. H. M., M. Walpole, B. Collen, A. van Strien, J. P. W. Scharlemann, R. E. A. Almond, J. E. M. Baillie, B. Bomhard, C. Brown, J. Bruno, K. E. Carpenter, G. M. Carr, J. Chanson, A. M. Chenery, J. Csirke, N. C. Davidson, F. Dentener, M. Foster, A. Galli, J. N. Galloway,

- P. Genovesi, R. D. Gregory, M. Hockings, V. Kapos, J.-F. Lamarque, F. Leverington, J. Loh, M. A. McGeoch, L. McRae, A. Minasyan, M. Hernández-Morcillo, T. E. E. Oldfield, D. Pauly, S. Quader, C. Revenga, J. R. Sauer, B. Skolnik, D. Spear, D. Stanwell-Smith, S. N. Stuart, A. Symes, M. Tierney, T. D. Tyrrell, J.-C. Vié, and R. Watson. 2010. Global Biodiversity: Indicators of Recent Declines. *Science in press* DOI: 10.1126/science.1187512.
- Calder, I. R. 1999. *The blue revolution: land use and integrated water resources management*. Earthscan, London, UK.
- Castella, J.-C., T. N. Trung, and S. Boissau. 2005. Participatory Simulation of Land-Use Changes in the Northern Mountains of Vietnam: the Combined Use of an Agent-Based Model, a Role-Playing Game, and a Geographic Information System. *Ecology and Society* **10**:27.
- CBD. 2000. *Decision V/6, Annex A, section 1*. Fifth conference of Parties. Convention on Biological Diversity, Nairobi, Kenya.
- Cernea, M. M., and K. Schmidt-Soltau. 2006. Poverty Risks and National Parks: Policy Issues in Conservation and Resettlement. *World Development* **34**:1808–1830.
- Cockerill, K., H. Passell, and V. Tidwell. 2006. Cooperative Modeling: Building Bridges between Science and the Public. *Journal of the American Water Resources Association* **42**:457–471.
- Cockerill, K., V. C. Tidwell, H. D. Passell, and L. A. Malczynski. 2007. Cooperative Modeling Lessons for Environmental Management. *Environmental Practice* **9**:28–41.
- Costanza, R. 2000. Visions of alternative (unpredictable) futures and their use in policy analysis. *Conservation Ecology* **4**:5.
- Costanza, R., and M. Ruth. 1998. Using Dynamic Modeling to Scope Environmental Problems and Build Consensus. *Environmental Management* **22**:183–195.
- Costanza, R., L. Wainger, C. Folke, and K. G. Maler. 1993. Modelling complex ecological economic systems: toward an evolutionary, dynamic understanding of people and nature. *Bioscience* **43**:545–555.
- Chapin, M. 2004. *A Challenge to Conservationists*. Pages 17–31. World Watch. Worldwatch Institute.
- Christensen, J. 2004. Win-Win Illusions. Over the past two decades, efforts to heal the rift between poor people and protected areas have foundered. So what next? *Conservation in Practice* **5**:12–19.
- Den Butter, F. A. G., and M. S. Morgan 2000. *Empirical models and policy making: interaction and institutions*. Routledge, London, UK.
- FAO. 2009. *The State of Food Insecurity in the World: Economic crises – impacts and lessons learned*. Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy.
- FAO. 2010. *Global Forest Resources Assessment 2010*. Food and Agriculture Organization of the United Nations, Rome, Italy.
- Ferraro, P. J., and A. Kiss. 2002. Direct Payments to Conserve Biodiversity. *Science* **298**:1718–1719.

- Fisher, B., K. Kulindwa, I. Mwanyoka, R. K. Turner, and N. D. Burgess. 2010. Common pool resource management and PES: Lessons and constraints for water PES in Tanzania. *Ecological Economics* **69**:1253–1261.
- Ford, A. 1999. *Modeling the Environment*. Island Press, Washington DC, USA.
- Forrester, J. W. 1958. Industrial dynamics: a major breakthrough for decision makers. *Harvard Business Review* **July-August**:37-66.
- Forrester, J. W. 1961. *Industrial Dynamics*. Productivity Press, Portland, USA.
- Forrester, J. W. 1969. *Urban Dynamics*. Pegasus Communications, Cambridge, USA.
- Forrester, J. W. 1971. *World Dynamics*. MIT press, Cambridge, USA.
- Garnett, S. T., J. Sayer, and J. d. Toit. 2007. Improving the Effectiveness of Interventions to Balance Conservation and Development: a Conceptual Framework. *Ecology and Society* **12**:2.
- Greenberger, M., M. A. Crenson, and B. L. Crissey 1976. *Models in the Policy Process: Public Decision Making in the Computer Era*. Russel Sage Foundation, New York, USA.
- Guha, R. 1997. The Authoritarian Biologist and the Arrogance of Anti-Humanism: Wildlife Conservation in the Third World. *The Ecologist* **27**:14-20.
- Hardner, J., and R. Rice. 2002. Rethinking green consumerism. *Scientific American* **287**:89-95.
- Hisschemöller, M., R. S. J. Tol, and P. Vellinga. 2001. The relevance of participatory approaches in integrated environmental assessment. *Integrated Assessment* **2**:57–72.
- Holling, C. S. 1978. *Adaptive environmental assessment and management*. John Wiley & Sons, London, UK.
- Holling, C. S., and G. K. Meffe. 1996. Command and Control and the Pathology of Natural Resource Management. *Conservation Biology* **10**:328-337.
- Hughes, R., and F. Flintan 2001. *Integrating conservation and development experience: a review and bibliography of the ICDP literature*. International Institute for Environment and Development, London, UK.
- Kahn, H., W. Brown, and L. Martel 1967. *The Next 200 Years: A Scenario for America and the World*. Morrow, New York, USA.
- Kahn, H., and A. J. Wiener 1969. *The year 2000: a framework for speculation on the next thirty-three years*. Macmillan, New York, USA.
- Karsenty, A. 2007. Questioning rent for development swaps: new marketbased instruments for biodiversity acquisition and the land-use issue in tropical countries. *International Forestry Review* **9**:503-513.
- Kassa, H., B. Campbell, M. Sandewall, M. Kebede, Y. Tesfaye, G. Dessie, A. Seifu, M. Tadesse, E. Garedew, and K. Sandewall. 2009. Building future scenarios and uncovering persisting challenges of participatory forest management in Chilimo Forest, Central Ethiopia. *Journal of Environmental Management* **90**:1004–1013.
- King, J. L., and K. L. Kraemer. 1993. *Models, facts, and the policy process: The political ecology of estimated truth* in: M. F. Goodchild, B. O. Parks, and L. T. Steyaert, editors. *Environmental Modeling with GIS*. Oxford University Press, New York, US.

- Kraemer, K. L., and J. L. King. 1986. Computer-Based Models for Policy Making: Uses and Impacts in the U.S. *Federal Government. Operations Research* **34**:501-512.
- Kremen, C., A. M. Merenlender, and D. D. Murphy. 1994. Ecological monitoring: a vital need for integrated conservation and development programs in the tropics. *Conservation Biology* **8**:388-397.
- Kremen, C., J. O. Niles, M. G. Dalton, G. C. Daily, P. R. Ehrlich, J. P. Fay, D. Grewal, and R. P. Guillery. 2000. Economic Incentives for Rain Forest Conservation Across Scales. *Science* **288**:1828-1832.
- Langsdale, S., J. Carmichael, S. Cohen, and B. J. Lence. 2005. *Water Resources Planning through Group Model Building in the Okanagan Valley, British Columbia, Canada*. World Water and Environmental Resources Congress. American Society of Civil Engineers, Anchorage, USA.
- Lewin, K. 1946. Action research and minority problems. *Journal of Social Issues* **2**:34-46.
- Loche, H., and P. Dearden. 2005. Rethinking protected area categories and the new paradigm. *Environmental Conservation* **32**:1-10.
- Lynam, T., F. Bousquet, C. L. Page, P. d'Aquino, O. Barreteau, F. Chinembiri, and B. Mombeshora. 2002. Adapting Science to Adaptive Managers: Spidergrams, Belief Models, and Multi-agent Systems Modeling. *Conservation Ecology* **5**:24.
- MA. 2005. *Millenium Ecosystem Assessment* URL [<http://www.millenniumassessment.org/>] visited January 2010
- Malleson, R. 2002. Changing perspectives on forests, people and 'development': Reflections on the case of the Korup forest. *IDS Bulletin* **33**:94-101.
- Martino, D. 2005. Unleashing the wild: response to Locke and Dearden's 'rethinking protected area categories'. *Environmental Conservation* **32**:195-196.
- McShane, T. O., M. P. Wells, and (eds) 2004. *Getting biodiversity projects to work: towards more effective conservation*. Colombia University Press, New York, USA.
- Meadows, D. H., D. L. Meadows, J. Randers, and W. W. Behrens 1972. *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. Universe Books, New York.
- Meadows, D. H., and J. M. Robinson 1985. *The electronic oracle: computer models and social decisions*. International Institute for Applied Systems Analysis.
- Meinke, H., W. E. Baethgen, P. S. Carberry, M. Donatelli, G. L. Hammer, R. Selvaraju, and C. O. Stöckle. 2001. Increasing profits and reducing risks in crop production using participatory systems simulation approaches. *Agricultural Systems* **70**:493-513.
- Mendoza, G. A., and R. Prabhu. 2006. Participatory modeling and analysis for sustainable forest management: Overview of soft system dynamics models and applications. *Forest Policy and Economics* **9**:179-196
- Morecroft, J. 2007. *Strategic Modelling and Business Dynamics: A Feedback Systems Approach*. John Wiley & Sons, West Sussex, England.

- Morecroft, J. D. W., and K. A. J. M. Van der Heijden. 1992. Modelling the oil producers - Capturing oil industry knowledge in a behavioural simulation model. *European Journal of Operational Research* **59**:102-122.
- Oates, J. F. 1999. *Myth and reality in the rainforest: how conservation strategies are failing in Africa*. University of California Press, Berkeley, USA.
- Otto, P., and J. Struben. 2004. Gloucester Fishery: insights from a group modeling intervention. *System Dynamics Review* **20**:287-312.
- Pagiola, S. 2008. Payments for environmental services in Costa Rica. *Ecological Economics* **65**:712-724.
- Pala, Ö., and J. A. M. Vennix. 2005. Effect of system dynamics on systems thinking inventory task performance. *System Dynamics Review* **21**:147-172.
- Perlin, J. 1989. *A Forest Journey: The Role of Wood in the Development of Civilization*. W.W. Norton, New York, USA.
- Peterson, G. D., G. S. Cumming, and S. R. Carpenter. 2003. Scenario Planning: a Tool for Conservation in an Uncertain World. *Conservation Biology* **17**:358-366.
- Radzicki, M. J. 1997. *Foundations of System Dynamics Modeling*. Sustainable Solutions, Inc.
- Randers, J. 1980. *Elements of the System Dynamics Method*. MIT press, Cambridge.
- Raskin, P., F. Monks, T. Ribeiro, D. v. Vuuren, and M. Zurek. 2005. *Global Scenarios in Historical Perspective* in: MA Ecosystems and Human Well-Being: Scenarios Findings of the Scenarios Working Group. Island Press, Washington DC, USA.
- Redford, K. H. 1992. The empty forest. *Bioscience* **42**:412-422.
- Rice, R. 2003. *Conservation Concessions - Concept Description*. Vth World Parks Congress: Sustainable Finance Stream. Conservation International, Durban, South Africa.
- Roberts, E. B. 1978. *Managerial Applications of System Dynamics*. MIT Press, Cambridge.
- Robiglio, V., W. A. Mala, and M. C. Diaw. 2003. Mapping Landscapes: Integrating GIS and Social Science Methods to Model Human-nature Relationships in Southern Cameroon. *Small-scale Forest Economics, Management and Policy* **2**:171 -184.
- Salafsky, N., and E. Wollenberg. 2000. Linking Livelihoods and Conservation: A Conceptual Framework and Scale for Assessing the Integration of Human Needs and Biodiversity. *World Development* **28**:1421-1438.
- Sayer, J. 2009. Reconciling Conservation and Development; Are Landscapes the Answer? *Biotropica* **41**:649-652.
- Sayer, J. 2007. *The People's Forest. Balancing local and global values*. PhD thesis, Autonomous University of Madrid (UAM), Madrid, Spain.
- Sayer, J. A., S. Maginnis, and S. Rietbergen. 2007. *Ecosystem Approaches to Sustainable Forest Management: Changing Realities*. Pages 35-43 in Dubé, and Schmithuesen, editors. Cross-sectoral policy developments in forestry. CAB International, Wallingford, UK.

- Schmidt-Soltau, K., and D. Brockington. 2007. Protected Areas and Resettlement: What Scope for Voluntary Relocation? *World Development* **35**:2182–2202.
- Schwartz, P. 1991. *The Art of the Long View: Planning for the Future in an Uncertain World*. Doubleday, New York, USA.
- Senge, P. M. 1990. *The Fifth Discipline: The Art & Practice of the Learning Organization*. Doubleday, New York, USA.
- SME 2010. *Spatial Modelling Environment Overview*. URL [<http://www.uvm.edu/qiee/SME3/SME3F.html>] visited January 2010
- Sommerville, M., J. P. G. Jones, M. Rahajaharison, and E. J. Milner-Gulland. 2010. The role of fairness and benefit distribution in community-based Payment for Environmental Services interventions: A case study from Menabe, Madagascar. *Ecological Economics* **69**:1262–1271.
- Standa-Gunda, W., T. Mutimukuru, R. Nyirenda, R. Prabhu, M. Haggith, and J. K. Vanclay. 2003. Participatory Modelling to Enhance Social Learning, Collective Action and Mobilization among Users of the Mafungautsi Forest, Zimbabwe. *Small-scale Forest Economics, Management and Policy* **2**:313–326.
- Stave, K. A. 2002. Using system dynamics to improve public participation in environmental decisions. *System Dynamics Review* **18**:139–167.
- Sterman, J. D., editor. 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World* McGraw Hill, Boston, USA.
- Sunderland, T., C. Ehringhaus, and B. M. Campbell. 2008. Conservation and development in tropical forest landscapes: a time to face the trade-offs? *Environmental Conservation* **34**:276–279.
- Sunderlin, W. D., S. Dewi, A. Puntodewo, D. Müller, A. Angelsen, and M. Epprecht. 2008. Why Forests Are Important for Global Poverty Alleviation: a Spatial Explanation. *Ecology and Society* **13**:24.
- Suwarno, A., A. A. Nawir, Julmansyah, and Kurniawan. 2009. Participatory modelling to improve partnership schemes for future Community-Based Forest Management in Sumbawa District, Indonesia. *Environmental Modelling & Software* **24**:1402–1410.
- Terborgh, J. 1999. *Requiem for nature*. Island Press=Shearwater Books, Washington DC, USA.
- The Economist. 2008. The price of conservation-the unkindest cut. Cameroon wants to sell a forest, but conservationists don't want to buy it. *The Economist*.
- Tidwell, V. C., H. D. Passell, S. H. Conrad, and R. P. Thomas. 2004. System dynamics modeling for community based water planning: Applications to the Middle Rio Grande. *Aquatic sciences* **66**:357–372.
- Van den Belt, M. 2004. *Mediated modeling. A system dynamics approach to environmental consensus building* Washington, DC.
- Van den Belt, M., L. Deutsch, and A. Jansson. 1998. A consensus-based simulation model for management in the Patagonia coastal zone. *Ecological Modelling* **110**:79–103.
- Van den Belt, M., J. R. Kenyan, E. Krueger, A. Maynard, M. G. Roy, and I. Raphael. 2010. Public sector administration of ecological economics

- systems using mediated modeling. *Ecological Economics Reviews* **11**:196-210.
- Van der Heijden, K. 1996. *Scenarios: The art of strategic conversation*. John Wiley & Sons, Chichester, UK.
- Vennix, J. A. M. 1996. *Group model building: Facilitating Team Learning Using System Dynamics*. John Wiley & Sons Ltd., Chichester, UK.
- Vennix, J. A. M., H. A. Akkermans, and E. A. J. A. Rouwette. 1996. Group model-building to facilitate organizational change: an exploratory study. *System Dynamics Review* **12**:39-58.
- Videira, N., P. Antunes, and R. Santos. 2009. Scoping river basin management issues with participatory modelling: The Baixo Guadiana experience. *Ecological Economics* **68**:965-978.
- Videira, N., P. Antunes, R. Santos, D. Borrego, and G. Lobo. 2006. *Mediated modelling to support public and stakeholder participation in water resources planning and management: The Baixo Guadiana experience, Portugal*. Pages 167-192. Advisor.
- Videira, N., P. Antunes, R. Santos, and S. Gamito. 2003. Participatory Modelling in Environmental Decision-Making: The Ria Formosa Natural Park Case Study. *Journal of Environmental Assessment Policy and Management* **5**:421-447.
- Vosniadou, S. 1994. Capturing and modeling the process of conceptual change. *Learning and Instruction* **4**:45-69.
- Walters, C. 1986. *Adaptive Management of Renewable Resources*. Macmillan, New York, USA.
- WB. 2010. *Understanding, measuring and overcoming poverty*. World Bank, Washington DC, USA.
- Wells, M., S. Guggenheim, A. Khan, W. Wardoyo, and P. Jepson. 1999. *Investing in biodiversity: a review of Indonesia's integrated conservation and development projects*. The World Bank, Washington DC.
- Wikipedia 2009. *The free encyclopedia*. URL [[http://en.wikipedia.org/wiki/System\\_dynamics](http://en.wikipedia.org/wiki/System_dynamics)] visited December 2009
- Wilshusen, P. R., S. R. Brechin, C. L. Fortwangler, and P. C. West. 2002. Reinventing a square wheel: critique of a resurgent "protection paradigm" in international biodiversity conservation. *Society and Natural Resources* **15**:17-40.
- Wunder, S. 2005. *Payments for environmental services: Some nuts and bolts*. Occasional Paper 42. Center for International Forestry Research, Bogor, Indonesia.
- Wunder, S., B. Campbell, P. G. H. Frost, J. A. Sayer, R. Iwan, and L. Wollenberg. 2008. When Donors Get Cold Feet: the Community Conservation Concession in Setulang (Kalimantan, Indonesia) that Never Happened. *Ecology and Society* **13**:12.

## Chapter 2

### Science for action: The use of scoping models in conservation and development

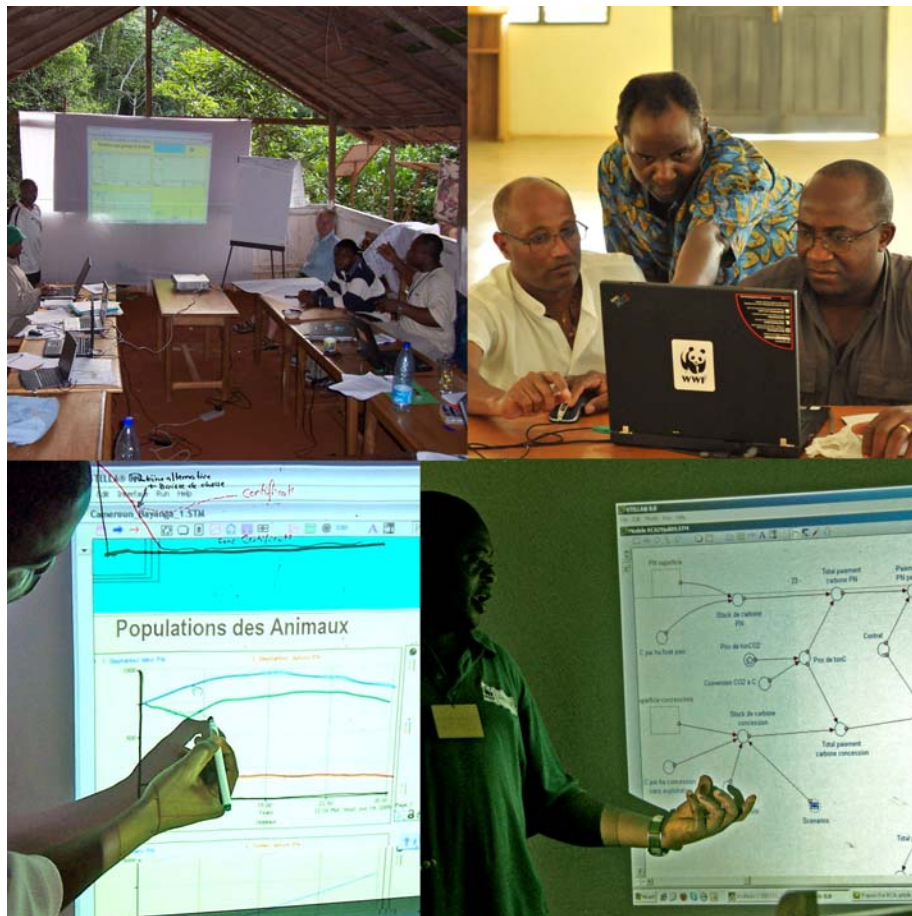


Photo right upper corner: Courtesy of Neil Collier



# Science for action: The use of scoping models in conservation and development

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## ABSTRACT

Addressing the all too familiar conflict between biodiversity conservation and enhanced human well-being is a complex exercise that attempts to fuse social, economic, cultural and biophysical perspectives. In most instances, a balance between conservation and development is sought whereby biodiversity is conserved and people's livelihoods improve. However, most attempts fail because they don't address system complexity, assume "win-win" situations, fail to plan for the impacts of society-wide changes happening beyond the project landscapes, and use top-down approaches. In this paper we explore the use of participatory system dynamics modelling to implement a 'landscape approach'. We advocate the use of 'scoping models' because of their ability to incorporate complexity and promote social-learning in a participatory environment, whilst increasing the capacity of local actors to manage complex social-ecological systems. We demonstrate their positive role in facilitating change in three landscapes in the tropics, particularly for policy making.

**Keywords:** participatory modelling, social-ecological systems, livelihoods, tropical forests, landscape.

## INTRODUCTION

Over the last few decades, conservation and development agencies have adopted an approach which seeks to integrate the aims of biodiversity conservation while enhancing human well-being through economic development – so called integrated conservation and development projects (ICDPs) (Alpert 1996; Wells 2004; Wells & McShane 2004). This approach has become more popular as agencies and governments recognise that poverty and biodiversity conservation are highly interrelated in conservation landscapes and so need to be addressed simultaneously. Rarely however, has

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this approach been successfully demonstrated to achieve the implied parallel aims of biodiversity conservation and improved livelihoods (Kremen *et al.* 1994; Wells *et al.* 1999). Key issues reported to attribute to the failings of ICDPs are (1) using a 'top-down' approach during conceptualisation and implementation (Chapin 2004), (2) failing to recognise that trade-offs occur between conservation and development (Barrett & Arcess 1995; Young *et al.* 2006), (3) failing to understand complex social-ecological systems behaviour (Sayer & Campbell 2004; Sayer *et al.* 2007) and (4) ignoring society-wide changes occurring beyond the borders of the landscape of interest (e.g. fluctuating global markets, new infrastructure projects) (McShane & Wells 2004). In addition, sets of measurable indicators of system performance are rarely employed by ICDPs to assess their functionality (Sayer *et al.* 2007).

The term ICDP has given way to the term 'landscape approach', the latter responding to the key issues identified to have attributed to ICDPs failings as reported above. That is, the landscape approach emphasises combining top-down planning with bottom-up approaches, identifying trade-offs, making stakeholders look beyond their discipline at the system's functioning and recognising society-wide trends as drivers of landscape change (Sayer 2007).

So the question that remains is 'how to implement a landscape approach?' Social-ecological systems are highly complex, with many feedback loops created by the interactions that occur between the social and biophysical spheres (Ostrom & Nagendra 2006; Liu *et al.* 2007). Increasing the level of understanding of complex systems often involves creating models that attempt to describe the behaviour of variables in response to one, or many factors (Low *et al.* 1999). Though highly complex models can produce interesting outcomes, Greenberger *et al.* (1976) concludes most of the insights are gained during the model building process, rather than after. We therefore propose participatory modelling, i.e. building a system dynamics model of the landscape with conservation and development actors, to contribute to the implementation of a landscape approach. Such participatory models have been characterised as 'throw-away models' (Sayer & Campbell 2004) or 'scoping models' (Van den Belt 2004). Though these models are rarely thrown away, the first term seeks to emphasize that the model in itself is not the goal; the objective is social learning through stakeholder interaction which takes place during the model building process. The second term, 'scoping models', refers to the roughness of the simulation outputs. First of all, this roughness is due to the models drawing on expert knowledge and estimates in case data is lacking (and data is always incomplete in these types of landscapes). Second, to be built and understood by a non-model expert public, the models need to compromise on complexity to gain on continuous stakeholder input and validation. The models thus include only those variables and relations which are thought crucial to outcomes, which is why the model is scoping or exploring rather than predicting the future. Precise predictions are practically impossible in social-ecological systems (Peterson *et al.* 2003), but we can gain understanding of major trends and driving factors of change in the landscape. Exploring plausible scenarios can

improve communication between different stakeholders and the model can be used to test the effectiveness of different policies or interventions. The simulations can help to understand how conservation and development outcomes influence each other, quantify trade-offs occurring and give insight on how external factors influence the landscape ([chapter 8](#)). We thus advocate the use of scoping models to contribute to taking a landscape approach because of their ability to incorporate complexity and promote social learning, whilst increasing the capacity of local players to plan for and manage complex social-ecological systems.

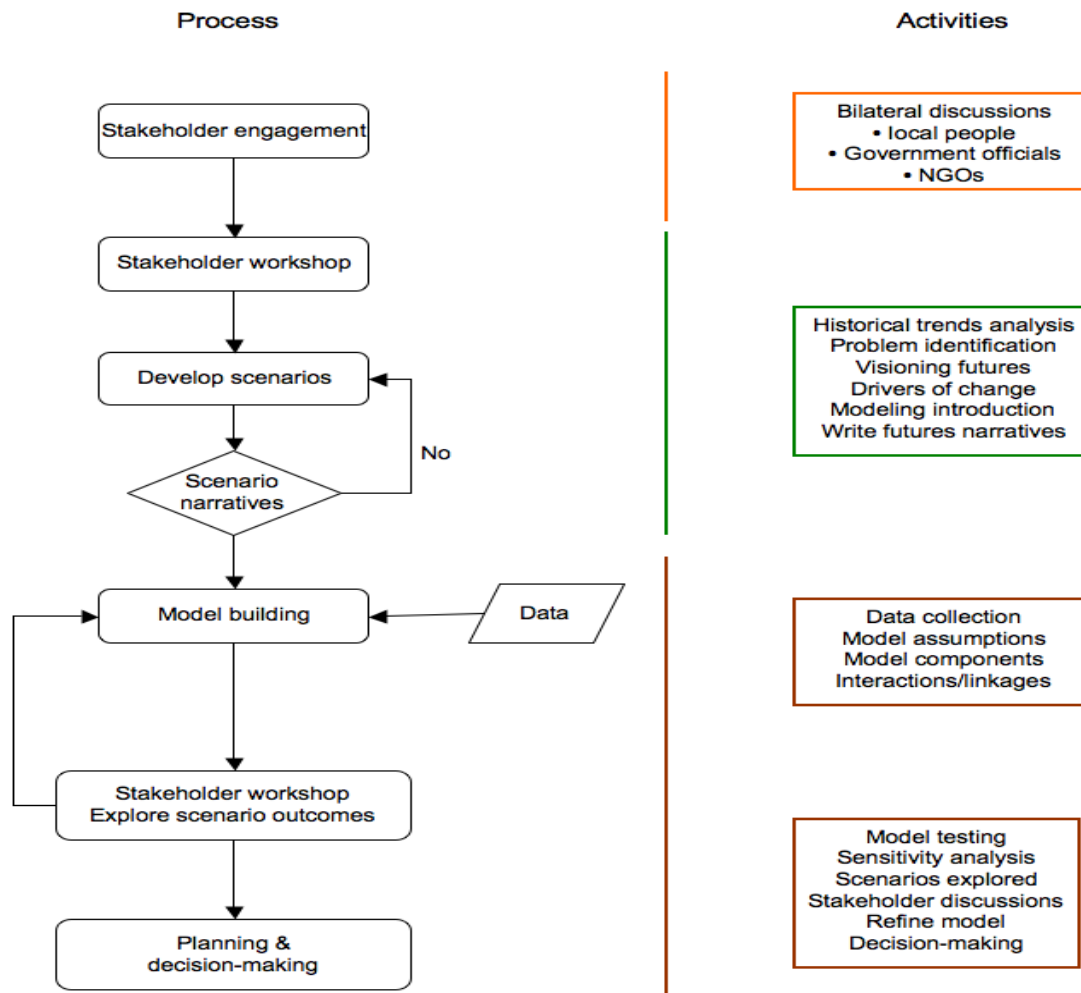
In this paper, we describe the participatory process of developing scoping models to understand complex social-ecological systems, and how to use them for planning and managing landscapes, particularly in the tropical regions of the world where there is rapid change (Kassa *et al.* 2009). We demonstrate their role in promoting social learning, which includes increasing understanding of social-ecological systems by stakeholders, and in facilitating change in three landscapes in the tropics. We also discuss potential problems and pitfalls of the approach, again referring to the case studies as illustration.

### **Scoping models and social-ecological systems**

Our definition of a scoping model encompasses quantitative system dynamics models of social-ecological systems that are conceptualised through stakeholder participation (i.e. participatory modelling) and built using easily understood computer software. All case studies used Stella (HPS 1996) as model building platform.

#### *Scoping models as platform for debate*

In social settings, where there is a cost or benefit associated with a particular set of scenarios, human emotions can have a significant influence on an individual's decision about the allocation of shared resources (Sanfey 2003; Xio & Houser 2005; Koenigs & Tranel 2007). This is particularly evident when there is a real or perceived unfairness or inequity in the outcomes. A strong attribute of scoping models is their ability to expose the range of likely outcomes associated with different scenarios and to reduce the ability of some actors to advocate a position that is unfair or that disadvantages others. In other words, building scoping models, using a participatory approach, may provide a more balanced forum in which to debate the merits of future courses of action and negotiate desired outcomes for all (Van den Belt 2004; Cockerill *et al.* 2006). At the same time, the model gives a range of expected impacts, making one realize at some times win-win solutions are extremely rare (e.g. [chapter 6](#)), changing the focus of negotiations towards winning more and losing less.

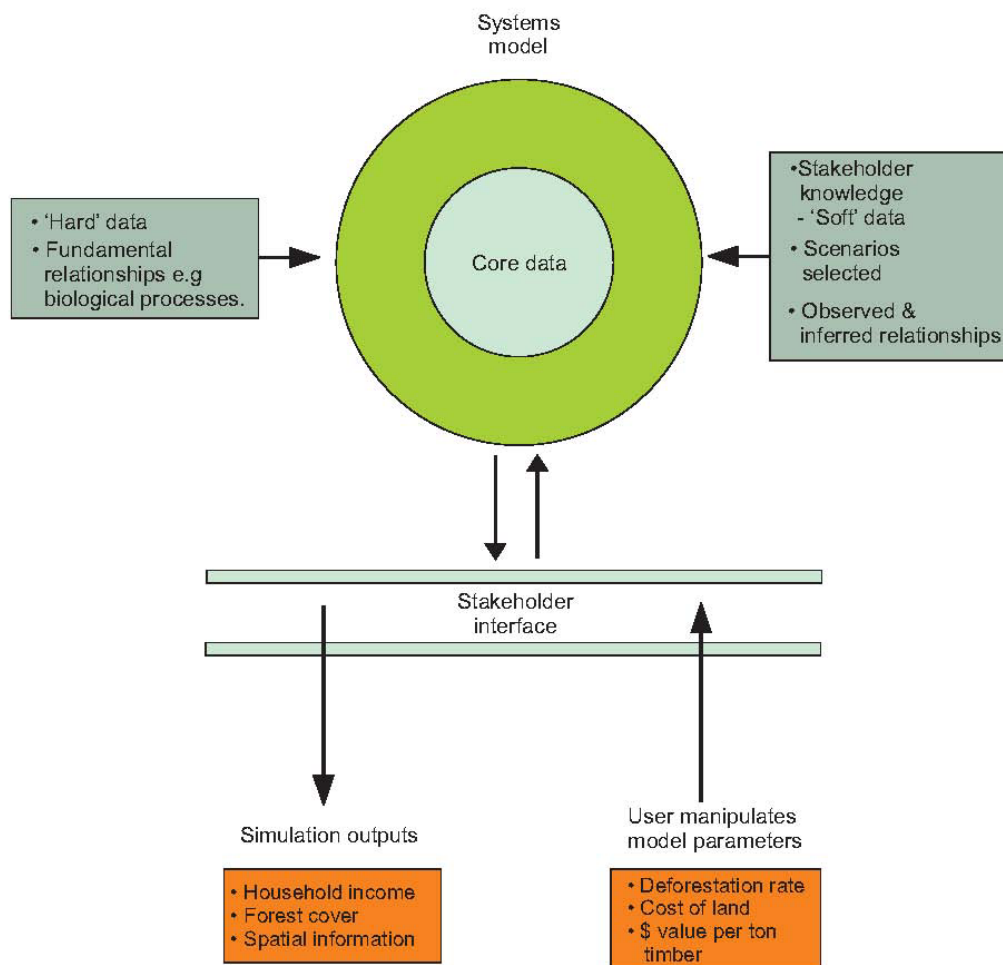


**Figure 1.** Process diagram for using participatory systems modeling in landscape approaches.

### *Scoping models influencing policy making*

Scoping models can meld outputs from more complex models (e.g. population dynamics, hydrologic models, sediment transport) into one easily manipulated model with which stakeholders can interact. Complex predictive models can be highly informative for many purposes – for example they have provided insights into the setting of priorities for conservation of plant and animal species, conservation spending and protected areas management (Mills *et al.* 1999; McMahon & Burton 2005; Bradshaw *et al.* 2007). However, they are not driven by participatory processes and generally do not allow easy stakeholder interaction with them: in some cases they may have user-friendly interfaces but the model generally remains a black box to stakeholders. At many scales (local, regional, and national), the delivery and uptake of recommendations stemming from such complex models can be

stifled because of their complexity since policy makers are likely to distrust a model they don't understand (SME 2010).

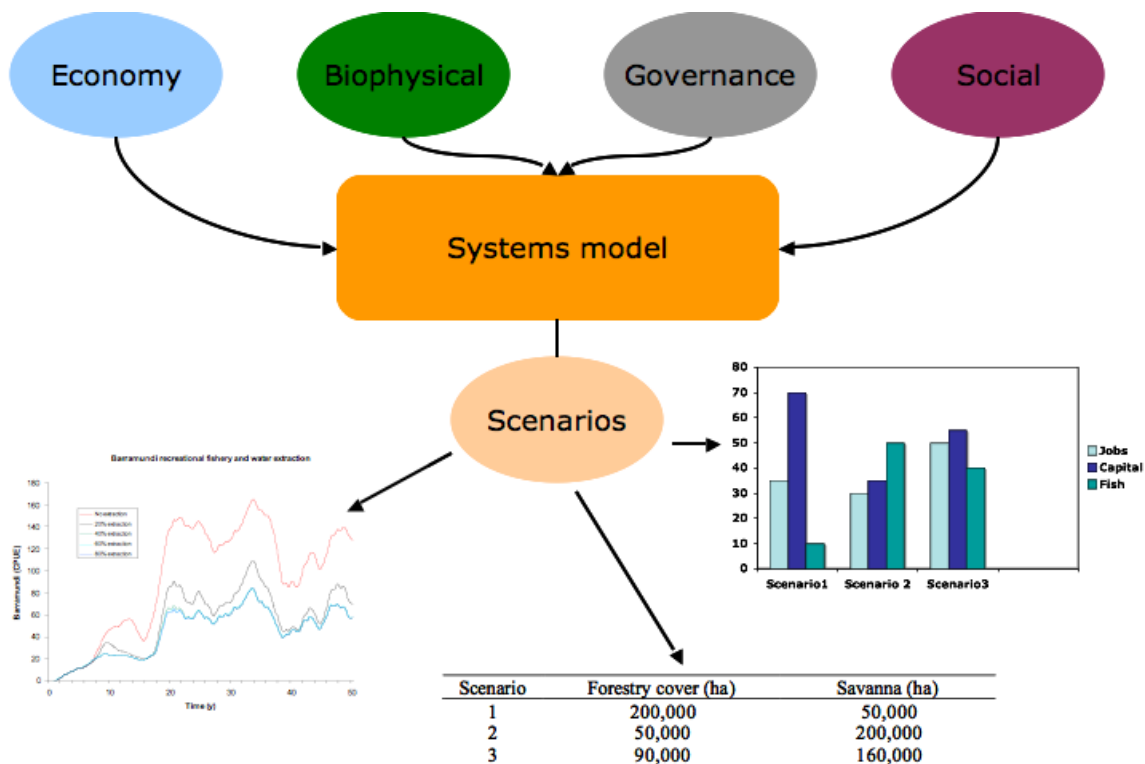


**Figure 2.** Conceptual diagram of a systems model built using scientific data and stakeholder knowledge.

### *The process of building a scoping model*

Building scoping models in conservation and development contexts is carried out at the landscape level and involves local players throughout the process. The process is carried out in many steps divided in three stages (Fig. 1). The process begins with stakeholder engagement: attracting the critical local people, organizations, government officials and experts that can help with model building and are likely to be the actors with key information and making decisions. The second stage involves the collective identification of problems the landscape faces, which local interventions often are aiming to overcome. In this phase, we apply historical trends analyses and visioning techniques used in social science research (Sayer *et al.* 2007). Understanding past trends helps to understand system behaviour and identify drivers of

change. This is succeeded with the joint definition of visions of system futures, i.e. scenarios, and finishes with creating futures narratives. The third stage focuses on modelling: building, testing, and refining the model. An initial model is built in this stage, involving high level participation from the stakeholders to establish a qualitative system design. The purpose of this process is to establish the key relationships and interactions within the system and in doing so help to clarify the nature of the issue(s) of concern for the local players, scientists and practitioners. Expert opinion is used where information is insufficient (Fig. 1 & 2). Data availability from disparate research disciplines is scoped and fed into the model transferring from a qualitative to a quantitative model. Best bets in terms of assumptions, initial parameter settings, and frameworks can be identified and discussed. The scenarios defined earlier are now explored using the model which allows us to understand conservation and development trade-offs occurring under the different scenarios, and to test the scope of impact of specific interventions or policies. A quantitative assessment of the various scenarios envisaged by the stakeholders can be performed and critically discussed (Fig. 3). This is by no means the end of the process – the modelling is iterative and dynamic and the model can be refined through discussions and consensus among stakeholders. Ideally, lessons learned from modelling are then used in landscape planning and decision making.



**Figure 3.** Schematic representation of the visualization of different scenarios explored with the model.

### *Prerequisites for building a scoping model*

Excellent facilitation is required to translate the system complexity into a simplified framework, and to narrow down to one or a few fundamental problems that become the focus of the modelling. The model should not aim at being all-inclusive but be designed to capture key processes of interest within the system. Using participatory modelling with a group of stakeholders may require 5-20 days of model building but this figure would depend largely on the availability of data and the time stakeholders can invest. The model sectors, major relations in the model and indicators of outcomes of interest are defined with the group, after which often some technical 'fixing' of parts of the model may be done by the modelling expert in absence of the participants. Following this, changes are communicated to participants and they continue to alter the model. The outcomes of a 5-20 day model building session include (1) clarification and a common understanding of the problems in the system, (2) exchange between stakeholders with different objectives and points of view (3) comprehension of relationships between the systems variables (4) increased understanding of trends and their underlying causes and (5) increased understanding of the system by stakeholders and (6) awareness of their capacities to intervene in the system.

### **Modelling in practice**

#### *Indonesian forests and oil palm*

The oil palm industry is a major driver of deforestation in Indonesia. It is not uncommon that companies acquire permits to clear land for oil palm production but instead cut the forest for timber without actually planting any oil palm (Wakker 2006). At the same time, the oil palm industry has contributed to economic growth and poverty alleviation (Susila 2004) although there are also people whose living conditions have worsened due to oil palm development. In Malinau district, government officials were discussing the possibility of 0.5-1 million ha of oil palm along the border with Malaysia to bring employment to the district and increase local revenues. At the same time, they declared that conserving forests is a priority of the district because of the heavy dependence by local people on forests for maintaining their livelihoods.

In a recent exploration of this conflicting and highly emotive dilemma, Sandker *et al.* ([chapter 5](#)) built scoping models with district officials to explore the two main issues in dispute: the development of the Indonesian economy and the conservation of primary forest ecosystems. The simulation outcomes were discussed with the head of district. The simulations of larger scale oil palm development demonstrated that significant improvements in household income could be attained by some; that others were likely to be negatively impacted; while a significant forest area would remain in the district. Such large-scale oil palm development would drive significant immigration that could change the entire socio-political make-up in the

district. The discussion the modelling generated and the output of the modelling stimulated constructive thinking and debate. In particular, district officials were extremely nervous about potentially high immigration rates and discussed alternatives to oil palm development such as payments for environmental services related to carbon. At the same time, it became clear that ecotourism, which was presented as a prime activity to integrate conservation and development outcomes, was unlikely to do much for the local economy and as such wouldn't satisfy development aspirations the way oil palm investments could. The potential benefits of carbon payments were much larger. The modelling raised the district head's interest in carbon payments and he has now accepted an offer from international donors to preserve forest carbon instead of clearing forest for timber and oil palm plantations.

### *Governance and anti-poaching in the Congo Basin*

African tropical forests are centres of high biodiversity with megafauna such as elephants (*Loxodonta cyclotis*: Matschie) and lowland gorillas (*Gorilla gorilla gorilla*: Matschie). They also support vast numbers of indigenous people that rely on natural resources to sustain their livelihoods. A tropical forest landscape in South East Cameroon forms an example of this situation.

In a case study that addressed the dual conservation and development goals described above, Sandker *et al.* ([chapter 6](#)) built a scoping model of this landscape with personnel of a conservation organization, development agencies, government officials and donors, to examine how conservation and livelihoods interact. The widespread views and beliefs of conservation stakeholders were that poaching of animals was the most pressing factor for conservation and as such conservation non-governmental organisations (NGOs) allocated a considerable budget to anti-poaching programmes with the assumption that these measures would provide best conservation outcomes. The study examined three scenarios that explored changes to ICDP budget allocations: (1) spend 85% of the entire budget on anti-poaching (as occurs currently), (2) re-allocate 20% of the budget from anti-poaching to improving governance of natural resource taxes to be used for local development, and (3) re-allocate 20% of the budget from anti-poaching to direct investment in local development. The simulations revealed that continued investment in anti-poaching measures would likely have good conservation outcomes contingent upon continued funding levels, if funding is reduced then conservation benefits are eroded quickly. Yet there would be very little local development under this scenario. Alternatively, governance reform at the district level (reduced corruption of forest concession taxes) would likely have almost as good conservation outcomes on the long term (i.e. reduced poaching) and may also improve livelihoods through increased household income. Direct investment in local development by the conservation NGO at the cost of anti-poaching gave poor outcomes for conservation, and hardly any improvement of local development. The modelling process initiated in this landscape stimulated much debate among

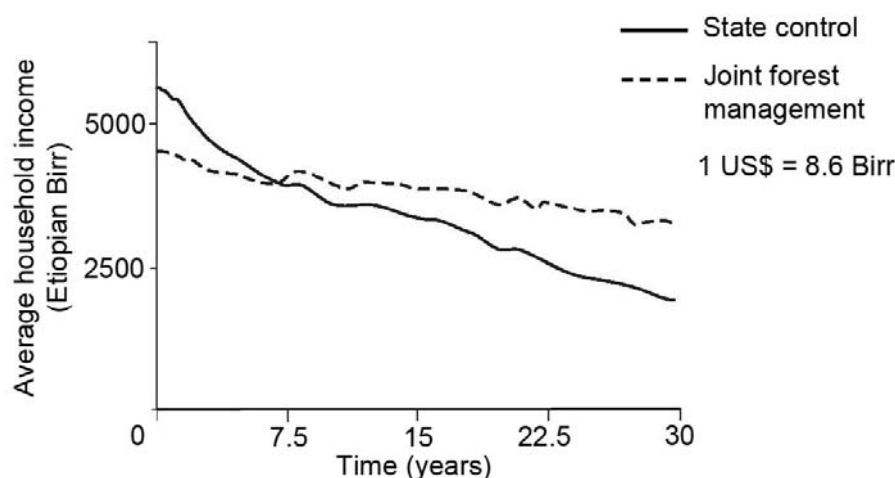


the local and national actors (parliamentarians, donors, NGOs) on the obstructions imposed by poor governance. Subsequently, the mayor siphoning off tax-money destined for local development lost the election to an opposition candidate that was advocating better governance as his election platform. The modelling stimulated local officials and NGO project managers to consider whether the project really integrated conservation and development or was mainly about conservation outcomes. Furthermore, it brought to question the sustainability of current interventions.

### *Community forest management in Ethiopia*

The Chilimo forest is a dry Afromontane forest located in the central plateau of Ethiopia approximately 100 km from the capital, Addis Ababa. In 1991, state control over the forest was weakened and there was significant deforestation in the subsequent period: the forest once covered approximately 22,000 ha but has now been reduced to approximately 6,000 ha. Approximately 3,000 households are present within, and immediately surrounding, the borders of the forest many of which rely on the forest to maintain their livelihood.

Scoping models were built to explore the trade-offs between biodiversity conservation and improvement of local livelihoods (Kassa *et al.* 2009). The model was built with a group of researchers and simulation outcomes were discussed with policy makers at central government level. One scenario that was explored in the modelling process was that of joint management of Chilimo forest by the local Ethiopian authorities and the community. In this scenario the local community would be active in decision-making and other on-ground management tasks related to the forest. This scenario was modelled against the 'business as usual' scenario where forest management was retained by the authorities. The modelling showed that on the long term, household income levels were higher under the joint management regime compared to the *status quo* (Fig. 4). Although total household income decreases over time under both management structures, after approximately seven years, participatory forest management results in higher household incomes for the remainder of the projection. The simulation demonstrated to the stakeholders that the pay-off from participatory forest management is likely to take some time to eventuate. The legitimacy of some simulation outcomes was questioned; farmers disputed income from joint forest management to be lower on the short term. Discussing this further lead to the insight that many of those short term benefits modelled were likely captured by some elites, so most of the households would not capture the benefits simulated under state control (Fig 4). The modelling process and the simulations generated were used to engage government officials and other stakeholders in the management issues of the forest and to stimulate policy and legislation changes to improve the governance and management of state forests. This resulted in the approval of a law facilitating joint forest management (Kassa *et al.* 2009).



**Figure 4.** A thirty year projection produced by the scoping model featuring estimated average household income (cash + subsistence) for local people who use Chilimo forest, Ethiopia

## DISCUSSION

### *Precipitating change*

By influencing the decision making process scoping models can result in impact. In Malinau carbon payment agreements have been signed. Such measures will also produce significant biodiversity conservation outcomes for the region (Strassburg *et al.* 2010). In Cameroon, the corrupt mayor ended in jail leaving the promise of improved governance with royalties being invested in development of the region. In Chilimo, the modelling precipitated change in the national legislation that resulted in greater community control over the forest (Kassa *et al.* 2009). These impacts appear to be largely due to the stakeholder group involved in the model building process, consisting of people with close connections to policy makers and thus creating an effective mechanism for change ([chapter 9](#)).

The results furthermore show that building scoping models can influence established mindsets. In the Cameroon landscape, investment in anti-poaching was perceived initially to be the best method of large mammal conservation. This was re-examined from the perspective of broader governance structures and alternative scenarios that brought better outcomes for people and nature. The ICDP personnel realized their interventions were largely biased on conservation, and they were doing little for development. They also realised anti-poaching was largely a holding operation. Corruption was identified as a major constraint in achieving both conservation and development. The severe corruption in Cameroon at most levels of society (Accessed March 2010 <http://www.transparency.org/>) present substantial barriers to conservation and development outcomes for

the landscape. Scoping models in this situation stress the importance of improved governance, which can be advocated by civil society organisations, international donors and conservation and development agencies (Sayer 2009). In Ethiopia, the modelling made farmers realise that income per household would considerably decline unless they start to strategically plan for the future and identify other income generating opportunities. These examples demonstrate the utility of scoping models to promote social learning; increase local understanding of the political and natural landscape; provide a forum for debate; and change perceptions.

We cannot claim that the successes documented here are due entirely to the participatory modelling process – it undoubtedly stems from a synergy between participatory processes per se *and* the construction of an interactive computer model. Building participatory scoping models is an engaging method that can conceptualize, and visualise social-ecological systems. Scoping models have a specific role to play in a much longer process of adaptive management of landscapes undergoing transformation (Holling 2001; Sayer *et al.* 2008).

#### *Stakeholder involvement*

An increasing level of importance is being placed on stakeholder involvement in natural resource management (Pound *et al.* 2003). The selection of which stakeholders to include in participatory modelling is highly context specific. An ideal modelling process would somehow incorporate all views. However, there are practical limitations to the number of stakeholders involved in the model building. Stakeholder representation and participation is cited as one of the most important, but not easily resolved, problems of participatory modelling approaches in natural resource management (Hare *et al.* 2003). In building scoping models, like with most participatory processes, we must find the ideal number of stakeholders with the right skills, opinions, views and ability to influence in order to capture the context of landscape and produce a model with utility. As stated earlier, for the model to achieve impact it is critical that the stakeholders who are engaged in participatory processes are, or can influence agents of change in the landscape. Furthermore, to inform the decision making process we need people with crucial knowledge and visions.

In Cameroon, local communities and especially Baka pygmies are often illiterate. It would be inappropriate to confront them with models and simulation graphs, rather other approaches can be used to include their vision on the future like rich pictures and participatory mapping (Sayer *et al.* 2007). In the Malinau district, extreme power inequalities exist (Boedhihartono *et al.* 2007). Decision-making on natural resource management and development issues is almost entirely under the control of government. As a consequence, the modelling was conducted with a small range of stakeholders, limited to experts and government officials. Like with

most participatory processes, some stakeholders will be excluded from the modelling, by accident or purposefully.

### *Weaknesses of scoping models*

Scoping models, like all models and participatory processes, have weaknesses that must be highlighted. Despite the user-friendliness of the system dynamics software Stella used in the examined cases, complexity is still identified by the participants as the largest impediment in building scoping models ([chapter 9](#)). The case studies also illustrate that building scoping models excludes some stakeholders and is mainly a tool for stakeholders with decision making power. Certain features or details are not captured with the scoping models; the Malinau modelling for example has been criticised for not including soft variables like conflict (Dudley *et al.* 2007). We believe that this is not a shortcoming of scoping models but of models in general, since a similar criticism holds for numerical or predictive models (Brook *et al.* 2002; Caswell 2001). The Ethiopian farmers raised the hidden detail of benefits captured by elites and such income differentiation not being captured by the projection of average household income. Thus the Chilimo model outcomes could be improved, but the insight is already gained through the discussion the modelling generated. We suggest a different forum, supplementary to the modelling, to discuss issues like the probability of arising conflicts, to include visions of stakeholders excluded from the modelling and to capture a higher level of detail. Modelling should be seen as one tool in a larger toolbox of approaches to contribute to landscape planning and decision making.

### *Overall reflexion*

In this paper we have: advocated for the use of scoping models in conservation and development landscapes; explored their workings and utility in modelling complex social-ecological systems; presented three diverse cases studies to illustrate the approach.

As with all participatory processes the number of participants is limited for various reasons such as complexity, logistics and the purpose of the modelling. Facilitation is crucial to overcome problems with complexity, while selecting stakeholders connected to the decision making process is crucial for the modelling to result in impact.

The three case studies show that trade-offs occur between conservation and development outcomes which were visualized with the scoping models and discussed with the stakeholders. In all three of the case studies building scoping models with local stakeholders influenced decision making in some form either at the landscape level (e.g. Malinau district signing for carbon payments) or beyond (e.g. the incorporation of joint forest management in a new law decree in Ethiopia). Scoping models can make a strong contribution to the formulation of scenarios for landscapes, be it navigating the trade-offs

in conservation and development or testing the effectiveness of different management approaches. Significant changes in stakeholder understanding and perceptions of the social-ecological systems were achieved in the three case studies, and as such building scoping models contributed to the implementation of a landscape approach. These types of changes are needed if we are to achieve landscape management that embraces a form of sustainable development that improves peoples' lives while remaining focussed on biodiversity conservation.

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## REFERENCES

- Alpert, P. 1996. Integrated Conservation and Development Projects. *BioScience* **46**:845-855.
- Barrett, C.B. and P. Arcese 1995. Are Integrated Conservation-Development Projects (ICDPs) Sustainable? On the conservation of large mammals in sub-Saharan Africa. *World Development* **23**:1073-1084.
- Boedhihartono, A. K., P. Gunarso, P. Levang, and J. Sayer. 2007. The principles of conservation and development: do they apply in Malinau? *Ecology and Society* **12**:2 URL [<http://www.ecologyandsociety.org/vol12/iss2/art2/>]
- Bradshaw, C.J.A., H.F. Mollet and M.G. Meekan. 2007. Inferring population trends for the world's largest fish from mark-recapture estimates of survival. *Journal of Animal Ecology* **76**:480-489.
- Brook, B.W., M.A. Burgman, H.R. Akcakaya, J.J. O'Grady and R. Frankham. 2002. Critiques of PVA ask the wrong questions: throwing the heuristic baby out with the numerical bathwater. *Conservation Biology* **16**(1): 262-263.
- Caswell, H. 2001. *Matrix population models: construction, analysis, and interpretation*. Second edn. Sinauer Associates, Inc. Publishers, Sunderland, Massachusetts.
- Chapin, M. 2004. *A Challenge to Conservationists*. Pages 17-31. World Watch. Worldwatch Institute.
- Cockerill, K., H. Passell, and V. Tidwell. 2006. Cooperative Modeling: Building Bridges between Science and the Public. *Journal of the American Water Resources Association* **42**:457-471.
- Dudley, R. G., D. Sheil, and C. Colfer. 2008. Simulating Oil Palm Expansion Requires Credible Approaches that Address Real Issues. *Ecology and Society* **13**:r1. URL [<http://www.ecologyandsociety.org/vol13/iss1/resp1/>]
- Greenberger, M., M. A. Crenson, and B. L. Crissey 1976. *Models in the Policy Process: Public Decision Making in the Computer Era*. Russel Sage Foundation, New York, USA.
- Hare, M., R.A. Letcher and A.J. Jakeman. 2003. Participatory modelling in natural resource management: A comparison of four case studies. *Integrated Assessment* **4**(2):62-72.
- Holling, C. 2001. Understanding the complexity of economic, ecological, and social systems. *Ecosystems* **4**:390-405.
- HPS (High Performance Systems) 1996. *Stella and Stella research software*. HPS, Hanover
- Kassa, H., B.M. Campbell, M. Sandewall, M. Kebede, Y. Tesfaye, G. Dessie, A. Seifu, M. Tadesse, E. Garedew, K. Sandewall. 2009. Building future scenarios and uncovering persisting challenges of participatory forest management in Chilimo Forest, central Ethiopia. *Journal of Environmental Management* **90**:1004-1013.
- Koenigs, M., and D. Tranel. 2007. Irrational economic decision-making after ventral prefrontal damage: Evidence from the ultimatum game. *Journal of Neuroscience* **27**:951- 956.

- Kremen, C., A.M. Merenlender and D.D. Murphy. 1994. Ecological monitoring: a vital need for integrated conservation and development programs in the tropics. *Conservation Biology* **8**:388-397.
- Liu, J., T. Dietz, S.R. Carpenter, M. Alberti, C. Folke, E. Moran, A.N. Pell, P. Deadman, T. Kratz, J. Lubchenco, E. Ostrom, Z. Ouyang, W. Provencher, C.L. Redman, S.H. Schneider and W. Taylor. 2007. Complexity of coupled human and natural systems. *Science* **31**:1513-1516.
- Low, B., R. Costanza, E. Ostrom, J. Wilson and C.P. Simon. 1999. Human-ecosystem interactions: a dynamic integrated model. *Ecological Economics* **31**:227-242.
- McMahon, C.R. and H.R. Burton. 2005. Climate change and seal survival: evidence for environmentally mediated changes in elephant seal, *Mirounga leonina*, pup survival. Proceedings of the Royal Society of London B – *Biological Science* **272**:923-928.
- McShane T. and Wells M. (eds) 2004. *Getting biodiversity projects to work: towards more effective conservation and development*. Columbia University Press, New York, USA.
- Mills, L.S., D.F. Doak and M.J. Wisdom. 1999. Reliability of conservation actions based on elasticity analysis of matrix models. *Conservation Biology* **13**:815-829.
- Ostrom, E. and H. Nagendra. 2006. *Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory*. Proceedings of the National Academy of Sciences USA **103**, 19224-19231.
- Peterson, G.D., G.S. Cumming, and S.R. Carpenter. 2003. Scenario Planning: a Tool for Conservation in an Uncertain World. *Conservation Biology* **17**:358-366.
- Pound, B., S. Snapp, C. McDougall and A. Braun (eds.) 2003. *Managing Natural Resources for Sustainable Livelihoods: Uniting Science and Participation*. Earthscan Publications Ltd, London, UK.
- Sanfey, A.G. 2003. Social decision-making: Insights from game theory and neuroscience. *Science* **318**:598-602.
- Sayer, J. 2007. *The People's Forest. Balancing local and global values*. Autonomous University of Madrid (UAM), Madrid, Spain.
- Sayer, J. and B.M. Campbell. 2004. *The science of sustainable development: local livelihoods and the global environment*. Cambridge University Press, Cambridge.
- Sayer, J., B.M. Campbell, L. Petheram, M. Aldrich, M. Ruiz-Perez, D. Endamana, Z.-L. Nzooh-Dongmo, L. Defo, S. Mariki, N. Daggart and N. Burgess. 2007. Assessing environment and development outcomes in conservation landscapes. *Biodiversity and Conservation* **16**:2677-2694.
- Sayer, J., G. Bull and C. Elliott. 2008. Mediating forest transitions: 'Grand design' or 'Muddling through'. *Conservation and Society* **6**(4):320-327.
- SME 2010. *Spatial Modelling Environment Overview*. URL [<http://www.uvm.edu/giee/SME3/SME3F.html>] visited January 2010
- Strassburg, B.B.N., A. Kelly, A. Balmford, R.G. Davies, H.K. Gibbs, A. Lovett, L. Miles, C. David L. Orme, J. Price, R.K. Turner and A.S.L. Rodrigues

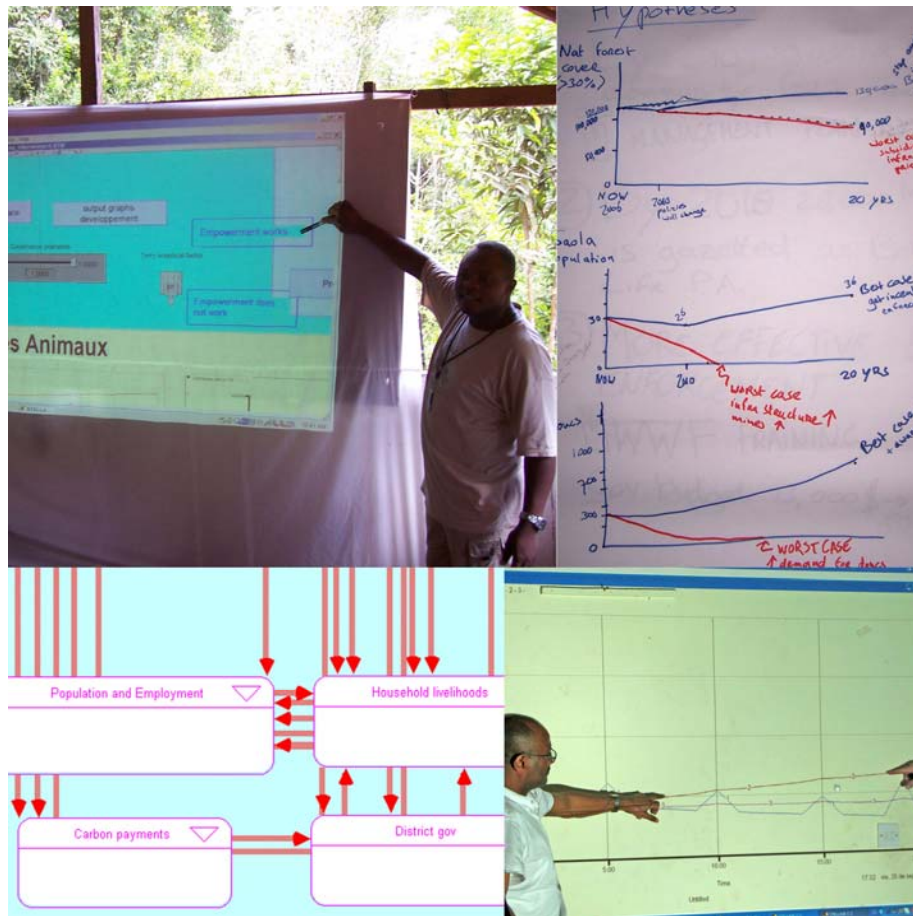
2010. Global congruence of carbon storage and biodiversity in terrestrial ecosystems. *Conservation Letters* **3**(2):98-105.
- Susila, W. R. 2004. Contribution of oil palm industry to economic growth and poverty alleviation in Indonesia. *Jurnal Litbang Pertanian* **23**:107-114.
- Timmermann, A., J. Oberhuber, A. Bacher, M. Esch, M. Latif and E. Roeckner. 1999. Increased El Niño frequency in a climate model forced by future greenhouse warming. *Science* **398**:694-697.
- Van den Belt, M. 2004. *Mediated modeling. A system dynamics approach to environmental consensus building*, Washington, DC.
- Wakker, E. 2006 The Kalimantan border oil palm mega-project. Aidenvironment. Commissioned by Friends of the Earth Netherlands and the Swedish Society for Nature Conservation. [online] URL: [http://www.orangutans-sos.org/downloads/palm\\_oil\\_mega\\_project.pdf](http://www.orangutans-sos.org/downloads/palm_oil_mega_project.pdf).
- Wunder, S., B. Campbell, R. Iwan, Wells, M., S. Guggenheim, A. Khan, W. Wardoyo, and P. Jepson. 1999. *Investing in biodiversity: a review of Indonesia's integrated conservation and development projects*. The World Bank, Washington DC.
- Wells, M. 2004. *The future of integrated conservation and development projects: Building on what works*. In: Getting Biodiversity Projects to Work: Towards More Effective Conservation and Development (eds. McShane T & Wells M). Columbia University Press, New York.
- Wells, M. and T. McShane. 2004. Integrating protected area management with local needs and aspirations. *Ambio* **33**:513-519.
- Xiao, E. and D. Houser. 2005. *Emotion expression in human punishment behavior*. Proceedings of the National Academy of Sciences USA 102, 7398-7401
- Young, O.R., F. Berkhout, G.C. Gallopin, M.A. Janssen, E. Ostrom, S. van der Leeuw. 2006. The globalization of socio-ecological systems: An agenda for scientific research. *Global Environmental Change* **16**:304-316





## Chapter 3

### What are participatory scoping models?



Response to Dudley *et al.* 2008. “Simulating Oil Palm Expansion Requires Credible Approaches that Address Real Issues”

## What Are Participatory Scoping Models?

[\*Marieke Sandker\*](#)<sup>1</sup>, [\*Bruce Campbell\*](#)<sup>1</sup>, and [\*Aritta Suwarno\*](#)<sup>1</sup>

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### THE ELEMENTS OF A PARTICIPATORY SCOPING MODEL

At the heart of our disagreement with Dudley *et al.* (2008) is what constitutes participatory modeling. For us, participatory modeling can be defined by a number of elements, including types of stakeholders engaged, and degree of engagement with those stakeholders. Another element of disagreement probably centers on the continuum from models as predictive tools to model as tools to explore scenarios. Part of the disagreement is tied up in different approaches to “soft” variables.

### TYPES OF STAKEHOLDERS ENGAGED

Dudley *et al.* (2008) raise questions as to exactly what stakeholders were involved in developing the model and how their needs and concerns have been incorporated. Sandker *et al.* (2007) are very clear that the participatory modeling was conducted with officials from different government agencies. Although in an ideal situation it would be appropriate to work with many other stakeholder groups as well, in Malinau this was not the aim. Earlier work by Edmunds and Wollenberg (2001) and later descriptions of activities in Malinau (Wollenberg *et al.* 2007) indicate the difficulty of multi-stakeholder platforms, and indeed warn against such platforms in situations in which power inequalities are extreme, as in Malinau. There is the additional problem that simulation models can be extremely complex and are perhaps not most suited for engagement with communities in which even computers are rare (Neil Collier, *personal communication*, for work in aboriginal communities); though the innovative work on combining role plays and models is illustrative, e.g., Lynam *et al.* (2002). For these reasons, we opted to work with

government officials, some of whom were advocating for oil palm and other investments. The model was built with them as well as with experts who gave inputs into the different domains covered by the model. We hoped that by exploring the pros and cons with the officials, better decision making would take place.

### DEGREE OF ENGAGEMENT

The meaning of participation can range from almost complete outside control with token involvement of the local people, to a form of collective action in which local people set and implement their own agenda in the absence of outside initiators and facilitators (Carter 1996, Nemarundwe and Richards 2002). The range of steps is: passive participation, cooperation, consultation, collaboration, and collective action. The ideal in many circumstances is collective action. We wanted to go as far as possible to that ideal.

It is apparently quite common to talk of participatory modeling but then to build models so complex that they are black boxes to participants and take so long to produce that the interest of some participants and stakeholders have long waned. For example, van Ittersum *et al.* (2008) also talk about participatory modeling but in the context of exceptionally detailed models, which can only be built by outside experts. Such models have their place, but we prefer the use of rapidly built models that can be used almost immediately to provoke discussion on topical issues. And we aim for our stakeholders to participate in the model building. In the context of Malinau this included some individuals spending time learning to undertake the modeling. There are pros and cons to such an approach; it does empower stakeholders to use the tool and understand many of

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the domains inside the model, but on the other hand the degree of complexity and sophistication in the model is limited. We see the trade-offs but definitely opt for simpler models with more engaged participants.

## Simplification

Dudley et al. (2008) query some of the model assumptions. Many things could be modeled, and some were, but within the confines of simplification and a short paper only a few things could be touched on by Sandker et al. (2007). In this reply, we look at three aspects that Dudley et al. (2008) raise: migration, deforestation, and negative impacts on local people.

Dudley et al. (2008) query the migration assumptions, and raise an interesting question as to whether as land is converted to oil palm, will local people who were formerly dependent on that land for subsistence, be more likely, over time, to find and accept work in plantations or processing factories? The focus of some of the key decision makers has been, and largely continues to be, development at almost any cost. Large-scale plantation development is a real interest. If that goes ahead, there are insufficient people in the district to provide the necessary labor, and, in any case locals are the ones least likely to secure jobs in such development (see also Potter 2004, Boedhihartono et al. 2007). In the model, migration is driven by the new jobs created. In the short term development will mean more immigration. The threshold for migrants to leave if employment drops is set high because we believe a large number of migrants will stay. Lowering the threshold, with migrants leaving already when employment drops below 60%, for example, would make practically no difference in the first 20 yr of the simulation, and after 40 yr the number of migrants will be 60 times the number at the start instead of 80 times, both equally large numbers. One can dispute whether the exact levels of immigration modeled are too high or too low, but the fact is that the installation of large-scale plantations will boost immigration (Benoit et al. 1989). Dudley et al. (2008) make a valid point that the migration consequences expected from money inflows from payments for environmental service (PES) should also be discussed with the decision makers, though the scale of immigration would be much smaller than with large scale plantations.

Another concern raised by Dudley et al. (2008) is that deforestation might be much higher than modeled. We did model a negative feedback in the plantation scenario through an increase in agriculture outside the plantations, leading to an additional 300,000 to 550,000 ha of primary forest loss besides the forest lost for oil palm clearing. We agree that there is a possibility that more forest could be lost than modeled, especially if large-scale fires would occur. However, since the remaining forest is located on steep slopes and harder to access, it is perhaps less likely to be converted.

Dudley et al. (2008) mention concerns of advocacy groups about the negative impacts of oil palm on local people, and query why we did not consider these. In the referee process of earlier drafts of the paper we were asked not to use the results from certain advocacy groups, as there was a disbelief in their veracity. It is clear there is limited data available on the local impacts of oil palm development, but there are now quite a few research projects that will provide this data in years to come (John McCarthy, *personal communication*, Patrice Levang, *personal communication*, Lisa Curran, *personal communication*).

## Including soft variables

Dudley et al. (2008) state that we should go beyond simple scenarios and that we should include components such as likelihood of ethnic strife and level of local peoples involvement, as encouraged by writers such as Sterman (1991). One aim of participation is consensus as to what should be in the model. We have often tried to introduce soft system variables into models, and the earliest versions of the Malinau model had such variables, e.g., strength of village level institutions. But during model development they were weeded out. In other, very different, contexts we have also found stakeholders unhappy to include soft variables. In Central Africa when dealing with nongovernment (NGO) officials, they were highly skeptical of including soft variables such as international commitment to biodiversity and degree of good governance in the landscape. They argued that such variables were not measurable, and that they would not believe the model outcomes if they were included in the model. They were not arguing that such variables were not important. They preferred examining the implications of such variables in different scenarios, e.g., model runs under poor

governance/high corruption vs. model runs with good governance. Thus, the soft variables were not dynamic variables but rather distinct scenarios.

## MODELS AS TOOLS FOR EXPLORING AND DISCUSSING SCENARIOS

We are not in the business of predictive modeling; given some of the technical points raised by Dudley et al. (2008), we query whether they have moved very far along the continuum of models as predictive tools to modes as tools for exploring and discussing scenarios. We come close to what van den Belt (2004) refers to as a scoping model. In such a model, a group of stakeholders interactively scope out a complex problem. The model serves to increase understanding but does not attempt to make predictions. This is illustrated in our earlier work with van den Belt (2004), in which a forest landscape in southern Zimbabwe was examined for its multiple goods and services, which were the interest of different stakeholders (Campbell et al. 2000). Scenarios that were explored included changing the rules related to landscape use, and what this meant for local livelihoods and for the forest industry.

The Malinau model served its purpose: provoking some useful debate amongst the real decision makers in the area. The technical points raised by Dudley et al. (2008) on time spans and soft variables are largely irrelevant to the intended purpose.

### Examining longer time periods

Dudley et al. (2008) call for examining the model over a longer period, given that plantations are involved and given that a so-called simple test of model validity is to run the model for a longer period. We disagree. Our stakeholders were local officials whose time horizon is closer to 3 yr than the 100 yr that Dudley et al. (2008) call for. Even our selected 40 yr time frame is pushing what is relevant to the local stakeholders in terms of the decisions they are making each year. We did not build the model for 100 yr, and if we did we would have had to include extra elements, e.g., limits to agricultural expansion. To illustrate this point, we made the changes requested by Dudley et al. (2008) for land area. However, it made no difference to the model outcomes that we displayed in the paper (see re-posted model <http://www.cifor.cgiar.org/conserv>

[ation/ ref/research/research.2.5.htm](#)).

### Soft variables

We return to soft variables. Dudley et al. (2008) would prefer that such variables be imbedded in the model: "Although the authors report that local leaders are concerned about immigration, this concern is .... (not) imbedded in the model." We assume that Dudley et al. (2008) would prefer that a variable "concern about immigration" be imbedded in the model and changes decision-maker policies that influence immigration. We do not see this as useful for our purpose. We are talking to decision makers and running scenarios using outcome variables that are important to them. It is not useful to try and have a model sector that incorporates their decision-making process in the model. It is more useful to run scenarios that show different immigration levels based on different assumptions, and then the decision makers can use the model results as one element in their real-life decision-making process.

## CONCLUSION

The model is merely a case of: if x, y, and z is assumed then this is what will occur. If, through engagement with stakeholders, concerns are raised and decision makers think more deeply about different options for the future, then the purpose of the modeling will have been achieved. Although it would have been ideal to perform a similar exercise with other Malinau stakeholders, especially local communities, this was not part of the original agenda. Participatory modeling, especially the type that deeply involves the stakeholders, is challenging. We note the recent steps taken by the Malinau district down the conservation and carbon pathway, e.g., <http://regserver.unfccc.int/seors/filestorage/cwjg41fo28xz50m.pdf>) and hope that participatory scoping models have a role to play in examining future scenarios.

*Responses to this article can be read online at:*  
<http://www.ecologyandsociety.org/vol13/iss1/resp2/responses/>

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## LITERATURE CITED

- Benoit, D., P. Levang, M. Pain, and O. Sevin.** 1989. *Transmigration and spontaneous migrations in Indonesia*. Orstrom and Department of Transmigration, Lampung Province, Jakarta, Indonesia.
- Boedhihartono, A. K., P. Gunarso, P. Levang, and J. Sayer.** 2007. The principles of conservation and development: do they apply in Malinau? *Ecology and Society* 12(2):2. [online] URL: <http://www.ecologyandsociety.org/vol12/iss2/art2/>.
- Campbell, B. M., R. Costanza, and M. van den Belt.** 2000. Land use options in dry tropical woodland ecosystems in Zimbabwe: introduction, overview and synthesis. *Ecological Economics* 33:341-352.
- Carter, J.** 1996. *Recent approaches to participatory forest resource assessment*. Overseas Development Institute, Oxford, UK.
- Dudley, R. D. D. Sheil, and C. J. Pierce Colfer.** 2008. Simulating oil palm expansion requires credible approaches. *Ecology and Society* 13(1):r1. [online] URL: <http://www.ecologyandsociety.org/vol13/iss1/resp1/>.
- Edmunds, D., and E. Wollenberg.** 2001. A strategic approach to multistakeholder negotiations. *Development and Change* 32:231-253.
- Lynam, T., F. Bousquet, C. L. Page, P. d'Aquino, O. Barreteau, F. Chinembiri, and B. Mombeshora.** 2002. Adapting science to adaptive managers: spidergrams, belief models, and multi-agent systems modeling. *Conservation Ecology* 5(2):24. [online] URL: <http://www.consecol.org/vol5/iss2/art24/>.
- Nemarundwe, N., and M. Richards.** 2002. Participatory methods for exploring livelihood values derived from forests: potential and limitations. Pages 168-197 in B. M. Campbell and M. K. Luckert, editors. *Uncovering the hidden harvest: valuation methods for woodlands and forest resources*. Earthscan Publications, London, UK.
- Potter, L.** 2004. *Can Indonesia's complex agroforests survive globalisation and decentralisation? A study in Sanggau district, West Kalimantan*. 15th Biennial Conference of the Asian Studies Association of Australia, Canberra, Australia.
- Sandker, M., A. Suwarno, and B. M. Campbell.** 2007. Will forests remain in the face of oil palm expansion? Simulating change in Malinau, Indonesia. *Ecology and Society* 12(2):37. [online] URL: <http://www.ecologyandsociety.org/vol12/iss2/art37/>.
- Sterman, J. D.** 1991. A skeptic's guide to computer models. Pages 209-229 in G. O. Barney, W. Kreutzer, and M. J. Garrett, editors. *Managing a nation: the microcomputer software catalog*. Westview Press, Boulder, Colorado, USA. Available online at: [http://web.mit.edu/jsterman/www/Skeptic's\\_Guide.pdf](http://web.mit.edu/jsterman/www/Skeptic's_Guide.pdf).
- van den Belt, M.** 2004. *Mediated modeling: a system dynamics approach to environmental consensus building*. Island Press, Washington, DC., USA.
- van Ittersum, M. K., F. Ewert, T. Heckeley, J. Wery, J. A. Olsson, E. Andersen, I. Bezlepina, F. Brouwer, M. Donatelli, G. Flichman, L. Olsson, A. E. Rizzoli, T. van de Wal, J. E. Wien, and J. Wolf.** 2008. Integrated assessment of agricultural systems: a component-based framework for the European Union (SEAMLESS). *Agricultural Systems* 96:150-165.
- Wollenberg, E., R. Iwan, G. Limberg, M. Moeliono, S. Rhee, and M. Sudana.** 2007. Facilitating cooperation during times of chaos: spontaneous orders and muddling through in Malinau District, Indonesia. *Ecology and Society* 12(1):3. [online] URL: <http://www.ecologyandsociety.org/vol12/iss1/art3/>.



## Chapter 4

### **Spatial Projections of Participatory System Dynamics Modelling Outcomes: Exploring Oil Palm and REDD consequences for Local Livelihoods in Papua, Indonesia**



Photo nutmeg: courtesy of Intu Boedhihartono



# **Spatial Projections of Participatory System Dynamics Modelling Outcomes: Exploring Oil Palm and REDD consequences for Local Livelihoods in Papua, Indonesia**

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## **ABSTRACT**

This paper reports on combining the system dynamics software STELLA with the spatial simulation software GEOMOD (IDRISI) in order to visualize simulated forest cover changes produced by STELLA on maps. A socio-ecological model has been built in STELLA for Kaimana district including spatial and many non-spatial components. The model is built in a participatory manner with district officials and non-governmental organization personnel. We used it to explore environmental and social impacts of large scale plantation investments or payments for Reducing Emissions from Deforestation and Forest Degradation (REDD). We focused on the socio-economic consequences district level decisions would have for local livelihoods. The simulated outcomes are fed into a strategic discussion aiming to better inform the decision making process in Kaimana. We report on advantages and shortcomings of combining the two simulation programs and give an overview of the conservation and development outcomes under each of the scenarios explored for the Kaimana district.

**Keywords:** Landscape modelling, Participatory modelling, System dynamics, STELLA, GEOMOD, IDRISI, REDD, Kaimana.

## **INTRODUCTION**

Participatory modelling is the act of building a model with a group of non-modellers under the guidance of a model expert facilitator (Van den Belt *et al.* 2006). In various landscapes this method has been applied in order to exchange knowledge between different stakeholders, increase understanding of landscape dynamics, explore scenarios, visualize trade-offs between conservation and development outcomes and create a shared vision to achieve change in the desired direction (Beall & Zeoli 2008; Sandker *et al.* 2009; Sandker *et al.* 2010). This form of modelling seeks to envision alternative futures rather than extrapolate past trends (e.g. Sandker *et al.* 2007), a key criticism of Costanza (2000) on current futures modelling

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practices. Participatory modelling seeks to balance simplicity with accuracy: the model doesn't give new insights if it is either too simple or too complex (Sandker *et al.* 2010). A constraint of the system dynamics software STELLA, used to build the participatory models in the mentioned studies of Sandker *et al.*, is that it's not spatially explicit (even though it simulates land-cover change). Simulation outcomes are therefore presented in graphs or tables, not in the form of maps. Maps and spatial representations are strong tools to envision and discuss preferred future landscape scenarios (Costanza & Voinov 2004), which is why we explore the presentation of participatory STELLA modelling land-use simulation results as maps in a simple way.

Spatial models are often highly complex, limiting participation of non-modellers and demanding a large amount of time investment in its creation. Many (spatial) model projections of future (land-cover) changes focus on extrapolating past trends (Costanza 2000), which might give accurate predictions of land-use changes in many developed country landscapes but wouldn't do so in the situation of many forest landscapes in developing countries at the verge of transition. Sayer (2007) claims changes in landscapes are generally not orderly or predictable, something which stakeholders with landscape scale objectives should take into account.

Examples exist of future projections obtained in a participatory way but producing purely spatial simulation outcomes (Castella *et al.* 2005; Hulse *et al.* 2004; Nelson *et al.* 2009). An advantage of participatory system dynamics modelling over spatial modelling is the simulation of many non-spatial elements fundamental to understanding outcomes in a landscape, like household income and even less tangible features like corruption (e.g. Sandker *et al.* 2009). This allows participatory modelling to extend deeper into the socio-political context of decision making.

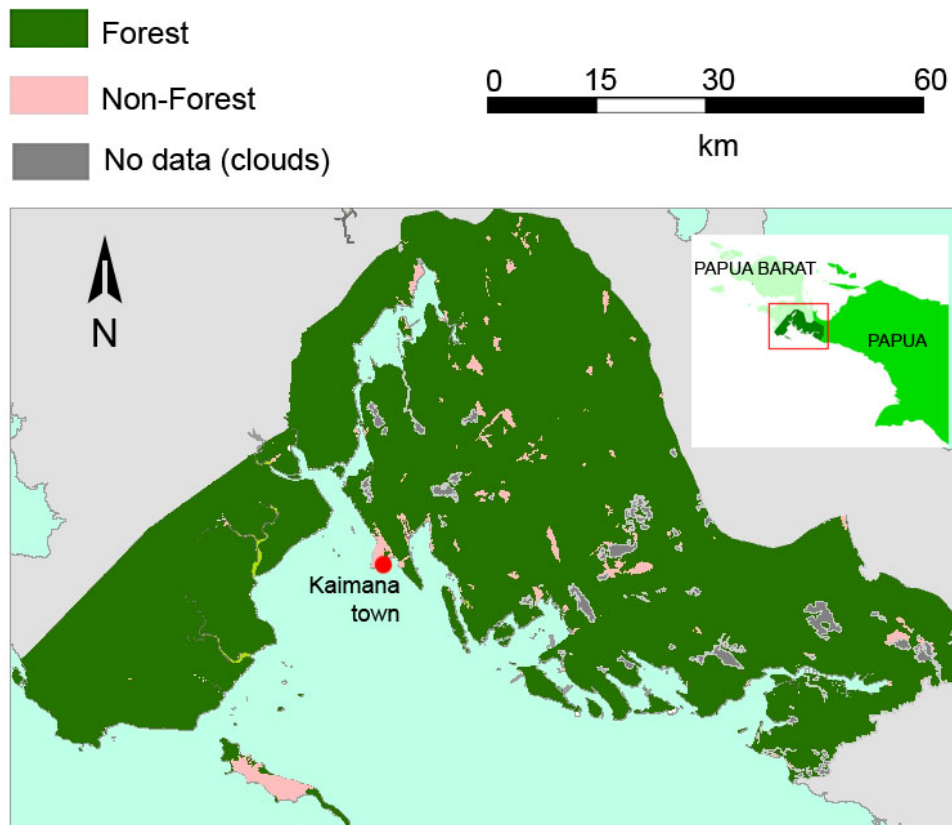
A spatial dimension is added to system dynamics modelling in the software SIMILE (Muetzelfeldt & Massheder 2003), though this seems to be either simple, for theoretical learning of a single feature displayed on square plots, or highly complex and time consuming thus allowing little participation (Legg 2003; Vanclay *et al.* 2003). Costanza & Maxwell (1991) combined STELLA system dynamics modelling with Geographic Information Systems (GIS), each stock in STELLA representing one grid cell on the map. This forms the basis of an integrated environment for high performance spatial modelling called SME (Spatial Modeling Environment) (Costanza & Voinov 2004). This again is highly complex and time consuming, e.g. to run the model eight parallel processors were needed. Furthermore, extensive information is needed to feed into the model. One would have to question whether the spatial representation of the explored scenarios would be worth the large time investment and whether we have enough spatial data for such a model to make sense. We opted to explore a much simpler and faster visual representation of the scenarios by combining the model platforms STELLA and GEOMOD (IDRISI).

We explore the spatial presentation of STELLA land-use simulation results for the district Kaimana in Papua, Indonesia. Papua is a location where the future will most likely bring radical changes, nothing like the landscape has experienced in the last decades, and visioning future land-cover changes in this situation is all but an extrapolation of past forest conversion trends. The local policy makers are faced with options which would have major consequences for (the spatial aspect of) the landscape. With participatory modelling we explored the consequences of major oil palm investments and payments for Reducing Emissions from Forest Degradation and Deforestation (REDD) and their consequences for forest dependant livelihoods and forest cover in Kaimana, Papua.

## METHODS

### *Kaimana district, livelihoods and land-use history*

The Kaimana district is located in Papua (Figure 1), East-Indonesia, sharing a border to the East with Papua New Guinea. Kaimana district extends over 17,298 km<sup>2</sup>, and is sparsely populated (2.4 people/km<sup>2</sup>) with a high concentration of people (50% of the total population) in and around the



**Figure 1.** Forest cover of Kaimana district in 2005

district capital Kaimana Town. There are few roads in the district and the main transport means for the rural population consists of canoes, using the vast river network or the sea. Almost all villages are located on the river shores. The local rural population is largely dependant on the forest, followed by small scale agriculture and fishing (Table 1). They use the forest for hunting, to collect non-timber forest products (NTFPs) and some villages are involved in community logging. All villages have forest gardens (often abandoned agriculture plots) where they grow certain NTFPs like nutmeg (Shepherd 2009). Forest re-growth on the agricultural plots is very important to restore soil fertility in the absence of fertilizers and plots are only productive for about two years (Shepherd 2009). We use mean subsistence and cash income of the local rural population as indicators of the consequences of a REDD policy or oil palm investments in the district on forest dependant livelihoods.

Kaimana district is currently for ~95% covered with forest (Table 1). There are currently six logging concessions with a license. The logging activities result in the conversion of primary into secondary forest, not in forest clearing. We consider primary logged-over forest as secondary forest.

**Table 1.** The model sectors with a summary of the information in each sector

Model sector	Information	Source
Land-use	<p>Total district area Kaimana= 17,298 km<sup>2</sup> (100%)</p> <p>Administrative classification (indicating use destination):</p> <p>Other land uses (APL)= 900 km<sup>2</sup> (5%)</p> <p>Conversion forest (HPK)= 2,844 km<sup>2</sup> (16%)</p> <p>Production forest (HP)= 3,106 km<sup>2</sup> (18%)</p> <p>Limited production forest (HPT)= 5,120 km<sup>2</sup> (30%)</p> <p>Protected area = 5,273 km<sup>2</sup> (30%)</p> <p>Unclassified = 55 km<sup>2</sup> (&lt;1%)</p> <p>Total districts' secondary forest in 2010= ~4,050km<sup>2</sup></p> <p>Total districts' primary forest in 2010= ~12,398 km<sup>2</sup></p> <p>Actual deforested area= ~850 km<sup>2</sup></p> <p>APL forest conversion for small scale agriculture= current area + new local households (hh)*1ha + number of unemployed migrants hh*1ha</p> <p>After 2 years agriculture land becomes fallow</p> <p>After 5 years fallow land becomes secondary forest</p>	<p>Forestry Master Plan, 2008</p> <p>Forestry Master Plan, 2008 ; compared with data Kelompok Pemangku Hutan Papua Barat Kaimana</p> <p>Expert estimation in line with historic deforestation trend</p>

Population and employment	<p>Total industrial timber production Kaimana district = <math>\sim 640,000 \text{ m}^3/\text{year}</math>  Timber extraction = <math>32 \text{ m}^3/\text{ha}</math>  Annual conversion of primary to secondary forest = <math>\sim 200 \text{ km}^2</math>  Parts of APL, HPK, HP and HPT are converted to oil palm and HTI depending on the scenario, part of APL is converted to forest garden  Total population Kaimana district 2008 = 41,660 people  49% of the population is urban (of which 55% is local, the rest migrant)  51% of the population is rural (of which 90% is local, the rest migrant)</p> <p>Birth rate = 1-4% (lowest for urban migrant population, highest for rural local population)  Death rate = 1%  Immigration rate = 2% (of migrant population)</p> <p>Immigration provoked by jobs = new jobs to migrants * 1.5  New jobs = new jobs in IPK, oil palm and HTI  Of new jobs, only 5% can go to local population  Maximum jobs local population = %age people of working age and gender * %age skilled local working age people * total local population  %age people of working age and gender = 20%  %age skilled local working age people = 20% now and increasing to 80% in 20 years from now (scenario 1)  20% now and increasing to 50% in 20 years from now (scenario 2)  10% now and increasing to 30% in 20 years from now (scenario 3)  Average annual salary (future) jobs = 10 million Rp (local) and 12 million Rp (migrant)  Jobs in land clearing (IPK) = 0.48 worker/ha  Jobs in oil palm (Sawit), acacia plantation (HTI) and logging (HPH) = 0.2 worker/ha</p>	<p>Forestry Master Plan 2008  Expert estimation based on historic data  See scenario description</p> <p>Kaimana Statistics Centre 2008  Combination of expert estimate and Kaimana Statistics Centre 2008  Extrapolation of population growth 2007 – 2008 from Kaimana Statistics Centre 2008, modified with expert judgment  Expert estimates</p>
Rural local household income	<p>Total mean income per capita = 4 million Rp in 2009  Rp = Indonesian Rupiah, 1US\$ = 9,328 Rp (February 2010)</p>	<p>Approximations based on practices in North Sumatera and Jambi, modified with expert judgment  Expert estimate</p>

Of total income 45% is cash and 55% subsistence	Shepherd <i>et al.</i> 2009
Forest products make up 43% of income, 41% of cash income in 2009	
Agriculture make up 39% of income, 42% of cash income in 2009	
Fisheries make up 15% of income, 11% of cash income in 2009	
The remainder is made up of salaries, fees and other	
Cash from agriculture is simulated to increase linearly with the increase in jobs growing to a maximum of 85% of total agricultural income	Expert estimate

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### *Scenarios*

Papua has a history of relatively low deforestation rates. However, the district head (*bupati*) has 25-30 proposals for oil palm plantations waiting on his desk while at the same time he has been approached by international investors interested in buying carbon stored in the forest to sell on the future REDD market (pers. com. vice-bupati 2009). Discussion with district officials and non-governmental organization (NGO) personnel resulted in the identification of three scenarios they thought plausible for Kaimana:

Scenario 1) "Small is beautiful-growth with conservation": as of year two in the simulation, each year 10,000 ha are allocated to oil palm and 10,000 ha are allocated to acacia plantation. The limit for suitable oil palm area is set at 190,000 ha (rePPPProt unpublished) and the limit for suitable acacia plantation area is set at 260,000 ha outside the suitable oil palm area (Ministry of Forestry, unpublished). A medium investment in NTFPs is made; each year '25ha + 0.1ha\*increase local rural households' is converted to forest garden.

Scenario 2) "Building an industrial future": as of year two in the simulation, each year 20,000 ha are allocated to oil palm and 20,000 ha are allocated to acacia plantation. The limit for suitable oil palm area is set at 320,000 ha (inspired by Conservation International suitability map) and the limit for suitable acacia plantation area is assumed 260,000 ha outside the suitable oil palm area. A low investment in NTFPs is made; each year '0.1ha\*increase local rural households' is converted to forest garden.

Scenario 3) "A future of forests-A focus on environmental services": as of year two in the simulation, each year 1,000 ha are allocated to oil palm and 5,000 ha to acacia plantation. We believe the introduction of plantations in Kaimana is inevitable and under the most conservative scenario the expansion is limited, not zero. A high investment in NTFPs is made; each year '50ha + 0.1ha\*increase local rural households' is converted to forest garden. The conservationists' scenario could be a consequence of implementation of a REDD policy. Ideally, under such a scenario, the local

population receives a share of REDD payments but given the situation of local people remotely distributed over the district and given high corruption levels in Indonesia we explore this scenario without any REDD payments received by the local population.

#### *Participatory modelling with STELLA*

Participatory modelling is the act of building a model with a group of non-model experts under guidance of a model facilitator. The objectives of participatory modelling include increasing understanding of complex dynamic systems (landscape in this study), thinking through drivers of change responsible for past and future trends of landscape aspects and promoting inter-disciplinary exchange of information and visions (Sandker *et al.* 2009, 2010; Van den Belt 2004). Data is often lacking in landscapes such as Kaimana and information gaps are filled with data from unpublished reports or local expert estimates. The simulated outcomes are therefore of indicative value, they explore future landscape pathways rather than predict precise outcomes. However, the model is conceptualized and the simulation results are validated by, and at the same time disseminated among, local experts. The participatory model has been built using the system dynamics software STELLA (HPS 1996). This icon-based model building tool makes system dynamics modelling accessible to a wider public and is readily understood by non-model experts (Van den Belt 2004). The Kaimana model consists of three sectors, given in Table 1 together with their most important variables, equations and information sources.

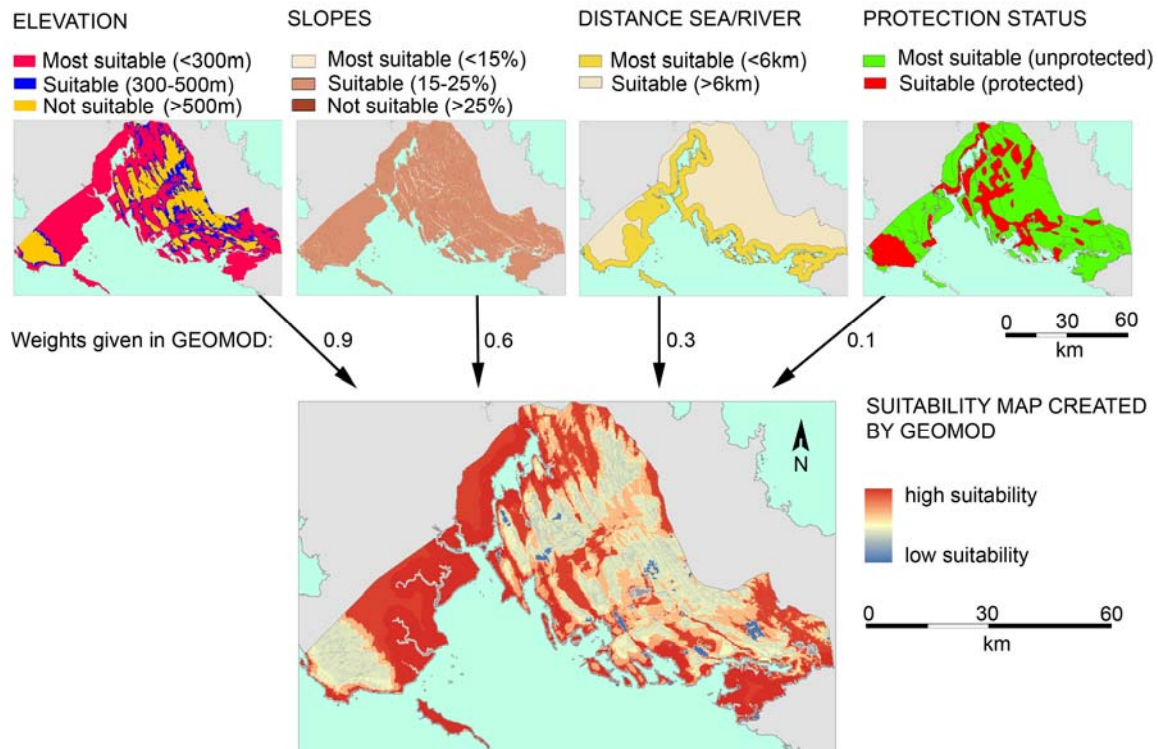
#### *Spatial projections with GEOMOD (IDRISI)*

When spatially projecting with GEOMOD, the forest cover change is simulated by STELLA, while the location of change is simulated by GEOMOD. GEOMOD is a land-use change simulation model that predicts the locations of grid cells that change over time (Eastman 2009 p. 84). The simulations can occur either forward or backward in time, we only use the forward simulation.

We entered in GEOMOD a map of beginning time, the 2005 map in Figure 1 being the most recent available to us, which has been re-classified into two categories 'forest' and 'non-forest'. The beginning time is thus set to 2005; the ending time of the simulation is set to 2030, coinciding with the ending time of the STELLA simulation.

GEOMOD can use two decision rules for simulating the location of change, one rule being based on proximity, the other on suitability. We exclude the decision rule based on proximity. Its inclusion would allow only cells on the boarder of forest and non-forest to be converted. If large-scale plantations will be installed in Papua, deforestation patterns will not be anything like the district has seen in the past, current deforested patches will not influence the location of future change. The suitability map is created instantaneously in GEOMOD by entering a number of driver maps (Figure 2). The driver maps

can be given different weights, we weighed elevation as highest (higher altitudes being most limiting to oil palm expansion), followed by slopes, distance from the sea and major rivers (to include transportation costs for oil palm companies) and finally the administrative limitations (categorizing national parks as less suitable). One could explore different scenarios with different weights for the administrative limitations map to explore different 'governance scenarios' where national parks are always excluded or where



**Figure 2.** Driver maps entered in GEOMOD and resulting suitability map

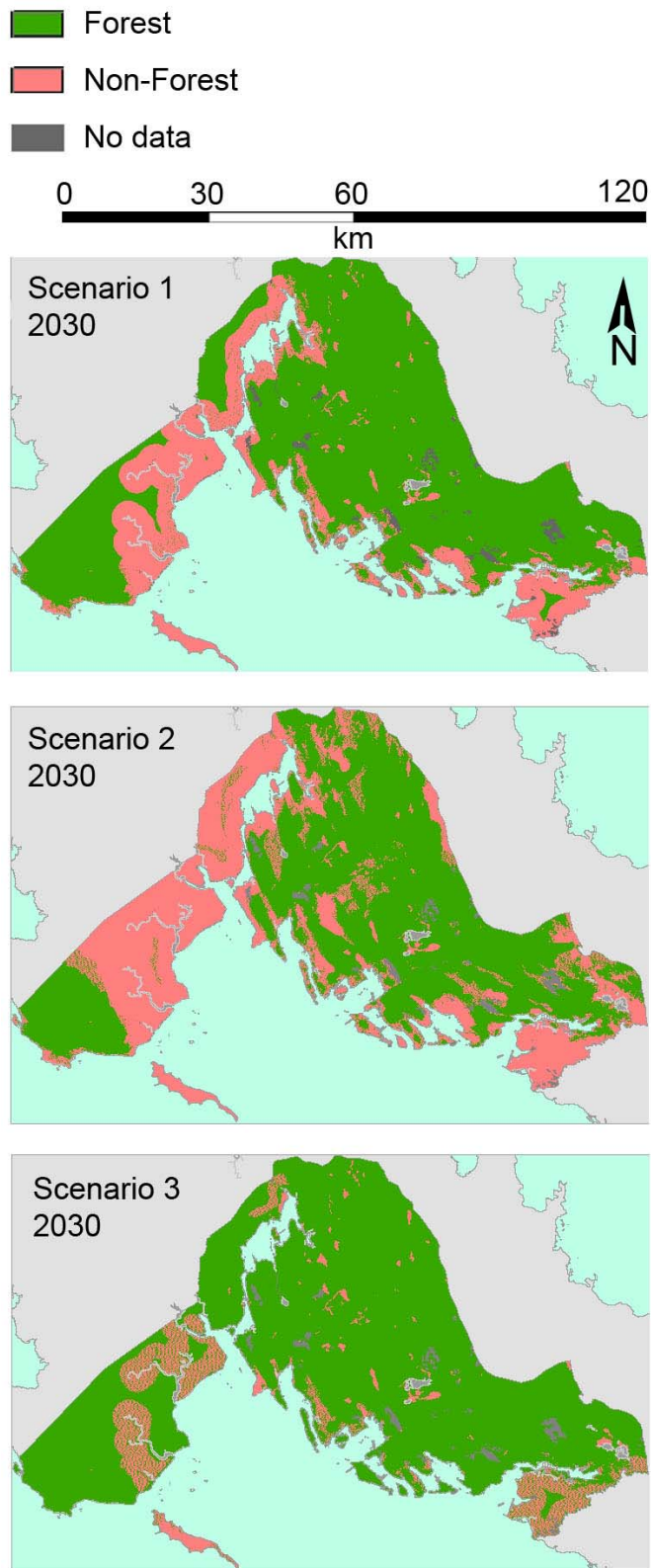
they can be degazetted to give way to oil palm companies. The driver maps we prepared, their weights given in GEOMOD and the resulting suitability map created by GEOMOD and used to predict the location of changing grid cells are given in Figure 2.

## Results and discussion

### *Land-use changes*

The land cover projections of the three scenarios suggest that Kaimana is at the verge of forest transition. The forest cover decreases from 16,450 km<sup>2</sup> in 2009 to 12,780 km<sup>2</sup>, 10,320 km<sup>2</sup> and 15,350 km<sup>2</sup> under scenario 1, 2 and 3 respectively in year 2030 (Figure 3). These forest cover changes are the





simulation result of STELLA where total forest cover is the sum of secondary and primary forest. Even under the most conservative scenario (scenario 3), the local district officials still expected 1,080 km<sup>2</sup> to become plantation after 20 years.

**Figure 3.** Maps produced by GEOMOD projecting forest cover in 2030 under the three scenarios explored

Under the industrial scenarios it is likely that a new major town will be created in the western part of the district as this is where the plantations are likely to concentrate (Figure 3). Furthermore, there is a risk of national parks being degazetted in the Western part of the district. Indeed, under both industrial scenarios (1 & 2), the national park near the sea shore in the Western part of Kaimana is not respected (Figure 2 and 3).

#### *Population increase*

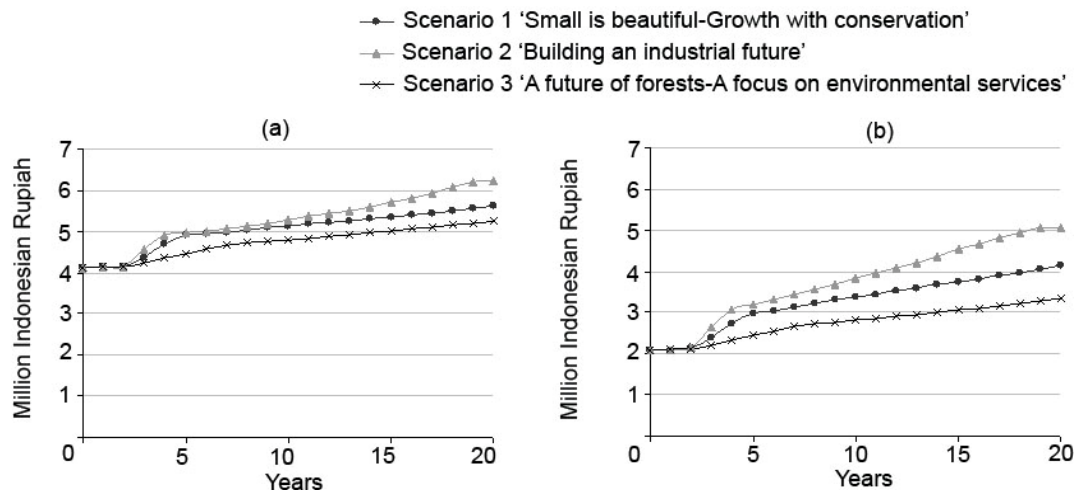
At the end of the simulation, the total population of Kaimana has increased from 41,660 people in 2010 to 460,000; 740,000 and 187,000 under scenario 1, 2 and 3 respectively. Even under the most conservative

scenario, the total population increases by 350%, mainly the result of people attracted to Kaimana by the jobs created in the plantations (Table 1). Under

scenario 3, if one were to assume substantial REDD payments being received by the entire Kaimana population (not excluding migrants), one can imagine people being attracted to the district to share in some REDD cash. There is a possibility that such enormous invasions of the district by migrants as suggested by the scenarios would result in increased conflicts, e.g. over access to land for agriculture or over benefit sharing from the plantations and REDD investments.

### *Income simulations*

Total per capita income and per capita cash show similar trends under the three scenarios increasing with 30-50% (Figure 4a) and 60-150% (Figure 4b) after 20 years. The income differences under the three scenarios are more marked in terms of cash. This is due to the simulated negative effects of large scale conversion of forests to oil palm causing loss in subsistence income. Negative effects simulated are pollution of the rivers and loss of forest. Water pollution causes income from fisheries to decrease with ~60% under the 'industrial future' scenario and with ~30% under the 'growth with conservation' scenario (Table 2). Forest loss causes income from forest



**Figure 4.** Simulation outcomes from STELLA of (a) total per capita income (subsistence and cash) and (b) per capita cash income for the local rural population of Kaimana

products to decrease by 25% and 35% under the 'growth with conservation' and 'industrial future' scenarios respectively. These negative effects on subsistence income are experienced by all people, while the benefits in terms of salaried jobs are only received by some. Under all scenarios, the current mainly subsistence economy converts into a cash economy; where now cash makes up for 45% of total income, it will consist of 70, 80 and 60% after 20 years under scenario 1, 2 and 3 respectively.

Under the three scenarios, the total amount of jobs increase radically, from around 500 jobs now to 82,000; 120,000 and 25,000 jobs for scenario 1, 2

and 3 respectively after 20 years of simulation. We expected though, the capture of jobs by local people to be limited, at best circa 10% of the total jobs go to local people but the most common percentage lies between 1-5%.

**Table 2.** Share of different activities (in %) of total per capita income for the local rural population of Kaimana now and at the end of the simulation under the three scenarios explored

	Agriculture	Forest	Fisheries	Salaries	Other
Now	46	36	17	1	1
Scenario 1 after 20 years	37	19	9	35	<1
Scenario 2 after 20 years	34	15	4	47	<1
Scenario 3 after 20 years	39	26	12	23	<1

Agriculture remains an important income source under all scenarios. Under scenario 1 and 2, we simulated agriculture to commercialize (Table 1) with the increased demand for food products from the huge population of salaried workers and with reduced transportation costs as a consequence of roads opening up the area. The production potential remains limited though because of low soil fertility. We assumed only the suitable land in the legally allocated area for forest conversion by local people is used for small-scale agriculture but given the enormous increase in population under the scenarios, much more forest might be converted.

### *REDD*

The total amount of carbon prevented from being emitted after 20 years under scenario 3 is 46 million ton C when assuming a baseline based on carbon emissions under scenario 1 or 89 million ton C assuming a baseline based on carbon emissions under scenario 2. If we were to approximate a payment based on these carbon quantities, assuming a price of 150,000 Rp (16 US\$)/ton CO<sub>2</sub> and 5% of the total REDD pay being equally captured by the local population, the annual per capita REDD pay would amount 1.5-2.9 million Rp the first year, going down to 0.3-0.6 million Rp after 20 years due to the growing population the REDD pay is shared among. Such payments would provide local people with a significant amount of cash.

## **CONCLUSION**

### *REDD potential in Kaimana*

A scenario where REDD policies would result in less conversion of forest into large scale plantations in Kaimana would avoid negative consequences from such large scale plantation invasion for the strongly forest-dependant local rural population though they would loose out on some extra cash. If local

people would also receive a share of the REDD payments they would be economically better off than under the industrial growth scenarios (1 & 2), with higher incomes and comparable cash inflow. Whether such payments would reach all remote villages is doubtful, but these remote villages are at the same time less likely to benefit from jobs and more likely to suffer negatively from consequences of large scale plantations.

#### *Combining participatory system dynamics modeling with GIS simulation*

GEOMOD proved relatively simple to handle and manipulate. One can change the selection of driver maps and their weight creating different suitability maps and running different simulations in less than 10 minutes, as long as these input driver maps are prepared beforehand. This preparation was more complicated and time consuming though, since the maps had to be converted into a format which could be read and understood by IDRISI. This proved to be time consuming for a spatial software expert without specific knowledge of IDRISI. A constraint of the projection is formed by the limitation of only two land-use types. Distinguishing between large scale plantation and small-scale agriculture, and between primary and secondary forest would probably have enriched the strategic discussion on Kaimana's future more.

Within the constraint of avoiding much complexity to keep the possibility of modeling in a participatory way, the combination of the GEOMOD (IDRISI) and STELLA model platforms proved promising. GEOMOD has provided a spatial dimension to the participatory model built in STELLA, moving the strategic use of the methodology a step forward in visualizing future landscape scenarios.

#### **ACKNOWLEDGEMENTS**

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#### **REFERENCES**

- Beall, A., Zeoli L., 2008. Participatory modeling of endangered wildlife systems: Simulating the sage-grouse and land use in Central Washington. *Ecological Economics* **68**:24-33
- Castella, J.-C., Trung T.N., Boissau S., 2005. Participatory Simulation of Land-Use Changes in the Northern Mountains of Vietnam: the Combined Use of an Agent-Based Model, a Role-Playing Game, and a Geographic Information System. *Ecology and Society* **10**:27  
Online [<http://www.ecologyandsociety.org/vol10/iss1/art27/>]
- Costanza, R., Maxwell T., 1991. Spatial ecosystem modelling using parallel processors. *Ecological Modelling* **58**:159-183.
- Costanza, R. 2000. Visions of alternative (unpredictable) futures and their use in policy analysis. *Conservation Ecology* **4**:5
- Costanza, R., Voinov A., 2004. *Landscape simulation modeling: A spatially explicit, dynamic approach*. Springer, New York (USA).

- Eastman R. 2009. *IDRISI Taiga, Guide to GIS and Image Processing*. Clark Labs, Worcester (USA).
- Forestry Master Plan (Dinas Kehutanan dan UNIPA) 2008. *Master Plan Kehutanan Kabupaten Kaimana.*, Manokwari (Indonesia).
- HPS (High Performance Systems) (1996) *STELLA and STELLA research software*. HPS, Hanover N.H. (USA).
- Hulse, D.W., Branscomb, A., Payne, S.G., 2004. Envisioning alternatives: using citizen guidance to map future land and water use. *Ecological Applications* **14**: 325-341
- Kaimana Statistics Centre (Badan Pusat Statistik) 2008. *Kaimana in Figures*. Kaimana district (Indonesia).
- Legg, C. 2003. CamFlores: A FLORES-type Model for the Humid Forest Margin in Cameroon. *Small-scale Forest Economics, Management and Policy* **2**:211-223.
- Muetzelfeldt, R., Massheder, J., 2003. The Simile visual modelling environment. *European Journal of Agronomy* **18**:345-358
- Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D.R., Chan, K.M., Daily, G.C., Goldstein, J., Kareiva, P.M., Lonsdorf, E., Naidoo, R., Ricketts, T.H., Shaw, M.R., 2009. Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. *Frontiers in Ecology and Environment* **7**:4-11
- Sandker, M., Campbell, B.M., Nzoo, Z., Sunderland, T., Amougou, V., Defo, L., Sayer, J., 2009. Exploring the effectiveness of integrated conservation and development interventions in a Central African forest landscape. *Biodiversity and Conservation* **18**: 2875-2892 ([chapter 6](#))
- Sandker, M., Campbell, B.M., Ruiz-Pérez, M., Sayer, J., Cowling, R., Kassa, H., Knight, A.T., 2010. The Role of Participatory Modeling in Landscape Approaches to Reconcile Conservation and Development. *Ecology and Society* **15**: 13 ([chapter 9](#))
- Sandker, M., Suwarno, A., Campbell, B.M., 2007. Will Forests Remain in the Face of Oil Palm Expansion? Simulating Change in Malinau, Indonesia. *Ecology and Society* **12**:37 ([chapter 5](#))
- Sayer, J., 2007. The People's Forest. Balancing local and global values. PhD thesis, Autonomous University of Madrid (UAM), Madrid (Spain).
- Shepherd, G. and staff from PEMALI and PERDU. 2009. People and forest-based livelihoods in Kaimana district: planning a sustainable future. Working paper for IUCN Livelihoods and Landscapes Programme, IUCN, Gland (Switzerland).
- Van den Belt, M. 2004. *Mediated modeling. A system dynamics approach to environmental consensus building*. Washington DC (USA).
- Van den Belt, M., Bianciotto O.A., Costanza, R., Demers, S., Diaz, S., Ferrera, G.A., Koch, E.W., Momo, F.R., Fernet, M., 2006. Mediated Modeling of the Impacts of Enhanced UV-B Radiation on Ecosystem Services. *Photochemistry and Photobiology* **82**: 865-877
- Vanclay, J.K., Sinclair, F.L., Prabhu, R., 2003. Modelling Interactions amongst People and Forest Resources at the Landscape Scale. *Small-scale Forest Economics, Management and Policy* **2**:117-120

## Chapter 5

### **Will Forests Remain in the Face of Oil Palm Expansion? Simulating Change in Malinau, Indonesia**



Photo lady at market: courtesy of Intu Boedhihartono



Research, part of a Special Feature on [Navigating Trade-offs: Working for Conservation and Development Outcomes](#)

## Will Forests Remain in the Face of Oil Palm Expansion? Simulating Change in Malinau, Indonesia

[Marieke Sandker](#)<sup>1</sup>, [Aritta Suwarno](#)<sup>1</sup>, and [Bruce M. Campbell](#)<sup>1,2</sup>

**ABSTRACT.** The severe tensions between conservation and development are illustrated by events in Malinau District (Kalimantan, Indonesia). Conservationists decry proposed plans for logging and conversion of pristine tropical forest to oil palm (*Elaeis guineensis*). Although the local government is willing to declare the district a “conservation district,” at the same time, it shows interest in oil palm conversion. This article explores the impact of the potential conversion of 500 000 ha of forest to oil palm on forest cover, immigration, and the local economy in Malinau. The simulation model was developed using STELLA® software, and relies on a combination of empirical data, data from the literature, and stakeholder perceptions. If a company were to clear the forest for timber without planting oil palm (as commonly happens), poverty levels are likely to rise rather than decline over the long term. If large-scale oil palm plantations were to be established, they could yield significant benefits to local authorities. However, such development would induce massive employment-driven migration, with wide-ranging consequences for the current inhabitants of the region. By visualizing and quantifying these trade-offs between conservation and development, the model stimulates debate and information exchange among conservationists, development actors, and district authorities so that well-informed choices can be made.

**Key Words:** *Decentralization; district revenue; forest cover; landscape dynamics; livelihoods; oil palm; participatory model; primary forest*

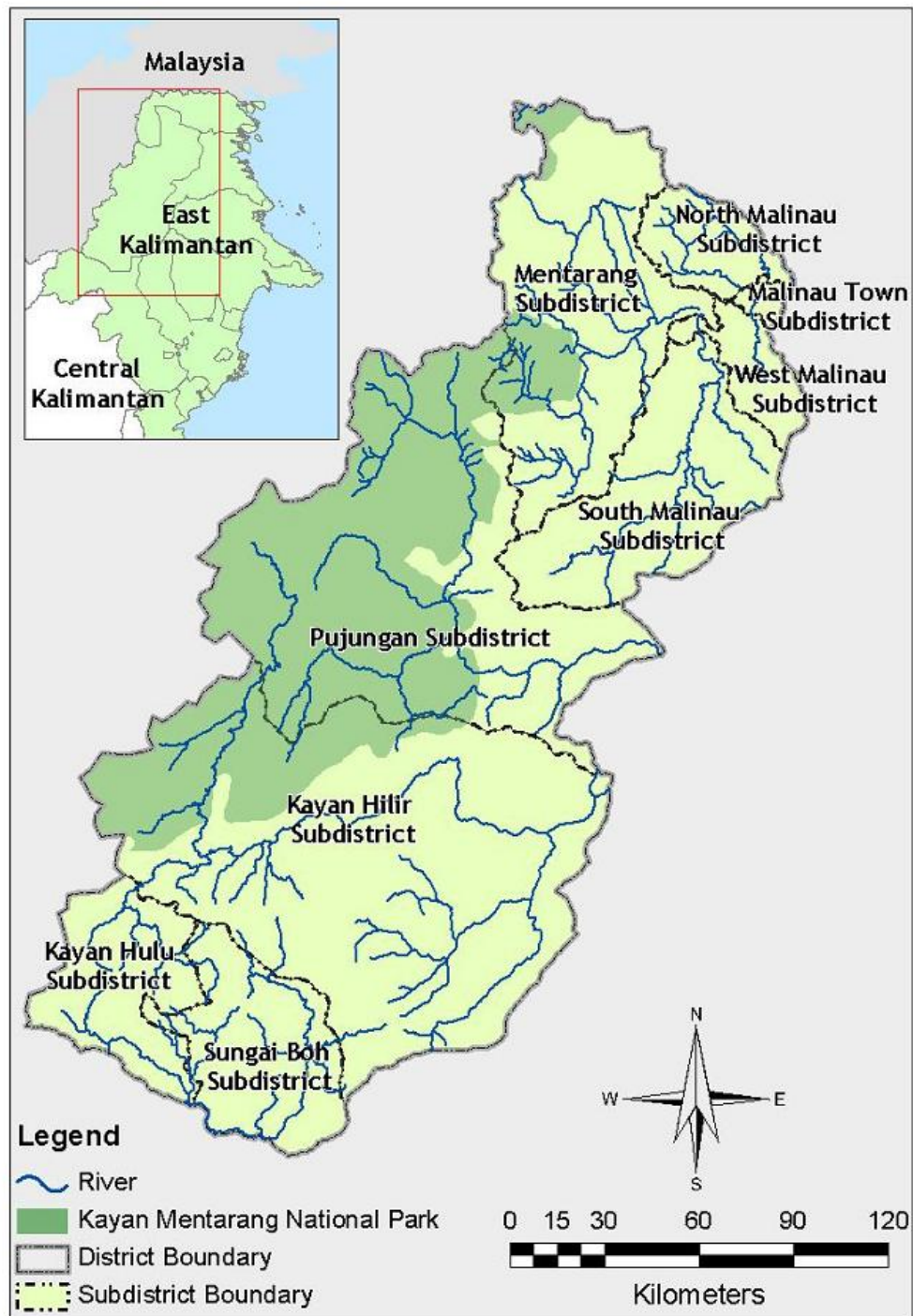
### INTRODUCTION

Environmentalists worldwide are concerned about the conversion of pristine Indonesian rainforests to oil palm (*Elaeis guineensis*). Between 1980 and 2000, global palm oil production increased by 360% to 20.9 million tonnes in 2000 (Koh and Wilcove 2007) and it is forecast that global demand will double in the next 20 to 30 years (Sargeant 2001, Reinhardt et al. 2007). Mittermeier and Bowles (1993) consider the forests in Kalimantan to be one of the world's 15 tropical rainforest hotspots. Malinau is one of the newly designated districts in East Kalimantan Province, Indonesia (Fig. 1). Over 95% of the 4.3 million-ha area is still covered with forest (Badan Pusat Statistik (BPS) Malinau, unpublished data). The local authorities recognize its value and have declared Malinau a “conservation district” (one of only three in Indonesia), although at the same time, they have welcomed palm oil investments.

In June 2005, the Indonesian Minister of Agriculture revealed a government proposal for the world's largest oil palm plantation of 1.8 million ha along the Malaysia–Kalimantan border, cutting through three national parks. Campaigns and lobbying by civil society, Indonesian media and foreign diplomats forced the Indonesian government to revise its position on the mega-project but, although the Indonesian president acknowledges that conservation concerns should be considered, he continues to support oil palm development (Wakker 2006). This is understandable considering the role of palm oil in the Indonesian economy. In 2004, the export value of palm oil in Indonesia comprised US\$4.1 billion—or 1.7% of the Indonesian gross national income (Koh and Wilcove 2007)—and roughly 4.5 million people rely on palm oil estates: 900 000 people through direct employment and another 3.6 million through downstream processing, service industries, and remittances (Sargeant 2001). Susila (2004) found that oil palm activities

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**Fig. 1.** Geographical features of Malinau District (Source: Topografi Kodam (TOPDAM) 2004 and Badan Perencanaan Pembangunan Daerah (Bappeda) 2002).





contribute 5–11 million IDR yearly or over 63% of smallholder household incomes in Kampar (Riau) and Musi Banyuasin (South Sumatra), and stated that the small proportion of poor people (<10%) in oil palm communities in these sites is an indication of the commodities' contribution to poverty alleviation. Conservationists face big challenges given the monetary benefits of oil palm.

For Malinau, we examine the scenario of clearing 500 000 ha of forest for oil palm and its consequences for local livelihood income, district revenue, and land-cover change. Given the employment created by such development, we also examine potential migration into Malinau. The aim of the paper is to simulate landscape dynamics in order to understand conservation and development trade-offs from the perspectives of different stakeholders.

## METHODS AND PROCESS

Simulation models and participatory modeling can be useful in stimulating discussion about the future, and can contribute to decisions about complex landscapes (Sayer and Campbell et al. 2004). Sayer and Campbell (2004) argue for the use of exploratory or scoping (as opposed to predictive) models, with model building and outcomes stimulating discussion amongst different stakeholders who have different perspectives on the trade-offs between conservation and development. We stress that this is a scoping model, not a predictive model.

The scoping model was built using the dynamic, userfriendly modeling software STELLA® v.8 (High Performance Systems 1996). Initially, the elements for a model were shared with researchers from the Center of International Forestry Research (CIFOR) and a scoping model was produced that simulated land-cover change (Sayer and Campbell 2004, Lynam et al. 2003). The results of the early simulations were discussed with researchers and staff of the district, including the district head (*Bupati*). This gave the modelers feedback on priority issues, and the model was then further developed. A workshop was then convened with 12 representatives from the district agencies at which available information and data were shared and discussed. This was followed by smaller workshops and modeling training with those officials interested in pursuing the modeling. In early 2007, the results were presented to CIFOR researchers and generated

much discussion. In late 2007, the scenario results were shared with district officials and the district head. More information on the modeling procedure can be found at: <http://www.cifor.cgiar.org/conservation/ref/home/index.htm>.

The model includes variables covering land use, human populations, employment, forest and plantation economics, and district income. To identify the current status of livelihoods in Malinau district, we used data from the district statistical office (*Badan Pusat Statistik*, BPS) and data from CIFOR researchers working in Malinau between 2000 and 2007. All monetary values are reported in Indonesian Rupiah (IDR), where ca. US\$1 = IDR 9500. The sensitivity of the model's response to some key variables (income from agriculture, oil palm, and timber salaries, emigration and immigration rate) has been explored by changing their values +/-20%.

## LAND USE, LAND-USE SCENARIOS, AND LAND-COVER CHANGE

### Main Land Use and Forest Types

With decentralization in 1999, land-use allocation has come increasingly under the control of the district government, although allocation in the forestry service area is still legally under the central government. Conservation and protection forest form a large part of Malinau, dominated by the Kayan Mentarang National Park (Table 1). The forests in the non-forestry service area and "conversion" forest are forests allocated for conversion to other uses (e.g., agriculture, plantations).

For the model, we have divided forests into primary forest, logged-over primary forest, secondary forest, and degraded forest (Fig. 2). Degraded forest comprises <5-year-old bush fallow (following abandoned swidden cultivation) and land cleared for mining. Based on the district offices' documentation on shifting cultivation for the years 2002–2006 and on the mining area, degraded forest occupies about 16 000 ha at the start of the simulation. Secondary forest comprises between 5- and 40-year-old bush fallow and very intensely logged forest. The intensely logged forest is largely a consequence of large- and small-scale conversion permits—IPK and IPPK, respectively. Based on documentation in the district offices and estimation

**Table 1.** Land-use allocation for Malinau (source: Dinas Kehutanan dan Perkebunan Kab. Malinau 2006, TGHK revised 2002 for mining area)

Land-use allocation 2006	Area (ha)
Total Area, Malinau District	4 262 070
Non-Forestry Service land	518 927
Of which:	
Mining concession (2002)	19 919
Currently under swidden agriculture (dryland paddy)	6 131
Currently under permanent agriculture (wetland paddy, crops, vegetables, fruits, and estate crops)	12 816
Forestry Service land	3 743 143
Of which:	
Conversion forest	225 828
Production forest	453 653
Limited production forest (on steep slopes)	1 280 836
Protection forest (national park and forest reserves)	1 782 825

of land under swidden cultivation over the period 1967–2002, secondary forest covers about 120 000 ha at the start of the simulation.

Secondary forest >40 years old is categorized as logged-over primary forest, although under the oil palm simulations, we assume no secondary forest is converted to primary forest due to increased forest clearing. Roughly 20% of the landscape (about 950 000 ha) was logged by 2004 (logged-over primary forest). The remaining 75% of the landscape (about 3 157 000 ha) is categorized as primary forest at the start of the simulation.

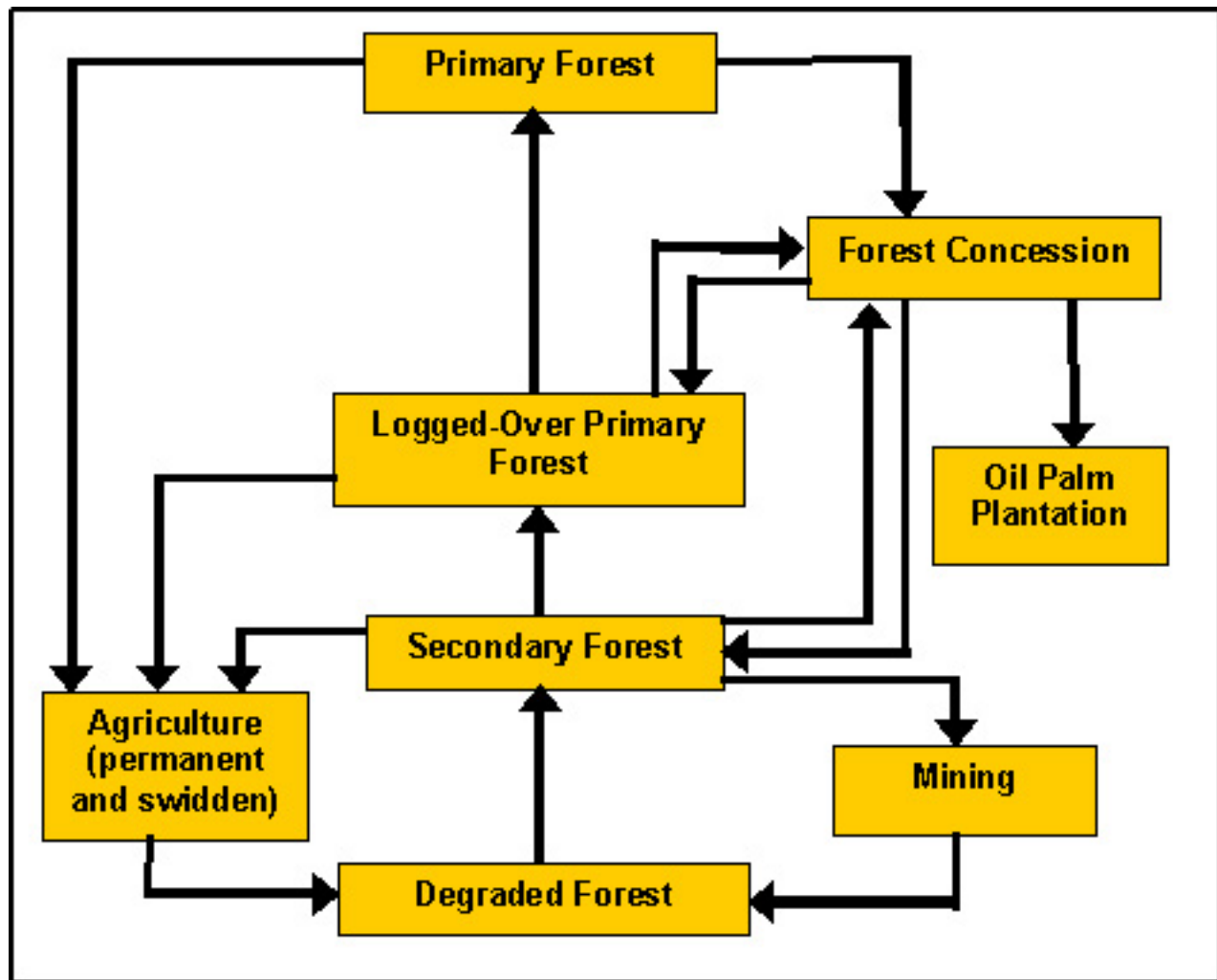
### Logging and Conversion Permits

With decentralization, district officials gained greater control over forest resources, often extending well beyond their official legal authority. They started issuing logging permits for small

concessions (IPPK) in areas supposedly classified as conversion forest (Obidzinski and Barr 2003). There was minimal regulation of the subsequent logging. Barr et al. (2001:13) report on the enthusiasm of a palm oil company manager about the decentralization process stating, “...operations will be much smoother and more efficient if companies can deal straight with the Bupati.”

A frequent practice observed in Indonesia is that IPPK (permit for large-scale forest conversion) concession holders do the logging, but have no intention of converting the area into plantations. Of 2.5 million ha cleared for oil palm in East and West Kalimantan, only 20% had been planted by 2005 (Wakker 2006), with the remaining area thought to be cleared mainly for its timber. In the neighboring district Berau, the governor is under prosecution for “abuse of power” because, between 1999 and 2002, he issued a permit to plant a million hectares of oil palm, and the company that received the permit

**Fig. 2.** Major land-use sectors captured in the model, showing the potential land-use transformations.



cleared the land, made use of the wood, but never planted oil palm (Castaño 2006). In Malinau, there have also been major proposals for oil palm where land is regarded as not suitable for oil palm, being remote, very steep, and with infertile soils (Basuki and Sheil 2005, Lynam et al. 2006), leading to the belief that the proposed development of oil palm is a guise for timber harvesting. Neighboring districts closer to the sea with extended lowlands would be more cost-effective investments for oil palm in the short term. However, the road network is rapidly expanding, with new roads now linking Malinau to Nunukan and Bulungan districts, so markets are effectively becoming more accessible and oil palm

investments more likely to happen, although some believe that the land capacity is such that oil palm will not be economically viable (Basuki and Sheil 2005).

### Oil Palm Scenarios

Currently there are no plantations in Malinau. In our simulation, we assume the development of oil palm will start in 5 years' time (2012). To explore the potential future impact of oil palm development, we have used four scenarios:

1. No oil palm development (as at present);
2. Forest clearing, but no oil palm planted (as has occurred elsewhere);
3. Forest clearing and oil palm plantation, assuming low employment rates, and
4. Forest clearing and oil palm plantation, assuming high employment rates.

In all scenarios, HPH/IUPHHK logging (large-scale concessions using less intensive logging) occurs throughout the simulation, starting with current levels and increasing by 50% toward the end of the simulation.

In scenarios 2–4, five logging permits for forest conversion are issued for an area of 100 000 ha each. Permits for plantation production are usually given for a 25- to 30-year period, and after that, they can be extended or terminated. The timber clearing through IPK permits in scenarios 2–4 is assumed to take place over a period of 20 years (from 2012–2032 in the simulation), increasing in intensity over time (too few workers and equipment are available in the first years). Thus, after 25 years, 500 000 ha of forest will be cleared.

Under scenario 2, we simulate “timber speculators,” who do intensive logging in primary logged-over forest, converting it to secondary forest. We assume that they mainly use the non-forestry service area and the area allocated as conversion forest (Table 1) although there will be some use of the permanent forest domain (about 70 000 ha). Furthermore, we assume that the company gives logging jobs to migrants only, and only pays a minimum compensation fee of IDR 5000/m<sup>3</sup> to villages (see below).

In scenarios 3 and 4, we simulate more responsible companies that plant the full 500 000 ha, 40% from secondary forest and 60% from primary logged-over forest, all of which is non-forestry service area and conversion forest. We assume the plantations are largely located in lowlands closer to transport routes (e.g., close to Malinau town). Scenario 3 assumes an employment of 0.1 jobs per ha of oil palm, which corresponds to current employment figures in Malaysian oil palm plantations (van Noordwijk, pers. comm. 2007). Scenario 4 assumes an average of 0.2 jobs per ha of oil palm, corresponding with Indonesian contexts (Sargeant

2001). It is assumed villages get a fee of 20 000 IDR/m<sup>3</sup> for the timber removed.

The timber compensation fees of IDR 5000–20 000/m<sup>3</sup> are a low to moderate estimate as Palmer (2004) mentions that fees can go up to IDR 50 000/m<sup>3</sup>, and Barr et al. (2001) measured up to IDR 30 000 IDR/m<sup>3</sup>. The IDR 5000 fee follows an example in Malinau mentioned by Barr et al. (2001: 32).

## Agriculture

For many years, livelihoods in Malinau district have been dominated by agriculture, hunting, and gathering. Of the local population, about 75% live outside the district capital, with the majority being swidden cultivators. A few are hunter-gatherers, but at least 80%–85% of these Punan households undertake farming (Levang et al. 2005). Despite the prevalence of agriculture, its formal contribution to the district's economy was only 6% in 2002 (BPS 2003 in Andrianto 2006). The population sub-model drives the rate of increase or decrease in farming households, and this feeds directly to the area farmed. A slight shift from jobs in agriculture to jobs in the service and trade industry is modeled as a result of urbanization.

We distinguish between permanent and swidden cultivation (Table 1). The former is intensive crop and tree production. Swidden cultivation is prevalent. It starts with the conversion of logged-over primary forest to dryland rice cultivation. After about 2 years, when crop yields are low and weed infestation increases, farmers abandon the field and it becomes bush fallow. At the moment, the pressure on the land is so low that bush fallow is left to grow into secondary forest, which is only turned into swidden fields again when it is very old and resembles primary forest. However, under the oil palm scenario, primary and old secondary forest in the vicinity of the villages will become scarce, and thus, farmers will be forced to reduce the fallow period, which will result in higher levels of weed infestation and lower per hectare swidden yields (modeled to drop by 30%).

## Mining

A small portion of the landscape is allocated to coal mining (Table 1), but of that, only about 30% has been mined. Recently mining activities ceased

because of the costs of extraction. It is difficult to predict future mining activities, but given the high transport costs in Malinau, we have assumed only a small annual increase in the area mined (e.g., from 1000 to about 2000 ha/year under scenario 4). This increase is due to population increase, where a proportion of the unemployed commence artisanal mining.

## Forest Products

People in Malinau depend heavily on forest products for their livelihoods. Levang et al. (2005) found that 72% of the local Punan people collect forest products, but only 16% rely on it for their main cash income. Their study shows that the mean annual income of a Punan household from agriculture is IDR 1.67–2.25 million, whereas that from forest products is IDR 1.72–4.56 million, depending on the remoteness of the villages. These figures apply better to the more remote hunter-gatherer communities. According to Pambudhi et al. (2004), oil palm and pulp plantations often displace villagers and their rattan gardens. An increase in IPK logging and plantations is assumed, in the model, to result in decreased availability of non-timber forest products (NTFPs). We assume in the model that about 70% of local people are involved in forest product collection, but that only 10% of migrants collect forest products.

## Simulated Land-cover Changes

Under the no plantation development scenario, we assume that the current secondary forest (about 120 000 ha) can grow into primary logged-over forest during the simulation, whereas under the other scenarios, we assume no such land-cover change because of the high pressure on the forest. Without plantation development, there is a loss of only about 5% of primary and primary logged-over forest over 40 years, largely as a result of on-going small-scale agriculture (Fig. 3). The simulations where forest conversion permits are issued (2–4) suggest a loss of about 20% of the primary and primary logged-over forest over 40 years.

Agriculture comprises a very small part of the landscape initially because of the low population numbers and the low commercial demand for agricultural products. With the forest clearance scenarios, agricultural area increases 4.5 to 11 times

(scenario 2 and 4, respectively), because of expanding populations (see next section). As land will become scarce in the legally available area, between 200 000 and 360 000 ha of forest in the permanent forest domain will be converted into agriculture under scenarios 2, 3, and 4. Degraded forest covers 16 000 ha at the start of the simulation, but this expands to about 60 000, 85 000, 100 000, and 140 000 ha in scenarios 1, 2, 3, and 4, respectively, mainly as a result of the increase in bush fallow.

Fire is not included in the model, and has not been a feature of Malinau. As such, the amount of forest lost could be underestimated in the oil palm scenarios. Fire is a significant threat in other parts of Indonesia, and forest concessionaires and those seeking to establish tree crop plantations are considered major contributors to fire frequency (Göñner 2000, Food and Agriculture Organization (FAO) 2003). Once fire enters the system, it may remain as a permanent feature (du Toit et al. 2004). The Department of Forestry and Plantations (1998, in Casson 2000) holds oil palm expansion partly responsible for the 1997–1998 forest and land fires that affected more than 5 million ha of forest in Kalimantan.

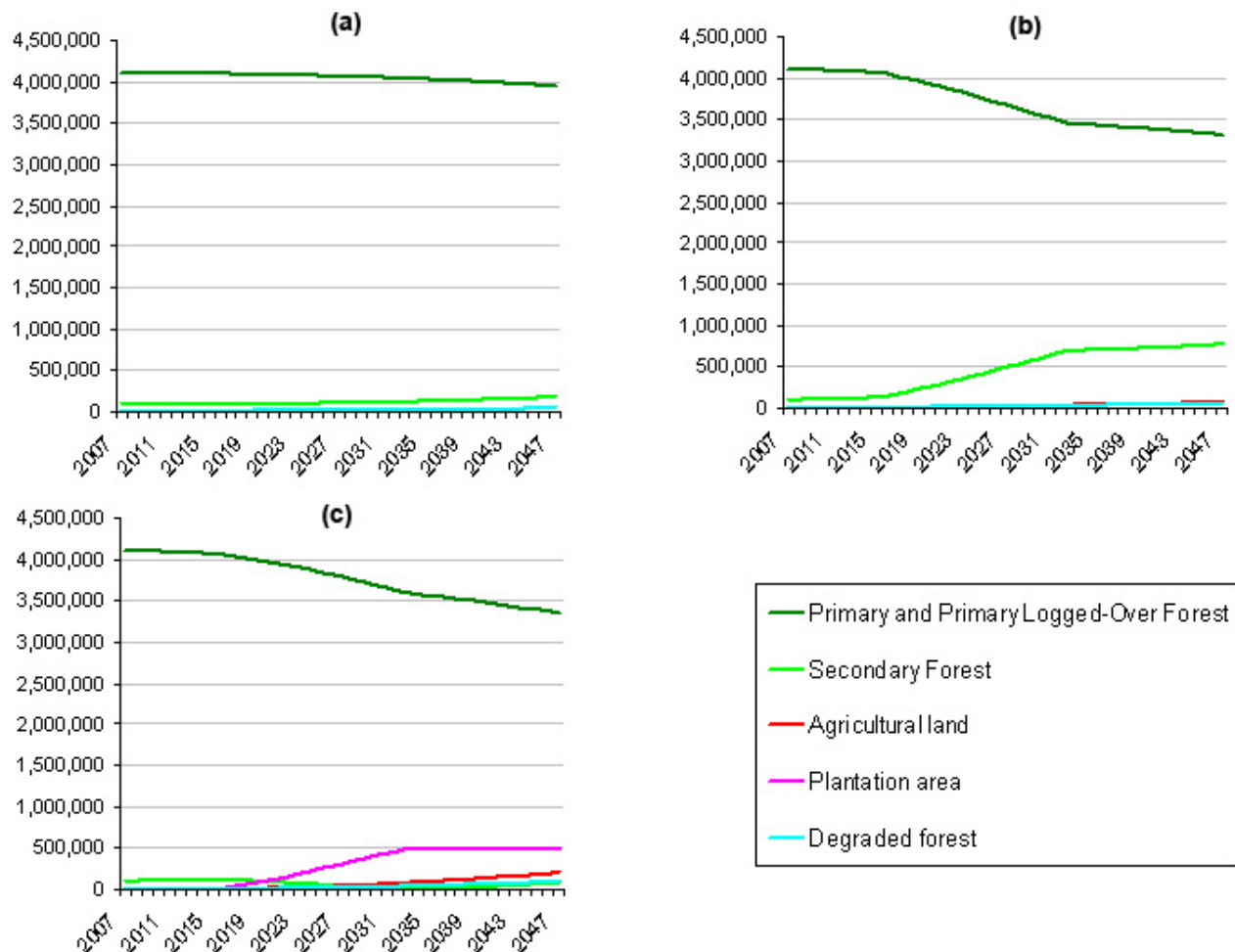
## ECONOMIC DEVELOPMENT

### Population Numbers

The total population in Malinau district was 59 212 in 2006 (BPS Malinau, unpublished data) and has increased by 6.5% yearly over the last 8 years (cf. Bappeda Tk II Bulungan 1998 in Barr et al. 2001; BPS Malinau, unpublished data). This high annual rate of increase is mainly caused by in-migration related to new economic opportunities. The average increase in the urban Malinau sub-district was 8.5%–9% compared with 3% in the rural sub-districts. The model simulates natural growth and in-migration, and differentiates between local people and transmigrants. CIFOR researchers estimate that of the 59 212 in the district about 7000 are immigrants, most living in Malinau town and some in Long Loreh, where the mining company was active. In-migration in the model is largely driven by jobs in IPK logging and oil palm plantations, where we assume that three people immigrate for each new job filled by a migrant, causing the migrant population to rise sharply with plantation development scenarios (Fig. 4). The total



**Fig. 3.** A 40-year simulation of land cover in Malinau district: (a) Scenario 1, No clearing permit given out; (b) Scenario 2, Forest clearing without oil palm planted; (c) Scenario 4, Plantation development (high employment).



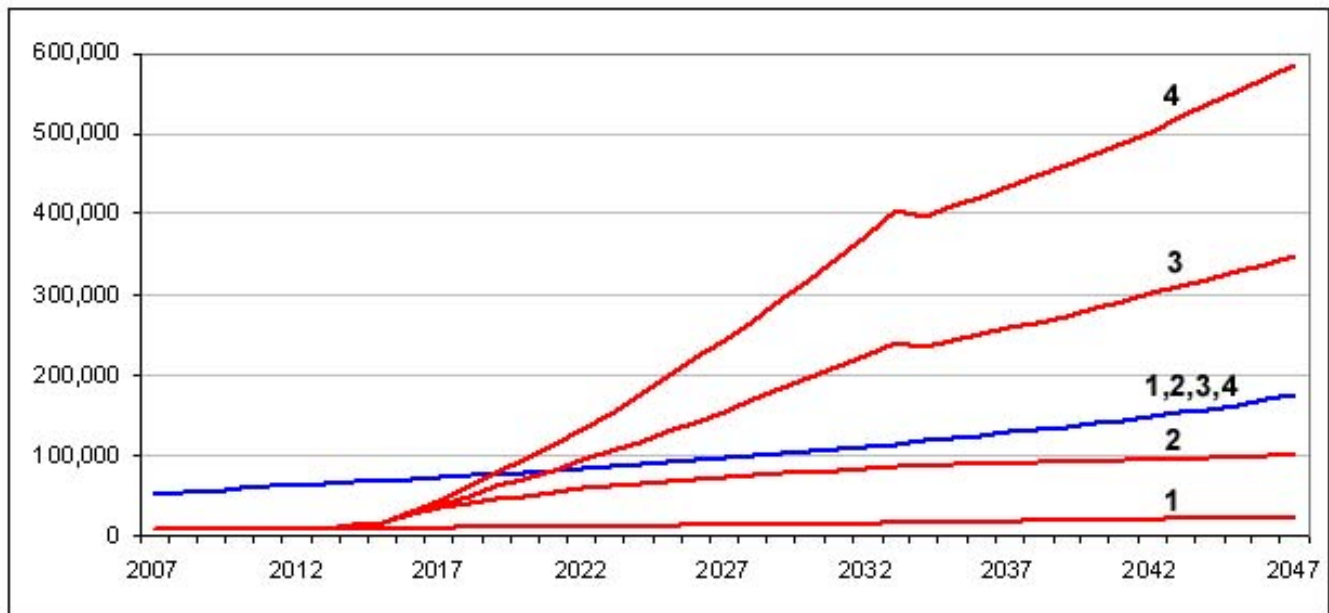
population in Malinau under the plantation development scenario will increase by 4.7 (scenario 2) to 13.5 times (scenario 4) after 40 years. After year 2027 of the simulation, the employment drops because of the sharp decrease in timber jobs (2027) when IPK logging stops. For the model, we assume that, where migrant employment drops under 35% (meaning less than 35% of employable migrants are employed), this results in out-migration rates as high as 2%. Under scenario 4, the now modest number of 7000 migrants will increase by a factor of 80 after 40 years. Although the local Dayak people are

currently in the majority, they will be a minority if 500 000 ha are planted with oil palm.

### Financial Compensation from Logging Companies to Local Communities

Decentralization not only resulted in district governments securing a greater share of forestry revenues, but also had implications for local communities. A 2000 law entitles communities to

**Fig. 4.** A 40-year simulation of total local population (blue lines) and migrant population (red lines) in Malinau district, under the four different scenarios (1= no plantation; 2 = IPK clearing without plantation development; 3 = plantation development assuming low employment; and 4 = plantation development assuming high employment).



demand compensation for timber harvesting from concession holders, although this law is open to dispute because of weak enforcement of property rights (Engel et al. 2006). Andrianto (2006) records greater conflicts among communities, and environmental degradation following the implementation of the new regulations regarding logging, and he concludes that, in West-Kutai and Malinau districts, the policies have failed to increase the standard of living of poor communities. On the contrary, Palmer (2004) states decentralization has undoubtedly led to higher capture of logging rents by the Sekatak community in Malinau. Palmer (2004) and Barr et al. (2001) indicate mixed outcomes from local negotiations, Barr et al. (2001:30) noting that many agreements are “absurd or have been unfulfilled.” Palmer (2004) mentions IPPK fees of around IDR 50 000/m<sup>3</sup> of timber going to local communities. Although this is low, it is five times more than those paid by the large logging companies that dominated the logging industry before decentralization.

### Household Income

At the start of the simulation, the percentage of households was highest in the agricultural sector (76%) (Table 2). With the exception of scenario 4, agriculture remains the most important sector throughout the simulations, although under scenarios 2–4, the number of households in the timber sector increases more than tenfold after 20 years (mainly because of IPK). In 2027, the most substantial number of households will be active in the oil palm sector in scenarios 3 and 4, although by 2047, this will have shifted to the agriculture and the trade and services sectors because the number of jobs in the oil palm sector does not continue to increase after 25 years even though the population does. The creation of employment in the region is substantial under the oil palm scenario, even when a low employment rate in oil palm plantations is used. With scenario 1, the total number of formal jobs available (in mining, timber and civil service) does not exceed 10 000. In the other scenarios, the number of formal jobs reaches as high as 22 000

(scenario 2), 71 000 (scenario 3), and 120 000 (scenario 4).

The significant amount of income generated by employment in oil palm in year 2027 under scenarios 3 and 4 is shown in Table 3. There are also associated expansions in other sectors, driven by the plantation economy. The income from agriculture increases substantially, for example. With an increase in employment, we assume a high demand for agricultural products and roads opening up the area improve market access. Where most of current production is for auto-consumption, we expect an increase in permanent agriculture and the demise (in proportionate terms) of swidden cultivation.

Levang et al. (2005) undertook household surveys, sampling 254 Punan households in six different settlements in Malinau and neighboring districts. They found 83% of the sampled households live under the US\$1/day poverty line. Average household incomes are improved under the oil palm scenarios (3 and 4), increasing by 60%–150%, but increasing <10% in scenario 1 without oil palm (Table 3, last row). Household incomes are also raised with forest clearing without oil palm (scenario 2) after 20 years, but once forest clearing stops, the average incomes decline, and after 40 years, average household incomes are lower than when no IPK forest clearing had occurred (scenario 1).

The above figures hide the differentiation between local and migrant households. The activity portfolio differs substantially for migrant and local households. Migrants are currently largely urban, with a high percentage of households active in the trade and service industries (Table 4). Jobs in the timber and plantation sector typically go to migrants, who often have higher schooling levels. Local people, however, are currently given priority for all jobs in the civil service, and they are the ones receiving compensation fees for logging (Table 4). Local people receive short-term benefits from scenario 2 (2027), with more commercialized agriculture, more civil service jobs, and timber fees. After 40 years, however, they are left with hardly any forest in proximity to their villages, reducing their income from forest products and shortening their fallow periods in shifting cultivation, and consequently lowering their yields. Migrants will receive most of the short-term benefits, getting most jobs in IPK forest clearing. After 40 years, the high

unemployment for migrants will cause some out-migration, although most are expected to remain; a portion will buy a piece of agricultural land and start farming for much lower earnings. This scenario is expected to cause high levels of conflict.

Scenarios 3 and 4 improve incomes for both local people as well as migrants. Local people's incomes increase most in year 2027 when timber fees increase >20 times (scenario 4 in Table 3), and drop thereafter when IPK logging ends. Local household incomes remain 30%–65% higher than under scenario 1 at the end of the simulation, mostly because of commercialization of agriculture, although jobs in the civil service, trade, and the service industry also contribute to higher incomes (Table 4a). Migrants' incomes are also highest in year 2027 because of jobs in IPK logging (Table 4b). After the sharp decline in IPK employment, some of the migrants will obtain employment on the plantations and some will buy some land for agriculture. Although incomes may have increased under oil palm development, overall well-being is more difficult to judge. Koczberski et al. (2001) and Casson (2000) report cases of local resentment over benefits from oil palm plantations going to outsiders. Colchester et al. (2006) give examples of increased social and financial costs with oil palm arrival. For example, there were social costs of resolving conflicts over land and benefit sharing associated with oil palm estates. Air quality declined, and there was a worrying increase in alcohol abuse in local communities. More research is needed on the negative and positive impacts on local people of oil palm plantations.

## District Development

Since Malinau was declared a new district in 1999, district income has increased dramatically from only IDR 5.8 billion in 2000 (Barr et al. 2001) to IDR 405 billion and IDR 615 billion in 2002 and 2003, respectively (Andrianto 2006). Using per ha and per m<sup>3</sup> payments applied to IPPK in Malinau (Barr et al. 2001), the issuance of IPK permits for the clearance of 500 000 ha forest will provide the district with a cumulative income of IDR 703 billion over 20 years. Under scenarios 3 and 4, an additional IDR 102 billion is provided over the 40-year simulation by oil palm production fees. However, the district income will increase by more than these fees alone, as the increased economic activity is



**Table 2.** Employment in different sectors (number of households per sector), and total population in Malinau district

	No. of Households <sup>†</sup>								
	Start		Simulation results						
	2007	2027					2047		
Primary activities of households:		1. No plantation development	2. Forest clearing without oil palm planting	3. Plantation development with 0.1 jobs/ha	4. Plantation development with 0.2 jobs/ha	1. No plantation development	2. Forest clearing without oil palm planting	3. Plantation development with 0.1 jobs/ha	4. Plantation development with 0.2 jobs/ha
Agriculture and NTFPs	9 900	17 700	21 800	24 700	28 500	31 500	43 000	54 800	76 600
Timber Concession	1 000	1 200	11 100	11 100	11 100	1 500	1 500	1 500	1 500
Plantation	0	0	0	21 100	42 200	0	0	31 600	63 200
Mining	200	300	300	300	300	500	500	500	800
Gov. officials and civil servants	1 300	2 400	3 500	4 200	5 300	3 700	4 300	6 200	9 800
Trade and service industries	1 400	4 300	8 900	15 400	22 400	11 300	18 300	35 200	58 700
Total households <sup>‡</sup>	12 900	23 300	35 700	53 500	72 500	42 200	58 000	95 900	148 400
Total population	60 000	108 600	166 300	249 200	338 100	196 500	270 200	446 700	691 500

<sup>†</sup> Average numbers of workers per household for the specified sectors are assumed to be as follows: agriculture – 3; mining and trade – 1; timber plantation and civil service – 1.5 workers per household.

<sup>‡</sup> The total of households involved per activity can be higher than the total households because some households are involved in more than one activity.

**Table 3.** Total income (in billions IDR) per sector for all households in Malinau, with the last row showing averages per household

Primary activities of households:	Start of simulation (2007)	Simulation results – 2027				Simulation results – 2047			
		1. No plantation	2. Forest clearing without oil palm planting	3. Plantation development with 0.1 jobs/ha	4. Plantation development with 0.2 jobs/ha	1. No plantation	2. Forest clearing without oil palm planting	3. Plantation development with 0.1 jobs/ha	4. Plantation development with 0.2 jobs/ha
Agriculture	27	51	89	155	245	93	131	382	845
Forest Products	26	45	21	38	36	76	0	17	15
Timber concessions	13	16	165	162	162	20	20	20	20
Plantation	0	0	0	300	600	0	0	449	899
Mining	0.2	0.3	0.3	0.2	0.3	0.4	0.5	0.5	0.7
Gov. officials and civil service	24	44	66	79	98	68	79	115	181
Trade and service industries	16	48	130	248	374	122	249	553	975
Timber fees	2.5	3.0	15.4	52.6	52.6	3.7	3.7	3.7	3.7
<i>Total</i>	<i>109</i>	<i>207</i>	<i>485</i>	<i>1034</i>	<i>1569</i>	<i>383</i>	<i>483</i>	<i>1540</i>	<i>2939</i>
<i>Average per hh (in millions IDR)</i>	<i>8.5</i>	<i>8.9</i>	<i>13.6</i>	<i>19.3</i>	<i>21.6</i>	<i>9.1</i>	<i>8.3</i>	<i>16.1</i>	<i>19.8</i>

expected to substantially augment tax payments in the district. The simulated additional tax payments over 40 years for scenarios 2–4 are IDR 22 billion, IDR 149 billion, and IDR 276 billion, respectively.

## DISCUSSION

### Are Payments for Environmental Services a Viable Economic Option for the District?

Given the economic attractiveness of the oil palm development scenario to district and national

government stakeholders, as well as to key local people (e.g., those who may benefit from land sales or various illegal transactions), the question is whether conservationists have alternative development scenarios. Much is made of direct payments for environmental services (PES) (Ferraro and Kiss 2002), and one could argue that the global community interested in biodiversity could change the incentive structure for local and district stakeholders by paying for biodiversity services provided by Malinau. However, the area is vast and the size of payments (needed to get household income increases similar to those offered by the oil

**Table 4.** Average annual cash income (millions IDR) for (a) local households, and (b) migrant households; and percentage contribution of each activity to annual income, under four different scenarios

(a) Local households	Start of simulation (2007)	Simulation results – 2027				Simulation results – 2047			
		1. No plantation	2. Forest clearing without oil palm planting	3. Plantation development with 0.1 jobs/ha	4. Plantation development with 0.2 jobs/ha	1. No plantation	2. Forest clearing without oil palm planting	3. Plantation development with 0.1 jobs/ha	4. Plantation development with 0.2 jobs/ha
Average annual hh income (in millions IDR)	7.8	8.2	9.3	14.6	16.6	8.4	6.7	10.7	13.8
<i>Share from:</i>									
Agriculture	28%	27%	32%	27%	28%	27%	34%	41%	43%
Forest products	29%	26%	10%	11%	9%	24%	0%	4%	2%
Timber, plantation, and mining jobs	7%	4%	4%	15%	20%	3%	4%	12%	17%
Civil service jobs	24%	23%	31%	19%	19%	20%	29%	21%	21%
Trade and service	9%	17%	15%	10%	9%	26%	33%	21%	16%
Timber fees	3%	2%	8%	18%	15%	1%	1%	1%	1%

[illegible]

palm scenarios) would range between US\$25–50 million/year. This is probably beyond most budgets for conservation. The difficulty of securing biodiversity payments is illustrated by Wunder et al. (2004).

Carbon (C) PES may have the highest potential for influencing district decisions regarding forest conversion. For C payments to provide the district (i.e., excluding household income considerations) with the same level of district income as scenario 4, an average yearly payment of IDR 27 billion would be needed (about US\$3 million/year). According to de Bruijn (2005), the C content of 1 ha primary forest is roughly 300 ton C/ha, whereas the C content for oil palm is 50–125 ton C/ha. A modest estimate of the amount of C to be saved from being emitted if the forest is not converted to oil palm plantation is thus 175 ton C/ha, equivalent to 647 ton CO<sub>2</sub>/ha (assuming it is mostly primary forest that is lost). For a total 500 000 ha of primary forest that would be lost in the plantation development scenario, it would be possible to recoup the foregone district income with a C payment, as, at US\$2/ton CO<sub>2</sub>, in excess of \$15 million/year could be generated if the payments were structured over 40 years. Karky (2006:14) mentions a “conservative price assumption” of US\$2/ton CO<sub>2</sub> on the Clean Development Mechanism (CDM) market. Avoided deforestation is not currently part of the CDM, so the price would probably be lower, but others talk of vastly higher prices in the future. Transaction costs on avoided deforestation would be high. For example, an elaborate monitoring system would need to be established to check compliance, but even then it is possible that C could compete with oil palm for district income. This PES scenario would not lead to jobs and higher economic development in the district. PES scenarios whereby some money is paid directly to communities would also need to be explored.

### **Can Ecotourism and Forest Product Certification Provide an Economic Alternative to Oil Palm Development?**

Approximate calculations indicate that Malinau would have to host 50 000–150 000 tourists each year to generate the household income that the oil palm scenarios produce (assuming tourists stay on average 10 days and spend US\$30/day that goes to Malinau households). Malinau has much to offer tourists with its vast intact forest and cultural

diversity, but despite 19 years of lobbying by a conservation NGO, Kayan Mentarang National Park registers fewer than 40 tourists a year (Iskandar, pers. comm. 2007). Ecotourism will not be able to compete with oil palm, at least in the foreseeable future. Furthermore, even under the oil palm scenarios, most of the district will remain forested so ecotourism development is not excluded from these scenarios.

Fair trade labels and natural product labels for forest products can increase prices, but not to the extent that would be required if forest products were to compete with plantations as a source of income for districts and households. To compete, incomes from forest products would have to grow at least by five- to seven-fold. Paz Soldan and Walter (2003) give an example of certified Brazil nuts in Chile, which after certification, had a 1.7–2.2 times higher price.

### **Conservation and Development Trade-offs**

Malinau district illustrates the tensions that exist between conservation and development, but also illustrates how these trade-offs are perceived differently by the various stakeholders. Malinau, with its vast forests is one of the rainforest biodiversity hotspots of the world (Mittermeier and Bowles 1993), and conservationists are up in arms over the proposed plans for logging and conversion to oil palm (e.g., see Wakker 2006, a study commissioned by Friends of the Earth). Even though the head of government in Malinau is willing to declare the district a “conservation district” (one of three in Indonesia), he sees no conflict between this declaration and his support for large-scale conversion to oil palm. When asked, local people are all in favor of some form of conservation measures being taken (Padmanaba and Sheil 2007), but local people also want the benefits of development (Levang et al. 2007).

Researchers have witnessed massive change in Malinau over the last decade (Sayer and Campbell 2004), and it is conceivable that land-use change is likely to be widespread and accelerating, largely driven by decisions made in the district capital and beyond. And these decisions will inevitably involve logging and plantation development, but perhaps also mining. Allocating primary and secondary forest to plantations and other intensive land uses can be to the benefit of many stakeholders, but it can simultaneously increase poverty for others. The

behavior of the plantation concessionaires is crucial as to the outcomes for local people. Careful decisions have to be made when selecting companies for land clearing, and contracts have to be watertight so that companies deliver on promises. If companies were to plant oil palm, some local people see the promise of jobs with higher cash incomes. District officials see greater economic activity, more immigrants, and larger district budgets. Migrants from other more populous districts see jobs. Some of the income gets back to the national coffers and the nation's politicians and officials see development occurring, which is a major aspiration. Even with 500 000 ha of forest cleared, most of the district would remain under forest at the end of the 40-year simulation period. If this is the case, then, many would argue that plantation development scenarios are not at odds with the district proposal of a conservation district. But such development does have its risks. First, we have not factored in fire; if large forest fires enter the system, as happened in 1997–1998 in other parts of Kalimantan, then forest quality could be substantially reduced. Third, with such a large migrant population under the oil palm scenarios, future pressures on the environment (e.g., artisanal gold panning) are likely to increase.

On the basis of economic argument, part of the forest is likely to be converted, although remoteness and poor soil quality may keep plantations out of Malinau for some time. There are social and environmental costs, not captured in the economic argument. For example, Koczberski et al. (2001) and Casson (2002) have both recorded resentment by local people toward migrants with jobs in plantations. In Malinau, this could be more extreme as local people will be quickly outnumbered by migrants. Colchester et al. (2006) report local people's complaints about plantations in other parts of Kalimantan where individual profit seeking has replaced traditions of communality and solidarity. However, Sheil et al. (2006) mention "decision makers prefer to focus on the general rather than the particular," so whether these negative aspects are taken into account when the decision on development is made remains to be seen.

If conservationists don't like the idea of large-scale land-cover change, do they have alternatives for those hungry for development? Certification of forest products and ecotourism alone are not likely to provide incentives to halt forest conversion.

Carbon payments could conceivably bring district benefits as high as those derived from logging and plantations. However, the science and politics of avoided deforestation is poorly developed, and requires urgent and major research investment. Decisions about developing plantations today will not wait for the long process of international negotiation on mechanisms for C payments.

## The Modeling Process

We reiterate that the model is not meant as a predictive tool—its primary use is to promote dialog about alternative trajectories of change. Like any model, ours makes many assumptions and simplifications. We have endeavored to make these assumptions and simplifications as reasonable as we can, based on the information available to us. Nonetheless, whether our model yields a credible representation of Malinau can be questioned by those who disagree with these choices or who would emphasize unknowns or uncertainties. For example, our model cannot be taken as evidence that 500 000 ha of oil palm developments in Malinau will be commercially successful—this would require field-based land-suitability evaluations, for example. Furthermore, a more thorough accounting of the impacts in each scenario would require environmental and social impact assessments focused on the specific areas to be planted in light of the specific development plans proposed and the management standards applied—something that we make no claim to have done. We would obviously expect that normal processes of civil society participation should underlie all decision making and that Indonesian laws regarding the changes in the status of land be respected.

The modeling process has already achieved some of its objectives. Debate within CIFOR was generated by the conflicting perspectives on oil palm development: as a source of economic development, and as a cause of forest destruction and negative impacts on forest-dependent people. Some scientists pointed to particular reports that needed to be cited showing the negative impacts of oil palm, and others requested that those references be removed because they were based on advocacy rather than scientific analysis. Very few detailed impact studies are available, and given the increased interest in oil palm for biofuel, research on the social and economic impacts of oil palm is urgently required.

The discussions at the district level tended to focus on in-migration and C payments. District officials were exceptionally nervous about the immigration rates that large-scale oil palm plantations would stimulate, as the district is currently dominated by Dayaks (who also hold positions of power) and this could change with high in-migration. The model filled its role as a means to stimulate discussion, and helped officials see some of the potential negative sides of large-scale oil palm development. The model supported policy changes on land use in Malinau, tempered local government's enthusiasm for oil palm (mostly in relation to migration), and spurred their interest in PES schemes as an alternative to oil palm development (Dwi, pers. comm. 2007). The district head requested help in using some of the model outputs at the United Nations Framework Convention on Climate Change in Bali in 2007, so that he could argue the case for avoided deforestation and a C market. Modeling has demonstrated its power in generating ideas and fostering shared understanding, allowing some of the ramifications of different courses of action to be explored. It also increases transparency in decision making. The model identified a number of areas where further research will be needed if sound land-allocation decisions are to be made in Malinau.

Responses to this article can be read online at:  
<http://www.ecologyandsociety.org/vol12/iss2/art37/responses/>

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## LITERATURE CITED

- Andrianto, A.** 2006. *The role of district government in poverty alleviation: case studies in Malinau and West Kutai Districts, East Kalimantan, Indonesia*. Center of International Forestry Research (CIFOR), Bogor, Indonesia.
- Badan Perencanaan Pembangunan Daerah (Bappeda).** 2002. District Planning and Development Agency, unpublished data on Kayan Mentarang National Park Boundaries.
- Badan Pusat Statistik (BPD) Malinau.** 2006. Kabupaten Malinau Dalam Angka. District Statistical Office, unpublished data.
- Barr, C., E. Wollenberg, G. Limberg, N. Anau, R. Iwan, M. Sudana, M. Moeliono, and T. Djogo.** 2001. *Case study 3: the impacts of decentralization on forests and forest-dependent communities in Kabupaten Malinau, East Kalimantan*. Case studies on Decentralization and Forests in Indonesia. CIFOR, Bogor, Indonesia.
- Basuki, I., and D. Sheil.** 2005. *Local perspectives of forest landscapes. A preliminary evaluation of land and soils, and their importance in Malinau, East Kalimantan, Indonesia*. CIFOR. Bogor, Indonesia.
- Casson, A.** 2000. *The hesitant boom: Indonesia's oil palm sub-sector in an era of economic crisis and political change*. CIFOR Occasional Paper 29, CIFOR, Bogor, Indonesia.
- Castaño, J., editor.** 2006. Kalimantan Governor Suspended for Plantation Fraud. *Tropical Timber Market Report* 11(23):4–5. (online) URL: <http://ce.coeco.catie.ac.cr/descargas/Dec06a.pdf>.
- Colchester, M., N. Jiman, M. Andiko, A. Sitait, A. Y. Firdaus, A. Surambo, and H. Pane.** 2006. *Promised land—palm oil and land acquisition in Indonesia: implications for local communities and indigenous peoples*. Forest Peoples Programme, Perkumpulan Sawit Watch, Huma and the World Agroforestry Center, Bogor, Indonesia.
- de Bruijn, A.** 2005. *Carbon dynamics simulation in Malinau Research Forest, Borneo, Indonesia*. Thesis, Wageningen University and Research Center, The Netherlands.
- Dinas Kehutanan dan Perkebunan Kab. Malinau.** 2006. District Forestry and Estates Crops Service, unpublished data.
- du Toit, J. T., B. H. Walker, and B. M. Campbell.** 2004. Conserving tropical nature: current challenges for ecologists. *Trends in Ecology and*



*Evolution* 19:12–17.

**Engel, S., R. Lopez, and C. Palmer.** 2006. Community-industry contracting over natural resource use in a context of weak property rights: the case of Indonesia. *Environmental and Resource Economics* 33(1):73–93. (online) URL: <http://www.springerlink.com/content/k44037146p22/>.

**Food and Agriculture Organization (FAO).** 2003. FAO facts and figures, country information: Indonesia forests and the forestry sector. [online] URL: [http://www.fao.org/spfs/indonesia/index\\_en.asp](http://www.fao.org/spfs/indonesia/index_en.asp)

**Ferraro, P., and A. Kiss.** 2002. Direct payments to conserve biodiversity. *Science* 29:1718–1719.

**Gönner, C.** 2000. Causes and impacts of forest fires: a case study from East Kalimantan, Indonesia. *International Forest Fire News* 22:35–40.

**High Performance Systems.** 1996. *STELLA and STELLA research software*. High Performance Systems, Inc. Hanover New Hampshire, USA.

**Karky, B. S.** 2006. *Case study 1: Kafley Community Forest, Lamatar, Nepal*. Pages 8–15 in D. Murdiyarso and M. Skutsch, editors. *Community forest management as a carbon mitigation option*. CIFOR, Bogor, Indonesia.

**Koczberski, G., G. Curry, and K. Gibson.** 2001. *Improving productivity of the smallholder oil palm sector in Papua New Guinea: a socio-economic study of the Hoskins and Popondetta schemes*. The Australian National University, Canberra, Australia.

**Koh, L. P., and D. S. Wilcove.** 2007. Cashing in palm oil for conservation. *Nature* 448:993–994.

**Levang, P., E. Dounias, and S. Sitorus.** 2005. Out of the forest, out of poverty? *Forests, Trees and Livelihoods* 15:211–236.

**Levang, P., S. Sitorus, and E. Dounias.** 2007. City life in the midst of the forest: a Punan hunter-gatherer's vision of conservation and development. *Ecology and Society* 12(1): 18. [online] URL: <http://www.ecologyandsociety.org/vol12/iss1/art18>.

**Lynam, T., F. Bousquet, C. le Page, P. d'Aquino, O. Barreteau, F. Chinembiri, and B. Mombeshora.** 2003. *Adapting science to adaptive*

*managers: spidergrams, belief models, and multi-agent systems modeling*. Pages 157–174 in B. M. Campbell and J. A. Sayer. *Integrated natural resources management: linking productivity, the environment and development*. CABI Publishing, Wallingford, UK.

**Lynam, T., R. Cunliffe, D. Sheil, M. Wan, A. Salim, H. Priyadi, and I. Basuki.** 2006. *Livelihoods, land types and the importance of ecosystem goods and service: developing a predictive understanding of landscape valuation by the Punan Pelanrau people of East Kalimantan*. CIFOR, Bogor, Indonesia.

**Mittermeier, R. A., and I. A. Bowles.** 1993. *The GEF and biodiversity conservation: lessons to date and recommendations for future actions*. Conservation International Policy Papers I. Conservation International, Washington, D.C., USA.

**Obidzinski, K., and C. Barr.** 2003. *Case study 9: the effects of decentralisation on forests and forest industries in Berau District, East Kalimantan* Case Studies on Decentralisation and Forests in Indonesia, CIFOR, Bogor, Indonesia.

**Padmanaba, M., and D. Sheil.** 2007. Finding and promoting a local conservation consensus in a globally important tropical forest landscape. *Biodiversity Conservation* 16:137–151.

**Palmer, C.** 2004. *The role of collective action in determining the benefits from IPPK logging concessions: a case study from Sekatak, East Kalimantan* CIFOR Working Paper 28, Bogor, Indonesia.

**Pambudhi, F., B. Belcher, P. Levang, and S. Dewi.** 2004. Rattan (*Calamus* spp.) gardens of Kalimantan: resilience and evolution in a managed non-timber forest product system. Chapter 22 in K. Kusters and B. Belcher. *Forest products, livelihoods and conservation: case studies of non-timber forest product systems. Volume 1 – Asia*. CIFOR, Bogor, Indonesia.

**Paz Soldan, M., and S. Walter.** 2003. *The impact of certification on the sustainable use of Brazil nut (Bertholletia excelsa) in Bolivia*. Food and Agricultural Organisation (FAO), Rome, Italy.

**Reinhardt, G., N. Rettenmaier, S. Gärtner, and A. Pastowski.** 2007. *Rainforest for biofuel?*

*Ecological effects of using palm oil as a source of energy.* WWF Germany, Frankfurt am Main, Germany. [online] URL: [http://www.wwf.de/fileadmin/fm-wwf/pdf\\_neu/wwf\\_palmoil\\_study\\_english.pdf](http://www.wwf.de/fileadmin/fm-wwf/pdf_neu/wwf_palmoil_study_english.pdf).

**Sargeant, H. J.** 2001. *Vegetation fires in Sumatra, Indonesia. Oil palm agriculture in the wetlands of Sumatra: destruction or development?* European Union Forest Fire Prevention and Control Project with Dinas Kehutanan Propinsi Sumatera Selatan. European Union and Ministry of Forestry, Jakarta, Indonesia.

**Sayer, J., and B. Campbell.** 2004. *The science of sustainable development: local livelihoods and the global environment.* Cambridge University Press, Cambridge, UK.

**Sheil, D., R. Puri, M. Wan, I. Basuki, M. van Heist, N. Liswanti, Rukmiyati, I. Rachmatika, and I. Samsuudin.** 2006. Recognizing local people's priorities for tropical forest biodiversity. *Ambio* 35(1):17–24.

**Susila, W. R.** 2004. Contribution of oil palm industry to economic growth and poverty alleviation in Indonesia. *Jurnal Litbang Pertanian* 23(3):107–114.

**Tata Guna Hutan Kesepakatan (TGHK).** 2002. Forest Land Use Consensus, unpublished data.

**Topografi Kodam (TOPDAM).** 2004. Military Regional Commands Topography, unpublished data on Malinau Administrative Boundaries.

**Wakker, E.** 2006 *The Kalimantan border oil palm mega-project.* Aidenvironment. Commissioned by Friends of the Earth Netherlands and the Swedish Society for Nature Conservation. [online] URL: [http://www.orangutans-sos.org/downloads/palm\\_oil\\_mega\\_project.pdf](http://www.orangutans-sos.org/downloads/palm_oil_mega_project.pdf).

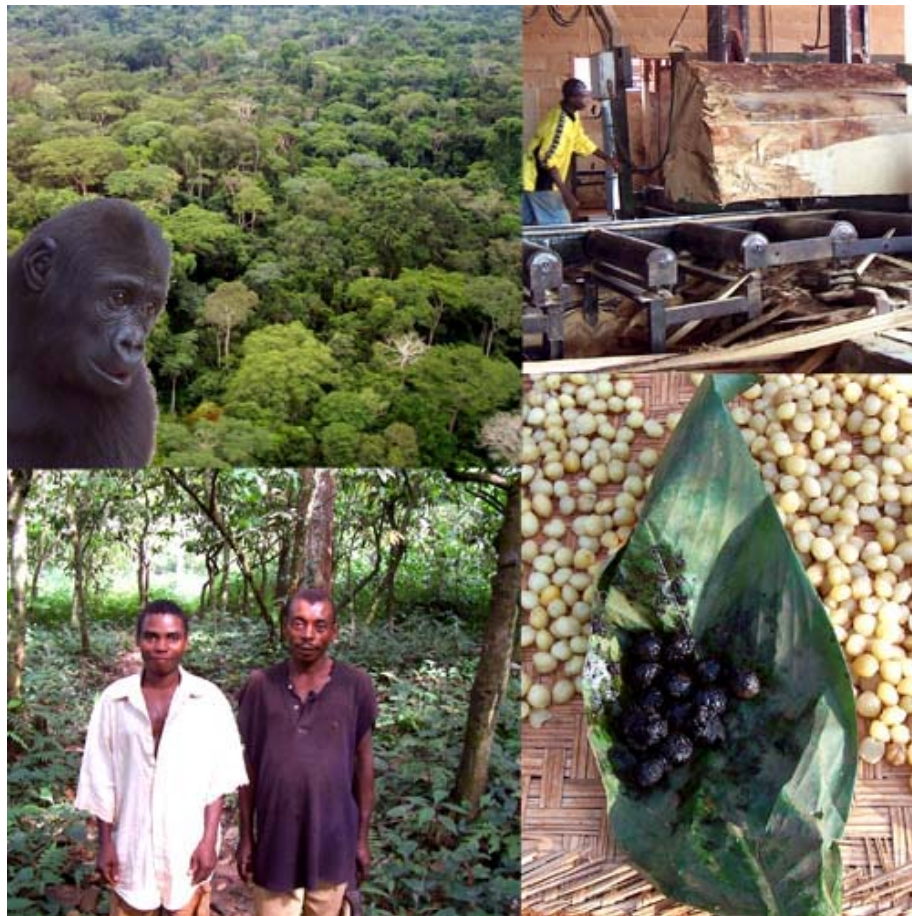
**Wunder, S., B. Campbell, R. Iwan, J. A. Sayer, and L. Wollenberg.** 2004. *When donors get cold feet: the community conservation concession in Setulang (Kalimantan, Indonesia) that never happened.* CIFOR, Bogor, Indonesia.





## Chapter 6

### Exploring the effectiveness of integrated conservation and development interventions in a Central African forest landscape



# Exploring the effectiveness of integrated conservation and development interventions in a Central African forest landscape

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**Abstract** Integrated conservation and development projects (ICDPs) have had limited success in addressing the often conflicting objectives of conservation and development. We developed a model with local participants to explore the trade-offs between conservation and development in southeastern Cameroon, where illegal hunting is regarded as the greatest challenge to conservation. We simulated the effects of different ICDP strategies by varying the degree of focus on antipoaching activities, anticorruption measures and direct development investments, and by varying the overall budget for such activities. Our outcome variables were numbers of selected wildlife species and household incomes. The model outcomes from the different scenarios were used to stimulate debate among stakeholders. Contributing to poverty alleviation while maintaining current animal population sizes will be extremely difficult and will require long-term external financial support. Devoting greater attention to improving local environmental governance emerged as the highest priority for this investment. We used the model outputs to inform some of the

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major policy makers in the region. Participatory modeling is a valuable means of capturing the complexities of achieving conservation at landscape scales and of stimulating innovative solutions to entrenched problems.

**Keywords** Cameroon · Corruption · Environmental governance · ICDP · Integrated conservation and development project · Participatory modeling · Trade-offs · Simulation models

### Abbreviations

ICDP      Integrated conservation and development project  
NGO      Nongovernmental organization  
SE TOU   South east technical operational unit

### Introduction

Reconciling conservation and development is notoriously difficult and the pursuit of this objective has led to polarized positions and contentious debate (e.g., Guha 1997; Oates 1999; Chapin 2004). A number of reviews suggest that integrated conservation and development projects (ICDPs) have not reconciled conservation and development agendas, and both conservationists and social scientists have harshly criticized ICDPs (e.g., Wells et al. 1998; Neumann 1998; Agrawal and Gibson 1999). Many believe integrated approaches have failed to deliver on their potential or promise. For example, in a review of 36 ICDPs, only five contributed directly to wildlife conservation (Kremen et al. 1994). McShane and Wells (2004) provide a comprehensive account of the difficulties of integrating conservation and development at the site level. Ferraro (2001) suggests that the indirect approach favored by ICDPs of providing alternative sources of products, income, or social benefits as a means of encouraging communities to cooperate in conservation initiatives is best described as “conservation by distraction”.

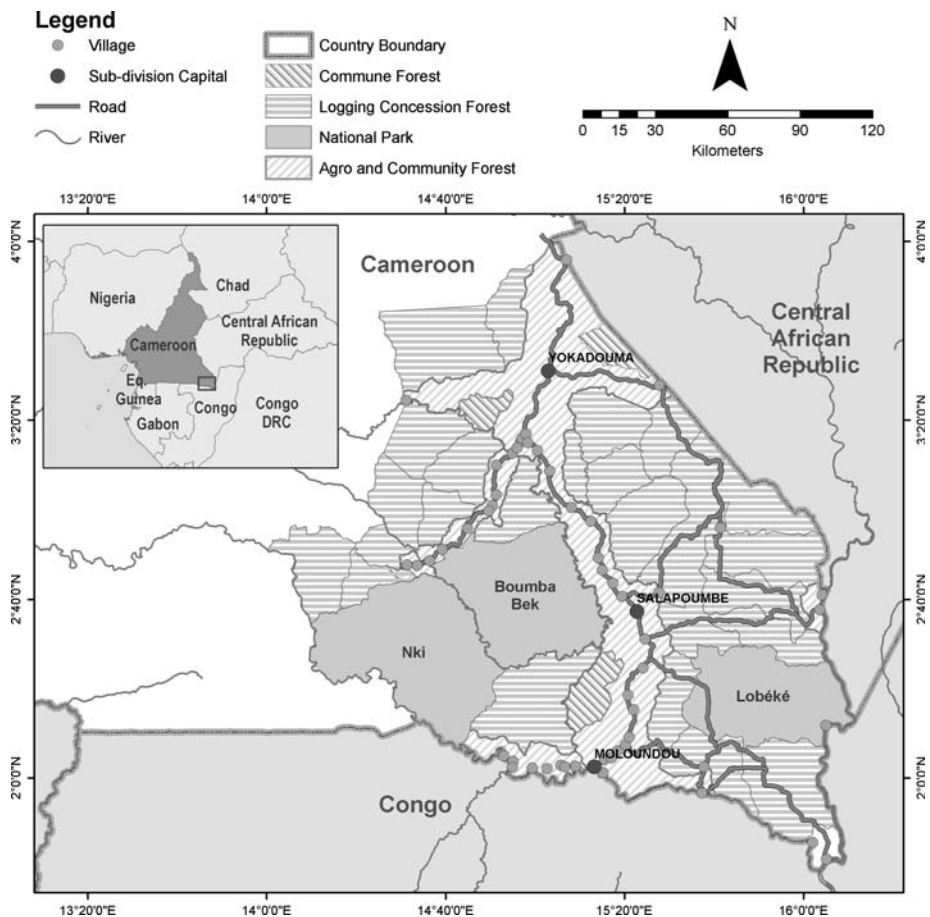
There are many advocates of disaggregating conservation and development initiatives. The proponents of the so-called preservationist or “fortress conservation” approach advocate focusing project investments on protection measures and largely excluding the economic and development aspirations of local people (Janzen 1986; Oates 1999; Terborgh et al. 2002; Sanderson and Redford 2003). However, critics argue that by pursuing a preservationist approach, local stakeholders are alienated (Chan et al. 2007), which ultimately leads to social conflict and noncompliance with conservation-related regulations (Ferraro and Kiss 2002; Romero and Andrade 2004; Robbins et al. 2006).

Some authors (Salafsky and Wollenberg 2000; Brown 2002; Malleon 2002) attribute the lack of success in integrating conservation and development interventions to the failure of conservation organizations to recognize that trade-offs exist and must be fully understood if they are to be reconciled. For example, it is argued there has been a persistent failure to provide communities with sufficient and appropriate alternative economic benefits to offset the restrictions on access to conservation areas (Ferraro 2001; Cernea and Schmidt-Soltau 2006). More specifically, Malleon (2002, p 100) suggests that, “[I]t is not the basic ICDP concept that has caused so many problems for Korup (National Park, Cameroon). Rather it is the lack of willingness among conservation biologists to support the devolution of the control of forest resources to communities and their failure to accept that difficult trade-offs have to be made between the interests of forest users, other key actors and the global concerns of conservation biologists.”

We examined the trade-offs and potential synergies between conservation and development in a case study in southeastern Cameroon, an area characterized by dire poverty and an exceptional diversity of large mammals (Mittermeier et al. 2005). We explored the use of a participatory systems modeling approach (Sayer and Campbell 2004) that involved the key conservation and development stakeholders in the region. We explored whether such an approach can stimulate discussion among the key stakeholders and promote action that generates conservation and development synergies. We take up the challenge of Cowling et al. (2004) of ensuring that the social aspects of conservation issues are tackled. In particular, we examined livelihood and governance issues for people in conservation landscapes.

## Study area

Our model focused on the “South East Technical Operational Unit” (SE TOU) in Cameroon (Fig. 1). Part of this area is included in the Tri National de la Sangha landscape that extends



**Fig. 1** Land use in the South East Technical Operational Unit of Cameroon (from maps from the German Development Cooperation and World Wildlife Fund)

into the Central African Republic and Congo-Brazzaville. The Tri National de la Sangha is one of 11 “landscapes” identified as conservation priorities under the Congo Basin Forest Partnership launched at the Johannesburg Earth Summit in 2002 (CBFP 2005). The area has outstanding assemblages of forest megafauna, including forest elephants (*Loxodonta cyclotis*), western lowland gorillas (*Gorilla gorilla gorilla*), chimpanzees (*Pan troglodytes troglodytes*), and bongos (*Boocercus euryceros*).

The total area of the SE TOU is 33,571 km<sup>2</sup> (26% national parks, 52% logging concessions, 3% commune forests, and 19% agroforests and community forests). Commune forest is for use by a commune—a local government unit headed by a mayor. It cannot be converted for agriculture but can be logged. Community forest can be converted and is subject to a management agreement between the state and local communities, through which the communities receive use rights, responsibilities and financial benefits from forest management. Sixty-five percent of the landscape is allocated to safari hunting (11,202 km<sup>2</sup> being community-managed and 10,722 km<sup>2</sup> state-managed), and these zones are superimposed on agroforestry and concession areas. The landscape is sparsely populated (ca. 4 people/km<sup>2</sup>) with many different ethnic groups. In the systems model we characterized them as Baka-pygmies (ca. 43%), and indigenous and migrant Bantu (ca. 50 and ca. 8%, respectively) (GTZ 2001). Logging is the main economic activity and concessionaires contribute significantly to infrastructure development.

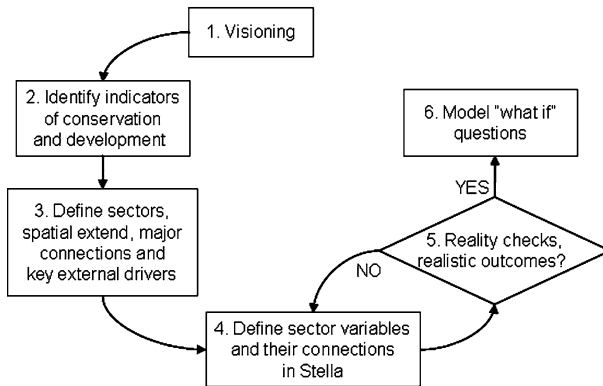
## Methods

We held four annual workshops (2004–2007), each with 15–25 experts from conservation and development agencies working in the study area. During these workshops we conducted visioning and modeling exercises. We based the participatory modeling approach on methods described by Lynam et al. (2002), Sayer and Campbell (2004), Sandker et al. (2007), and described on [http://www.cifor.cgiar.org/conservation/\\_ref/research/index.htm](http://www.cifor.cgiar.org/conservation/_ref/research/index.htm). The model was built in Stella (version 8) (HPS 1996), a user friendly modeling language with an icon based interface. As early as the first workshop in 2003 a model was produced showing the impact of various interventions on forest conservation and livelihoods. At subsequent workshops the model was further refined and we incorporated new sectors, data, and insights and explored new scenarios.

An idealized sequence of steps can be identified from our approach although as in many multi-stakeholder processes there was plenty of iteration, backtracking, and changes in direction from one workshop to the next (Fig. 2). In the first step, we developed visions of the future around topics of interest. As a prelude to visioning, we encouraged participants to think about change by discussing historical events that affected conservation and development outcomes. We examined underlying trends in ecological and socioeconomic variables. We then identified some potential major drivers of change, and developed positive and negative scenarios from poverty and biodiversity perspectives. In so doing, we identified the key issues for future modeling.

The second step consisted of identifying conservation and development outcome indicators so we could be sure to cover these in the model. Because deforestation rates were low, most conservation efforts focused on preventing poaching of large mammals. Thus we used the population of forest elephants and western lowland gorillas as indicators of biodiversity conservation performance. We also included the populations of duikers (*Cephalophus* spp.) as biodiversity indicators because they are the most important species for (legal) subsistence hunting (Nzoo 2003). Hunting pressure on





**Fig. 2** The modeling process

duikers is high. We considered four individual species of duikers: Peter's duiker (*Cephalophus callipygus*), bay duiker (*Cephalophus dorsalis*), blue duiker (*Cephalophus monticola*) and yellow-backed duiker (*Cephalophus sylvicultor*). Duikers differ from elephant and gorilla in that they have very high birth rates and are largely hunted for subsistence and local sale, whereas elephants and gorillas have low birth rates and are mainly hunted for external commercial markets. Poaching of elephants for their tusks is largely by outsiders, or by locals temporarily employed by outsiders, whereas gorillas are poached to provide bushmeat for far-off urban centers. Due to the value of ivory, the hunting pressure on elephants is considerably higher than that on gorillas. As indicators of local development, we used average household cash income and the effective local development budgets (consisting mainly of forest taxes and wildlife royalties). Cash income is highly sought after by local people, and the local development budgets—the budgets actually used for development projects, so excluding the share which is misappropriated are regarded as a good indicator of access to health and education facilities.

The third step consisted of conceptualizing the landscape; this involved defining the major sectors for the model (see Table 1), the spatial dimensions, and the major connections between sectors and the key external drivers. This step is conducted on paper or in Stella's "map layer". The fourth step was the detailed model building in Stella: defining the main variables (stocks and converters in model terms) in each sector, collecting the initial values for these variables, and defining how variables influenced each other. Small groups of stakeholders worked on different sectors according to their specific knowledge, e.g., the governance sector of the model (on misappropriation of natural resource taxes) was built through a forum of local nongovernmental organizations (NGOs) working in the area. Table 1 specifies the main stocks and the data sources for initial values, and the main flows. These flows can be in- and out-flows to stocks (e.g., birth and death of human population) or flows between stocks (e.g., forest is converted into agriculture). We collected additional primary data through 50 household surveys among Baka-pygmyes and Bantu in three villages in 2006 to fill information gaps.

The fifth step consisted of reality checks, running the model under different conditions and exploring how simulations compared to what is known by stakeholders. The simulations often led to revisions of assumed variables and relationships and revealed the need for additional data, for instance in this study data from household surveys.

**Table 1** Overview of the sectors of the landscape model, and some of main stocks and flows

Sector	Stocks (with information sources)	Flows (with driving factors or information sources)
Land-use	Current land-uses (2003 landsat images, GFW 2005)	Land-use changes (driven by population increase)
Human population	Baka, local Bantu and immigrant populations (GTZ 2001), employment rate (jobs in other sectors), hunters (determined by population size and employment rate) and employment	In- and out-migration (driven by employment and loss of income), urbanization (UN 2006), natural population growth (UNFPA 2007; GTZ 2001)
Household income	Current average household income for Baka, local Bantu and immigrants (2006 household surveys, CEFAID 2005)	Income from various activities broken down by the three types of households (2006 household surveys, logging employment, bushmeat hunting)
Wildlife	Current population sizes of elephants, gorillas and duikers (Nzoo 2003; Nzoo et al. 2005; Ekobo 1998)	Natural birth and death rates (Cowlshaw et al. 2004, estimates by biologists), carrying capacities (estimates by biologists), extraction by hunting
Bushmeat hunting	Current number of elephants and gorillas poached per year, current number of snares for duiker hunting (estimates from ecoguards; 2006 household surveys)	Change in hunting (determined by numbers of hunters, loss of income, and directly affected by animal density, awareness creation, antipoaching activities)
Safari hunting	Current wildlife royalties paid (safari director interview), employment in safari sector (GFW 2005; safari director interview)	Change in wildlife royalties payment (depending on the number of safari hunters coming in each year, which will decrease if some key safari hunting species, like elephant, become rare)
Logging concessions	Current timber extraction (GFW 2005), logging employment (concession director and worker interviews), timber royalties (MINEFI unpublished), contribution to antipoaching (only if certified)	Change in extraction (depending on sustainability harvest—certification), employment and royalties (depending on extraction), and cost-effectiveness of the concession
Governance	Development budgets commune and communities (mainly timber tax and wildlife royalties), budget spent per development activity, and misappropriation (budget statements, NGO estimations)	Budget inflows (royalties paid, direct development investment) and budget spending (better governance)
ICDP interventions	Current ICDP budget (conservation NGO), current share spent on antipoaching, ecomonitoring, awareness creation, better governance, direct development investment, certification	Change in ICDP budget: three scenarios explored; change in budget spending: three scenarios explored (Table 2)



Once the model simulations were found to be realistic by all stakeholders, we moved to the final step of exploring scenarios. In some circumstances consensus was not reached by the stakeholders. In such situations we explored scenarios with alternative assumptions. To explore the existing and potential ICDP interventions in the landscape we introduced them in the model and defined their expected impact pathways. We defined the impact of each ICDP intervention—ranging from zero to a maximum expected impact—as a function of the budget spent on the activity (e.g., when US\$ 1.5/ha or more is spent on antipoaching, a maximum of 80% of snares will be removed). This data was supplied by those working on these issues in the landscape. The scenarios were explored by varying the budget allocations to the different activities (antipoaching, anticorruption measures, and direct development investments) and by changing the overall ICDP budget.

We explored trade-offs and synergies between conservation and development by developing conservation and development indices (Fig. 5). The conservation index is the mean of standardized values for elephant, gorilla, and duiker numbers, with standardization performed using minimum and maximum numbers for each variable. The development index is the mean of standardized values for household income and for local development budgets. We then plotted the mean index values for three time periods.

Toward the end of the model building process, we presented the results to a forestry donor forum and to parliamentarians in the capital, Yaoundé, to stimulate discussion on possible solutions to the problems identified.

## Funding and implementation scenarios

The current donor budget for conservation-development activities in the SE TOU is under the control of one large international NGO and is about US\$ 1.7 million/year. In most donor-funded contracts for ICDPs there are objectives, activities or conditions related to the sustainability of interventions. The donor funds are meant to set in place systems and processes that will remain after the projects are completed. For this reason, and because participants from the conservation NGO did not believe the current funding levels could be maintained indefinitely, participants suggested that a reduced-funding scenario be

**Table 2** Share of total ICDP budget spent on different interventions under the three management strategies explored

Interventions	Management strategy		
	Antipoaching	Better governance direct	Development investment
Antipoaching			
Inside park (%)	24	19	19
Outside park (%)	36	28	28
Ecological monitoring (%)	24	19	19
Awareness creation (%)	5	5	5
Sustainable forest management (%)	10	10	10
Lobbying for redistribution of royalties/taxes and activities that strengthen community governance (%)	0	20	0
Local development budget (%)	0	0	20

simulated. We explored the outcomes from activities under three different budget scenarios: a fixed high ICDP budget over the next 25 years, a diminishing ICDP budget dropping gradually to 30% of the current budget over 25 years, and a “no ICDP budget” in which no donor funds are available for conservation-development initiatives.

After much discussion at the workshops, we settled on simulating three intervention strategies. The first and current strategy was called the antipoaching strategy in which the bulk of the ICDP budget is spent on antipoaching and ecological monitoring (Table 2). In the second strategy, the governance strategy, some of the budget goes to lobbying at the central government level to redirect forest taxes to community organizations without the funds passing through the local administration and to improving the governance of these community organizations. In the third intervention strategy, the direct development investment strategy, governance activities are not undertaken; rather, funds are allocated directly to the communities for local development initiatives.

### **Governance of forest taxes and wildlife royalties**

Companies pay taxes for the exploitation of timber, which includes taxes on forest rents, timber production, and product export. The most substantial of these are the forest rent taxes or area fees. They comprised 51% of the total amount of taxes paid by forest concessions from 2001 through 2005, and in 2005 the annual area fees amounted US\$ 7.5 million in the SE TOU (MINEFI, unpublished data; MINEFI 2005). According to the Cameroonian forest law of 1994, a portion of the area fees should flow back into the communes and communities from which the resources were exploited. For example, 40% of the area fees should be made available to the communes (for development projects executed by the communes) and 10% should be made available to the communities (for development projects in villages).

The forest taxes generate considerably more local income than the wildlife royalties. In 2005 in the SE TOU, US\$ 59,000 in wildlife royalties was received by communities (Ngono, personal communication), which is insignificant when compared with the 10% of forest area fees of US\$ 752,700 for the same year (MINEFI, unpublished data; MINEFI 2005). However, the redistributed forest area fees are often not managed transparently, and the bulk is misappropriated. The scale of misappropriation is estimated during the modeling by NGOs at 80–85% of the money destined to the communes and 75% of the money destined to communities. The recently established community-managed hunting zones bypass local administrations and the wildlife royalties and go directly to community structures that use it for local development projects. However, the effectiveness of this community-based approach is also of concern. For example, the amount of money spent on the administration of the funds is relatively high (33% of the total budget for the period 2001–2005) and Baka-pygmies receive few benefits from the disbursements (CEFAID 2004). However, according to the NGOs so far the level of misappropriation is significantly reduced under this arrangement.

The better governance scenario simulates strengthened community control and reduced levels of misappropriation. Although stakeholders thought governance could be improved if funds flowed directly to communities, they did not think misappropriation of commune forestry taxes could be halted. Thus, we simulated two governance scenarios, a more “optimistic” one in which misappropriation was reduced by 40% for both commune and community forestry taxes and a more “realistic” one in which only the misappropriation of community forestry taxes could be reduced, but not that of communes.

## How to interpret the model's outcomes

In modeling landscapes such as the Tri National de la Sangha, there are numerous data gaps. In these cases we used expert knowledge and key informant interviews to estimate missing values (Table 1). Where possible, we got estimates from different sources to cross-check values, e.g., the number of animals poached per year was assessed through the 2006 household surveys and through ecoguard estimates. The figures entered in the model were midpoints. Where there were major discrepancies we conducted additional interviews. Nonetheless, it was impossible to fully remove all subjectivity from the model. For example, many stakeholders believed that if greater monetary benefits from natural resources could flow to local people, communities would work with authorities to reduce poaching. There is evidence that this is happening on a small scale, but many expressed doubt that this will apply at a larger spatial scale. Many of the stakeholders building the model were making budget decisions regarding the activities in the Tri National de la Sangha, preparing work plans, and implementing actions on the ground. Thus, their extensive local knowledge was already being used to drive conservation and development actions, and the simulations were what stakeholders believed to be happening, or might happen, on the basis of their knowledge.

## Results

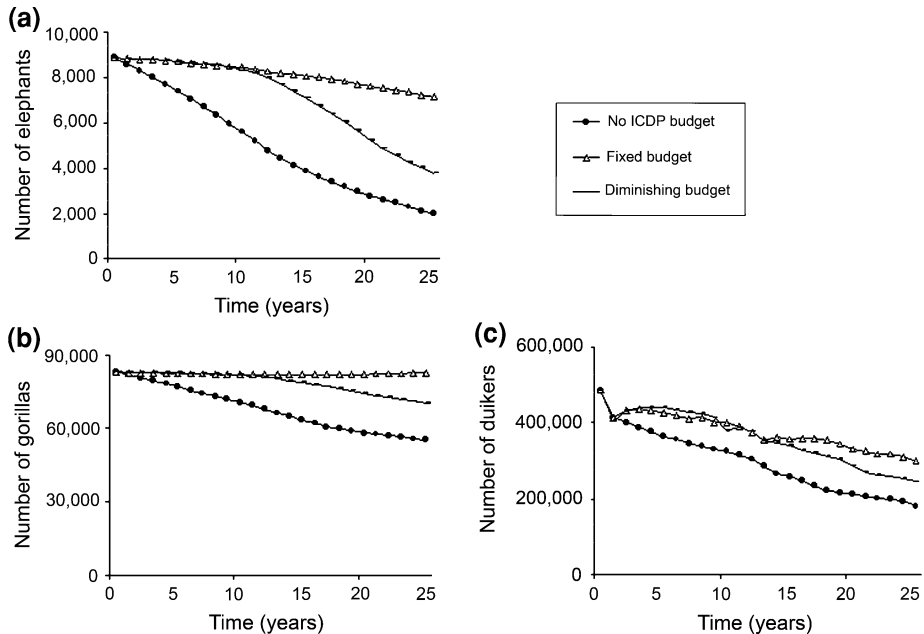
### Human population growth

The simulation of human population in SE TOU showed a 1.6 times increase over 25 years. This increase was mainly due to birth rate because in- and out-migration is estimated to be about equal at the beginning of the simulation. Out-migration was simulated as increasing in the future because we assumed a continuation of the present trend for people to migrate to cities.

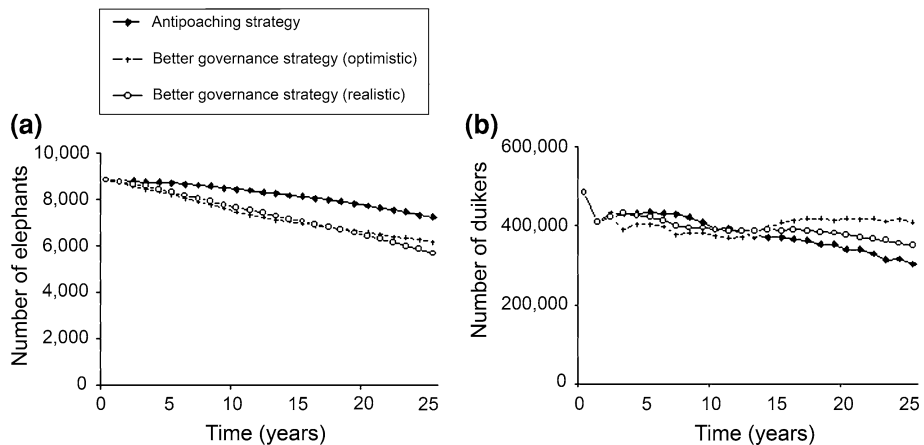
### Animal population dynamics

The increase in human population resulted in increased pressure on animals as a source of bushmeat for consumption and cash. However, with the current fixed high ICDP budget and an antipoaching strategy, the ICDP activities seemed sufficient to maintain large populations of the selected large mammals over 25 years even though there would be continuing modest declines in numbers of elephant and duiker (Fig. 3). If there was a diminished ICDP budget, wildlife populations, especially elephants, would decline more rapidly.

The different intervention strategies lead to different outcomes for elephants and duikers (Fig. 4) but not for gorillas because they experience limited poaching. With a fixed high ICDP budget, an antipoaching strategy lead to 28% higher elephant numbers after 25 years compared with the realistic governance strategy (because the application of the strategy does not relate strongly to elephant hunting, given that the latter is driven by outsiders). With the optimistic governance strategy, larger sums of money made their way back to households and communities who, it was hypothesized, would see the benefits of wildlife and natural resources and thus work closely with the authorities and observe regulations to reduce poaching. The effect was greater for duikers because local people drive this hunting. The direct development scenario is not shown because it was intermediate in its effects between the antipoaching and governance scenarios.



**Fig. 3** Simulation of **a** elephant, **b** gorilla, and **c** duiker numbers under three different integrated conservation and development project (ICDP) budget scenarios: no ICDP budget, fixed high budget, and diminishing budget. An antipoaching strategy is followed in all simulated ICDPs (i.e., a large proportion of funds goes toward antipoaching)



**Fig. 4** Simulation of **a** elephant and **b** duiker numbers for three different intervention strategies: antipoaching, optimistic governance, and realistic governance, assuming a fixed high ICDP budget

For a diminished ICDP budget the outcomes for elephant numbers were 20% lower after 25 years for the antipoaching and realistic governance scenario compared with the optimistic governance scenario. The differences among intervention scenarios for duikers were

more marked. The budget for antipoaching diminished but this was offset by improvements in local governance and better local stewardship.

### Household income and local development budgets

The household surveys revealed an average cash income in the SE TOU of US\$ 250 per capita per year. Thus, poverty levels are considerably higher than in the rest of Cameroon, where the average annual per capita income is US\$ 1010 (World Bank 2006). Of the households surveyed, 70% live below US\$ 1 per person per day. The difference between the Bantu and Baka average cash income was significant: US\$ 1,966 and US\$ 864 per household per year, respectively. For the Bantu, agriculture was the most important cash source, whereas for Baka the collection of forest products, bushmeat hunting, and agriculture were equally important.

Of all the intervention strategies, only the optimistic governance scenario substantially improved household incomes in the long-term (Table 3). The increase was a result of the increased development budgets of which a share was spent on improving agricultural production and market linkages. Agriculture is more important for the Bantu, so their household income increased by 24%, whereas that for the Baka only increased by 13%. The direct development scenario was not as good at delivering household benefits in the long-term because the development budgets did not grow as strongly as they did in the case of the optimistic governance strategy.

Although the antipoaching scenario did not show improved household incomes, it did indicate a positive effect on the local development budgets. The local development budgets dropped by <5% after 25 years (Table 3), whereas with no funds directed to antipoaching these budgets would drop by almost 30%. This decrease was due to elephants becoming increasingly scarce and this scarcity subsequently leading to safari companies leaving the zone and no longer contributing to the local development budgets. The impact of the governance reforms, especially the optimistic reform scenario, was huge (Table 3). Where the ICDP budget was reduced, only better governance scenarios could lead to increases in local incomes. Governance problems appeared to be at the heart of the underdevelopment in the area. In the optimistic better governance scenario, there was a tenfold increase in local development budgets, and the scenario was set up to only assume a 40% reduction in misappropriation of funds.

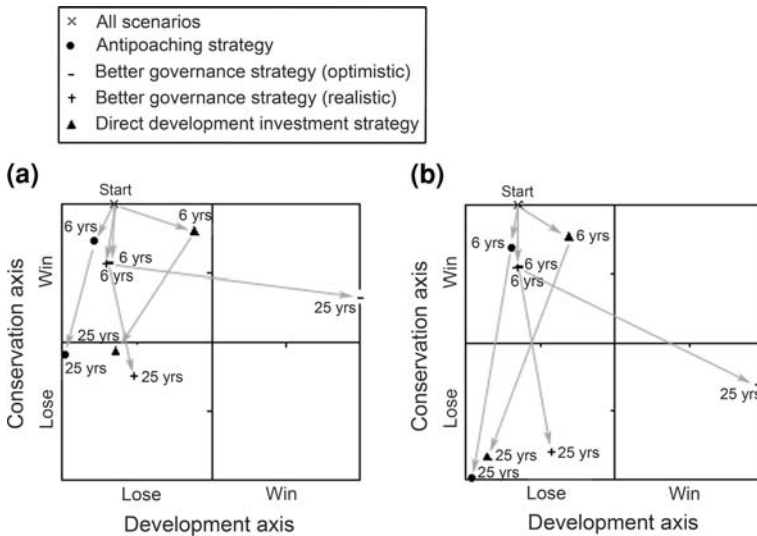
### Synergies and trade-offs

Exploring trade-offs and synergies between conservation and development was not simple because trade-off conditions change over time and different indicators of conservation (e.g., elephant vs. duiker) and development (e.g., local development budgets vs. household incomes) show different patterns. The conservation and development indices (see methods) show little potential for win-win situations (Fig. 5). For the first 6 years of the simulation conservation thrived and development stagnated. Positive results for both conservation and development were only achieved under the optimistic governance scenario with a fixed budget (Fig. 5a). The long-term outcomes for conservation under all the other scenarios were not promising, with declines in the conservation index, especially when the ICDP budget diminished (Fig. 5b). The different ICDP interventions did not do much for local development, except under the optimistic and to a smaller extent the realistic governance scenarios.

**Table 3** Simulation results of average annual household income and annual local development budgets from forestry taxes and wildlife royalties for the three management strategies explored assuming a fixed integrated conservation and development budgets

	Management strategy							
	Antipoaching		Better governance				Direct development investment	
			Optimistic scenario <sup>a</sup>		Realistic scenario <sup>a</sup>			
	Household income (US\$)	Development budget (US\$)	Household income (US\$)	Development budget (US\$)	Household income (US\$)	Development budget (US\$)	Household income (US\$)	Development budget (US\$)
Now	1,452	241,071	1,452	241,071	1,452	241,071	1,452	241,071
In 5 years	1,443	242,849	1,452	252,037	1,424	245,856	1,611	586,583
In 10 years	1,399	244,074	1,487	512,414	1,459	399,261	1,554	585,829
In 15 years	1,436	240,657	1,760	1,901,321	1,550	688,522	1,543	584,199
In 20 years	1,417	240,468	1,765	2,332,497	1,513	677,929	1,509	564,521
In 25 years	1,388	233,323	1,666	2,352,880	1,497	670,066	1,446	525,767

<sup>a</sup> The optimistic governance scenario assumes that under the better governance strategy misappropriation is reduced by 40% for both the commune and community forest area fees; the realistic governance scenario assumes misappropriation is reduced by 40% for community forest area fees only



**Fig. 5** Trade-offs between conservation and development for different intervention strategies assuming **a** a fixed high ICDP budget and **b** a diminished ICDP budget. Only the present (start), 6-year, and 25-year scenario values are shown (see methods for axis derivation)

### Promoting dialogue

The model building promoted considerable discussion among the workshop participants. Initially the scenarios focused on the typical conservation concerns: animal numbers and how antipoaching could be organized. Only through questioning by the facilitators did the governance issues surface. The discussions made conservation agents question two of their underlying assumptions: they were effectively combining conservation and development, and their work would yield sustainable outcomes. In the case of the first assumption, project documents and presentations from conservation agencies characterized their approach as “conservation and development”. The model outputs questioned whether the development outcomes were being considered seriously because most of the modeled scenarios did not contribute to lifting people out of poverty. An analysis of project budgets showed clearly how the bulk of the work was directed to conservation activities, such as antipoaching and ecological monitoring. Another refrain from conservation agencies was that their projects are sustainable, yet the diminished ICDP budget scenario showed clearly that long-term outcomes could not be assured once external funding is withdrawn. Currently, different donor and stakeholder forums in the region are discussing how to assure long-term funding.

The NGO participants who were shown the modeled results were shocked by the simulated difference between the potential commune budget for development and what was actually spent on development projects. They indicated their intention to use the simulated budget graphs to create awareness among the population and government about the misappropriation taking place. In fact, during the last municipal elections in Cameroon in July 2007, the then mayor of Yokadouma lost his local constituent support and a new mayor advocating better governance was subsequently elected.

## Discussion

### Role of participatory modeling

Participatory modeling is an efficient way to gather information and, more importantly, to stimulate discussion among different stakeholders (van Noordwijk et al. 2001; Bousquet et al. 2007). Because data is often lacking on the relationships among components of modeled socioecological systems, such simulations largely reflect local expert opinion. Various points of view and subjective criteria elicited from different local experts are made explicit in the modeling process so as to improve understanding and shared representation of the problems at hand and to provide an improved basis for negotiation when views are divergent (Bousquet et al. 2007; Castella et al. 2007). Understanding of the trade-offs and synergies between conservation and development improves during the modeling process and this encourages participants to seek alternative solutions. Models can help capture the complexity of conservation landscapes (Castella et al. 2007). We found that although discussions are useful to change ways of thinking at the project level it is often impossible for local implementing agencies to change projects drastically because project activities and budgets are largely fixed externally. The discussions with donors, parliamentarians, and local development NGOs emerged as major opportunities for influence because they were in a better position to facilitate change. The model was useful in redirecting discussion toward livelihoods in conservation projects hitherto largely focused on animal populations, antipoaching, and ecological monitoring. The model encouraged project implementers to consider long-term perspectives.

### Possible scenarios for improving conservation outcomes

The antipoaching strategy did little for local people and in many ways was only a holding operation. McShane and Wells (2004) conclude most ICDPs need ongoing financial support or they collapse. In the case of the SE TOU, if conservation funds became unavailable, and antipoaching efforts had to be scaled back, animal populations would decline dramatically. We therefore question the long-term impact of such short-term interventions. Securing biodiversity with the current approaches will require continuing external funding. Unfortunately, the funding for most ICDPs is relatively short-term and few institutional or fiscal mechanisms exist to ensure long-term support for protected and surrounding areas (Emerton et al. 2006).

Our results suggest that a conservation-development approach that does not give attention to governance does little for people in the long-term and will do little for animal populations unless donor investments continue. Investing solely in livelihood projects without governance reform (the direct development scenario) will also do little to secure long-term outcomes for people and nature. Our model suggests that the only hope for improving long-term conservation and development is if considerable effort is given to governance reform. Some of the workshop participants did not believe the governance work would be successful, especially at the commune level, where misappropriation is endemic (see also Oyono et al. 2006). And even if it was successful, many participants thought satisfactory management of the local development budgets was only possible if civil society could exert pressure through NGOs. Decentralization brings increased vulnerability to misappropriation by local elites (Assemble-Mvondo 2006). This negative aspect of decentralization is well documented in Indonesia (Fritzen 2007; Duncan 2007) and other countries (Ribot 2007).



Integrated sustainable-use approaches that focus on empowering local communities to improve livelihoods on the basis of sustainable management of biological resources have gathered ground in recent years (e.g., Wilshusen et al. 2002; Hutton and Leader-Williams 2003; Bennett et al. 2007). In some cases, large amounts of funding allocated for local conservation and development activities are misappropriated by local elites (Fritzen 2007; Ribot 2007). It is therefore surprising that the conservation-development literature gives so little attention to governance (Barrett et al. 2001; Smith and Walpole 2005). Many authors have sought to explain why ICDPs do not reach their dual objectives but they have generally failed to recognize weak governance as one of them (Alpert 1996; Chape 2001; Schmidt-Soltau 2004; Christensen 2004). There are few empirical studies that explicitly highlight the linkages between corruption and conservation (Smith et al. 2003a; Ferraro 2005), and some suggest that the perceived linkages are more complex than previously thought (Barrett et al. 2006), with causality remaining unclear. Our work shows that the impacts of poor governance can be simulated in models and that, in the case of south-eastern Cameroon, none of the present approaches to conservation and development problems will succeed in the absence of improved governance. Combating corruption is complex and difficult especially in countries with weak governments (Smith et al. 2003b; Palmer 2005) and worldwide there is little progress on improving governance (Kaufmann 2003). However, Cameroon does show a very modest but positive trend in improving governance between 1996 and 2007 and examples of other African countries like Tanzania and Madagascar show corruption can be controlled significantly in a short period (Kaufmann et al. 2007). The replacement of the corrupt mayor by one promoting better governance is a positive signal for the SE TOU landscape and might indicate that it is on the road towards truly integrating conservation and development.

## References

- Agrawal A, Gibson CC (1999) Enchantment and disenchantment: the role of community in natural resource management. *World Dev* 27:629–649. doi:[10.1016/S0305-750X\(98\)00161-2](https://doi.org/10.1016/S0305-750X(98)00161-2)
- Alpert P (1996) Integrated conservation and development projects. *Bioscience* 46:845–855. doi:[10.2307/1312970](https://doi.org/10.2307/1312970)
- Assembe-Mvondo S (2006) Decentralized forest resources and access of minorities to environmental justice: an analysis of the case of the Baka in southern Cameroon. *Int J Environ Stud* 63:681–689. doi:[10.1080/00207230600963825](https://doi.org/10.1080/00207230600963825)
- Barrett CB, Brandon K, Gibson C, Gjertson H (2001) Conserving topical biodiversity amid weak institutions. *Bioscience* 51:497–502. doi:[10.1641/0006-3568\(2001\)051\[0497:CTBAWI\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2001)051[0497:CTBAWI]2.0.CO;2)
- Barrett CB, Gibson C, Hoffman B, McCubbins MD (2006) The complex links between governance and biodiversity. *Conserv Biol* 20:1358–1366. doi:[10.1111/j.1523-1739.2006.00521.x](https://doi.org/10.1111/j.1523-1739.2006.00521.x)
- Bennett E, Blencowe E, Brandon K, Brown D, Burn RW, Cowlshaw G, Davies G, Dublin H, Fa JE, Milner-Gulland EJ, Robinson JG, Rowcliffe JM, Underwood FM, Wilkie DS (2007) Hunting for consensus: reconciling bushmeat harvest, conservation and development policy in West and Central Africa. *Conserv Biol* 21:884–887. doi:[10.1111/j.1523-1739.2006.00595.x](https://doi.org/10.1111/j.1523-1739.2006.00595.x)
- Bousquet F, Castella J-C, Trébuil G, Barnaud C, Boissau S, Kam SP (2007) Using multi-agent systems in a companion modeling approach for agroecosystem management in South-east Asia. *Outlook Agric* 36:57–62
- Brown K (2002) Innovations for conservation and development. *Geogr J* 168:6–17. doi:[10.1111/1475-4959.00034](https://doi.org/10.1111/1475-4959.00034)
- Castella J-C, Kam SP, Quang DD, Verburg PH, Hoanh CT (2007) Combining top-down and bottom-up modelling approaches of land use/cover change to support public policies: application to sustainable management of natural resources in Northern Vietnam. *Land use policy* 24:531–545. doi:[10.1016/j.landusepol.2005.09.009](https://doi.org/10.1016/j.landusepol.2005.09.009)

- CBFP (Congo Basin Forest Partnership) (2005) The forests of the Congo basin: a preliminary assessment. Central African Regional Programme for the Environment, Kinshasa, Democratic Republic of Congo, Washington, DC
- CEFAID (Centre pour l'Éducation, la Formation et l'Appui aux Initiatives de Développement au Cameroun) (2004) Evaluation des COVAREF UTO/SE. CEFAID, Yokadouma
- CEFAID (Centre pour l'Éducation, la Formation et l'Appui aux Initiatives de Développement au Cameroun) (2005) Etude socio-économique effectuée dans les villages voisins de l'Unité Forestière d'Aménagement 10064. CEFAID, Yokadouma
- Cernea MM, Schmidt-Soltau K (2006) Poverty risks and National Parks: policy issues in conservation and development. *World Dev* 34:1808–1830. doi:[10.1016/j.worlddev.2006.02.008](https://doi.org/10.1016/j.worlddev.2006.02.008)
- Chan KMA, Pringle RM, Ranganathan J, Boggs CL, Chan YL, Ehrlich PR, Haff PK, Heller NE, Al-Khafaji K, Macmynowski DP (2007) When agendas collide: human welfare and biological conservation. *Conserv Biol* 21:59–68
- Chape S (2001) An overview of integrated approaches to conservation and community development in the Lao People's Democratic Republic. *Parks* 11:24–32
- Chapin M (2004) A challenge to conservationists. *Worldwatch magazine* Nov/Dec. Worldwatch Institute, Washington, DC
- Christensen J (2004) Win-win illusions. *Conserv Pract* 5:12–19. doi:[10.1111/j.1526-4629.2004.tb00079.x](https://doi.org/10.1111/j.1526-4629.2004.tb00079.x)
- Cowling RM, Knight AT, Faith DP, Lombard AT, Desmet PG, Driver A, Ferrier S, Maze K, Rouget M (2004) Nature conservation requires more than a passion for species. *Conserv Biol* 18:1674–1677. doi:[10.1111/j.1523-1739.2004.00296.x](https://doi.org/10.1111/j.1523-1739.2004.00296.x)
- Cowlishaw G, Mendelson S, Rowcliffe JM (2004) The bushmeat commodity chain: patterns of trade and sustainability in a mature urban market in West Africa. ODI wildlife policy brief 7. Overseas Development Institute, London
- Duncan CR (2007) Mixed outcomes: the impact of regional autonomy and decentralization on indigenous ethnic minorities in Indonesia. *Dev Change* 38:711–733. doi:[10.1111/j.1467-7660.2007.00430.x](https://doi.org/10.1111/j.1467-7660.2007.00430.x)
- Ekobo A (1998) Large mammals and vegetation surveys in the Boumba-Bek and Nki project area. World Wildlife Fund, Yokadouma
- Emerton L, Bishop J, Thomas L (2006) Sustainable financing of protected areas: a global review of challenges and options. Best practice protected area guidelines series 13. International Union for Conservation of Nature, Gland
- Ferraro P (2001) Global habitat protection: limitations of development interventions and a role for conservation performance payments. *Conserv Biol* 15:990–1000. doi:[10.1046/j.1523-1739.2001.015004990.x](https://doi.org/10.1046/j.1523-1739.2001.015004990.x)
- Ferraro P (2005) Corruption and conservation: the need for empirical analysis. A response to Smith and Walpole. *Oryx* 39:257–259. doi:[10.1017/S003060530500075X](https://doi.org/10.1017/S003060530500075X)
- Ferraro PJ, Kiss A (2002) Direct payments to conserve biodiversity. *Science* 298:1718–1719. doi:[10.1126/science.1078104](https://doi.org/10.1126/science.1078104)
- Fritzen SA (2007) Can the design of community-driven development reduce the risk of elite capture? Evidence from Indonesia. *World Dev* 35:1359–1375. doi:[10.1016/j.worlddev.2007.05.001](https://doi.org/10.1016/j.worlddev.2007.05.001)
- GFW (Global Forest Watch) (2005) Interactive forestry atlas of Cameroon. World Resources Institute, Washington, DC
- GTZ (German development cooperation) (2001) Etude Socio-économique de l'UTO Sud-est. Rapport Définitif, Yokadouma
- Guha R (1997) The authoritarian biologist and the arrogance of anti-humanism: wildlife conservation in the third world. *Ecologist* 27:14–20
- HPS (High Performance Systems) (1996) Stella and Stella research software. HPS, Hanover
- Hutton JM, Leader-Williams N (2003) Sustainable use and incentive-driven conservation: realigning human and conservation interests. *Oryx* 37:215–226. doi:[10.1017/S0030605303000395](https://doi.org/10.1017/S0030605303000395)
- Janzen D (1986) The future of tropical ecology. *Annu Rev Ecol Syst* 17:305–324. doi:[10.1146/annurev.es.17.110186.001513](https://doi.org/10.1146/annurev.es.17.110186.001513)
- Kaufmann D (2003) Rethinking governance: empirical lessons challenge orthodoxy. World Economic Forum, Geneva
- Kaufmann D, Kraay A, Mastruzzi M (2007) Governance matters VI: governance indicators for 1996–2006. In: World Bank policy research working paper No. 4280 World Bank, Washington, DC, USA
- Kremen C, Merenlender AM, Murphy DD (1994) Ecological monitoring: a vital need for integrated conservation and development programs in the tropics. *Conserv Biol* 8:388–397. doi:[10.1046/j.1523-1739.1994.08020388.x](https://doi.org/10.1046/j.1523-1739.1994.08020388.x)

- Lynam T, Bousquet F, Le Page C, d'Aquino P, Barreteau O, Chinembiri F, Mombeshora B (2002) Adapting science to adaptive managers: spidergrams, belief models, and multi-agent systems modeling. *Conservation Ecology* 5: <http://www.consecol.org/vol5/iss2/art24/>
- Malleson R (2002) Changing perspectives on forests, people and 'development': reflections on the case of the Korup forest. *IDS Bull* 33:94–101. doi:[10.1111/j.1759-5436.2002.tb00011.x](https://doi.org/10.1111/j.1759-5436.2002.tb00011.x) (Institute of Development Studies, Brighton, UK)
- McShane T, Wells M (eds) (2004) *Getting biodiversity projects to work: towards more effective conservation and development*. Columbia University Press, New York
- MINEFI (Ministry of Economy and Finance) (2005) Programme de sécurisation des recettes forestiers. Rapport annuel provisoire d'activités. Exercice 2005. MINEFI, Yaoundé
- Mittermeier RA, Kormos CF, Goetsch-Mittermeier C, Robles-Gil P, Sandwith T, Besancon C (2005) *Transboundary conservation: a new vision for protected areas*. Conservation International, Arlington
- Neumann RP (1998) *Imposing wilderness: struggles over livelihood and nature preservation in Africa*. University of California Press, Berkeley
- Nzoo ZL (2003) Suivi écologique dans le Parc National de Lobéké et sa zone périphérique : données de base sur la dynamique des populations de grands et moyens mammifères et des activités anthropiques. World Wildlife Fund, Yokadouma
- Nzoo ZL, Bassama C, Ndinga H (2005) Populations des grands et moyens mammifères dans les UFA 10–008, 10–009, 10–010, 10–012: données de base pour l'aménagement durable des concessions. World Wildlife Fund, Yokadouma
- Oates JF (1999) *Myth and reality in the rainforest: how conservation strategies are failing in Africa*. University of California Press, Berkeley
- Oyono PR, Ribot JC, Larson AM (2006) Green and black gold in rural Cameroon: natural resources for local governance, justice and sustainability. *Environmental governance in Africa working papers* 22. World Resources Institute, Washington, DC
- Palmer C (2005) The nature of corruption in forest management. *World Econ* 6:1–10
- Ribot JC (2007) Waiting for democracy: the politics of choice in natural resource decentralization. World Resources Institute, Washington, DC
- Robbins P, McSweeney K, Waite T, Rice J (2006) Even conservation rules are made to be broken: implications for biodiversity. *Environ Manage* 37:162–169. doi:[10.1007/s00267-005-0009-5](https://doi.org/10.1007/s00267-005-0009-5)
- Romero C, Andrade G (2004) International conservation organisations and the fate of local tropical forest conservation initiatives. *Conserv Biol* 18:578–580. doi:[10.1111/j.1523-1739.2004.00397.x](https://doi.org/10.1111/j.1523-1739.2004.00397.x)
- Salafsky N, Wollenberg E (2000) Linking livelihoods and conservation: a conceptual framework and scale for assessing the integration of human needs and biodiversity. *World Dev* 28:1421–1438. doi:[10.1016/S0305-750X\(00\)00031-0](https://doi.org/10.1016/S0305-750X(00)00031-0)
- Sanderson SE, Redford K (2003) Contested relationships between biodiversity conservation and poverty alleviation. *Oryx* 37:389–390. doi:[10.1017/S003060530300070X](https://doi.org/10.1017/S003060530300070X)
- Sandker M, Suwarno A, Campbell BM (2007) Will forests remain in the face of oil palm expansion? Simulating change in Malinau, Indonesia. *Ecol Soc* 12:37. <http://www.ecologyandsociety.org/vol12/iss2/art37/>
- Sayer J, Campbell B (2004) *The science of sustainable development*. Cambridge University Press, Cambridge
- Schmidt-Soltan K (2004) The costs of rainforest conservation: local responses towards integrated conservation and development projects in Cameroon. *J Contemp Afr Stud* 22:93–117. doi:[10.1080/0258900042000179625](https://doi.org/10.1080/0258900042000179625)
- Smith RJ, Walpole MJ (2005) Should conservationists pay more attention to corruption? *Oryx* 39:251–256. doi:[10.1017/S0030605305000608](https://doi.org/10.1017/S0030605305000608)
- Smith RJ, Muir RDI, Walpole MJ, Balmford A, Leader-Williams N (2003a) Governance and the loss of biodiversity. *Nature* 426:67–70. doi:[10.1038/nature02025](https://doi.org/10.1038/nature02025)
- Smith J, Obidzinski K, Subarudi, Suramenggala I (2003b) Illegal logging, collusive corruption and fragmented governments in Kalimantan, Indonesia. *Int For Rev* 5:293–302
- Terborgh J, van Schaik C, Davenport L, Rao M (2002) *Making parks work: strategies for preserving tropical nature*. Island Press, Washington, DC
- UN (United Nations) (2006) *World urbanization prospects: the 2005 revision*. Database. Department of Economic and Social Affairs, New York
- UNFPA (United Nations Population Fund) (2007) *Country profiles for population and reproductive health, policy developments and indicators 2005*. UNFPA, New York
- van Noordwijk M, Tomich TP, Verbiest B (2001) Negotiation support models for integrated natural resource management in tropical forest margins. *Conservation Ecology* 5: <http://www.consecol.org/vol5/iss2/art21/>

- Wells M, Guggenheim S, Khan A, Wardoyo W, Jepson P (1998) Investing in biodiversity. A review of Indonesia's integrated conservation and development projects. World Bank, Washington, DC
- Wilshusen PR, Brechin SR, Fortwangler CL, West PC (2002) Reinventing a square wheel: critique of a resurgent "protection paradigm" in international biodiversity conservation. *Soc Nat Resour* 15:17–40. doi:[10.1080/089419202317174002](https://doi.org/10.1080/089419202317174002)
- World Bank (2006) GNI per capita 2005, atlas method and PPP, world development indicators database. World Bank, Washington, DC



## Chapter 7

### REDD payments as incentive for reducing forest loss: A case from Ghana



Photos: Courtesy of Neil Collier, Johannes Förster and Roland Sandker

## REDD payments as incentive for reducing forest loss

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### Keywords

Avoided deforestation; carbon payments; landscape; participatory modeling; payments for environmental services; STELLA.

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### Abstract

Strategies for reducing emissions from deforestation and forest degradation (REDD) could become an important part of a new agreement for climate change mitigation under the United Nations Framework Convention on Climate Change. We constructed a system dynamics model for a cocoa agroforest landscape in southwestern Ghana to explore whether REDD payments are likely to promote forest conservation and what socio-economic implications would be. Scenarios were constructed for business as usual (cocoa production at the expense of forest), for payments for avoided deforestation of old-growth forest only and for payments for avoided deforestation of all forests, including degraded forest. The results indicate that in the short term, REDD is likely to be preferred by farmers when the policy focuses on payments that halt the destruction of old-growth forests only. However, there is the risk that REDD contracts may be abandoned in the short term. The likeliness of farmers to opt for REDD is much lower when also avoiding deforestation of degraded forest since this land is needed for the expansion of cocoa production. Given that it is mainly the wealthier households that control the remaining forest outside the reserves, REDD payments may increase community differentiation, with negative consequences for REDD policies.

### Introduction

Reducing emissions from deforestation and forest degradation (REDD) is considered as a possible means for mitigating climate change (UNFCCC 2007). Payments for decreased CO<sub>2</sub> emissions from deforestation and degradation is considered one possible mechanism, with payments based on the difference between realized emissions and projected emissions from a historical emission baseline (Kanninen *et al.* 2007; Righelato & Spracklen 2007).

A concerted effort of policies and payments for environmental services can reduce deforestation (e.g., Pagiola 2007). However, in many tropical landscapes governance is weak and funds for payments for environmental services schemes are limited. In addition, in many tropical landscapes commercial agriculture is the main agent of deforestation (oil palm, cocoa, rubber, and soy) (Lambin *et al.* 2001). Under these circumstances, can REDD payments provide the incentives to halt deforestation? We examined this question for southwestern Ghana, a



region where forest has been and continues to be lost to cocoa production. Ghana receives support for developing early REDD activities from the World Bank's Forest Carbon Partnership Facility. Using simulation modeling, we examine whether REDD payments to farmers would provide the necessary incentives for farmers to opt for reducing deforestation and forest degradation instead of cultivating their land. We also examine some of the socioeconomic implications of REDD, given that many policy makers are driven by development issues rather than environmental issues.

## Methods

### The landscape

The Wasa Amenfi West district in southwestern Ghana covers an area of 34,646 km<sup>2</sup> of which 25% is natural forest. The district experienced heavy in-migration by farmers growing cocoa, the most important cash crop, resulting in a population of 156,260 inhabitants in 2000 (District Report 2005, unpublished). Forest reserves account for 12% of the total landscape and are largely managed by private logging companies. A smaller part of the reserves are Globally Significant Biodiversity Areas (NRMP 1999), which are excluded from any extractive use, just as the sacred forests outside the reserves. Deforestation in the landscape has occurred mainly outside forest reserves, driven by local farmers clearing for cocoa production.

### Participatory modeling

Participatory modeling consists of building a model together with actors from the landscape with the aim of exploring future landscape pathways. The aim of this specific model building exercise was to assess the current state and dynamics of the Wasa Amenfi West landscape, sketch expected future dynamics, compare REDD payments with the opportunity costs of cocoa production in this setting and feed this into expert discussion. REDD's feasibility will depend strongly on local government and landholders' motivation to participate. Through participatory scenario exploration these actors directly communicate foreseen obstacles and likely preferences. To be built in a participatory way, the model needed to compromise on complexity to gain in continuous participant input and validation. The simulation outcomes therefore are rough indications rather than precise predictions, but they are validated by expert opinion.

The model building was initiated in a workshop setting, involving a district official from the Ministry of Food and Agriculture, cocoa farmers, a representative of a timber company, personnel from local and international envi-

ronmental NGOs, and remote sensing and modeling experts. Data were obtained from a study on land cover change (Förster 2009), district reports and the literature (e.g., for carbon stocks). The model was produced using the best available data, whenever data was lacking a mediated estimate was made by the local experts (Table 1).

The system dynamics model was built using the stock-and-flow model software STELLA (HPS 1996). With its icon-based interface, STELLA is readily understood by participants without a modeling background (Sandker *et al.* 2007, 2009; Van den Belt 2004). The model structure consisted of several submodels or "sectors" representing components of the social-ecological system such as land-use change, population dynamics, carbon dynamics, income, and REDD payments (Table 1).

In the model, deforestation is driven by growth in rural population and in line with forest conversion rates as for the period 2000–2007. We modeled the conversion of forest to cocoa plantations for large and small landholders. Some of the large landholders have old-growth forest on their land, while smallholders have only access to secondary forest. When available, 90% of the large landholders' demand for cocoa land will be taken from old-growth forest; after depletion of the old-growth forest, the entire demand will shift to secondary forest. Little off-farm employment exists in this remote rural part of southwest Ghana. As a result, farmers all stated that growing enough food for the family and making some cash from cocoa were the two main farming goals (G. Shepherd and S. Nyame 2009, personal observation). We modeled all households to reserve at least one ha of land for food crops.

Farmer income was modeled calculating the net income from the cocoa plantations. The time to maturation of cocoa is 8 years, followed by a 20 year production period. In the first 2 years the cocoa saplings are intercropped with food crops. Average values are used in the model, e.g., for cocoa production per ha. Further assumptions and data inputs are provided in Table 1 and the full model details are given in Appendix S1.

Farmer decision making was not modeled since there was not enough information on how this occurs (see Wilson 2007 on the complexity of farmer decision making). Rather, we explored what would happen to farmer income and carbon stocks if farmers opted for or did not opt for REDD. To compare the scenario's attractiveness we used the discounted value of per capita cash income over 20 years, referred to as net present value (Appendix S1), though this is only one element of a very complex decision making process. We also approximate after how many years in the simulation the net present value of the REDD scenario would drop below the net present value of cocoa cultivation, indicating likely contract breaking,



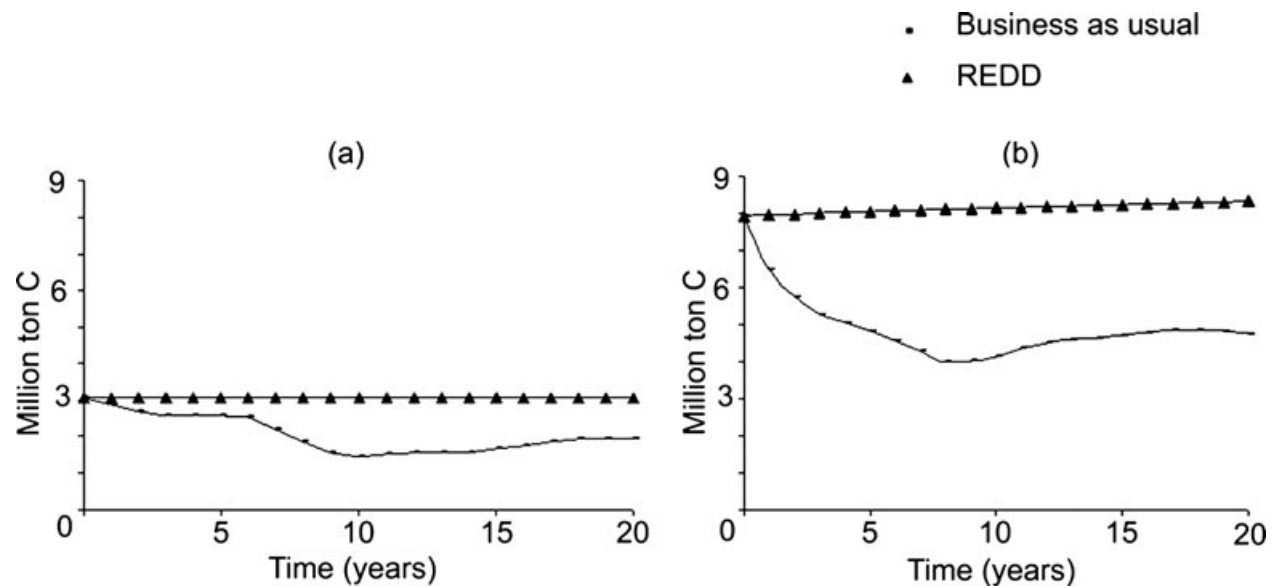
**Table 1** Model structure, data input and assumptions

Model sector	Contents	Assumptions and data	Information source
Land use dynamics	Main land-uses: young cocoa intercropped with food crops, productive cocoa agroforest systems, secondary (tree height <25 m) and old growth forest (tree height >25 m) outside the reserves; reserves, timber and rubber plantations. Conversion is mainly from primary and secondary forest to cocoa, driven by the rural population	<p>District size is 346,462 ha of which 12% is forest reserve</p> <p>Land cover outside forest reserves in 2008: 2% urban and bare soil, 3% non forested fallow, 8% food crops, 6% food crops intercropped with young cocoa, 19% 2–8-year-old cocoa, 42% productive cocoa, 0% forested fallow, 5% timber and rubber, 10% secondary forest, and 5% old growth (of which one quarter is sacred forest)</p> <p>We assume deforestation of old growth forest to continue linearly with the same annual quantity as seen between 2000 and 2007</p> <p>Sacred forest is not converted</p> <p>Old growth forest is located on the land of the large landholders as well as 80% of the secondary forest</p> <p>Smallholders have average parcel sizes of 6 ha of which on average 5 ha are currently in use (including fallow), 4.5 ha being cocoa</p> <p>Large landholders have average parcel sizes of 30 ha of which on average 21 ha are currently in use, 18 ha being cocoa</p> <p>Cocoa starts to produce after 8 years, remains productive for 20 years followed by a fallow period of 3 years</p> <p>For the first 2 years, young cocoa is intercropped with food crops</p> <p>The food crop area will be at least 1 ha per rural household</p> <p>There is a preference for converting old growth forest rather than secondary forest into cocoa by large landholders. Without restrictions 90% of their demand for new cocoa land is assumed to come from old growth forest</p> <p>Timber and rubber area remain fixed</p> <p>Population size 2008 = 190,400 people</p> <p>Population growth rate = 2.5%</p> <p>85% of the population is rural</p> <p>Average household size = 5 people</p> <p>14% of the households are large landholders, 86% smallholders</p>	<p>District report 2005</p> <p>Mediated estimates using Aster 2007 images and 2009 household surveys</p> <p>Mediated estimates using Aster 2007 and Landsat 2000 images</p> <p>Local expert knowledge</p> <p>Mediated estimates based on 2009 household surveys and local expert knowledge</p>
Rural population dynamics	Population increase is mainly caused by birth in the district as the in- and out migration was expected to be minor		<p>Mediated estimate using district report 2005 data and local expert knowledge</p> <p>Average from data collected in 2000</p> <p>Local expert estimates</p>

Continued

**Table 1** Continued

Model sector	Contents	Assumptions and data	Information source
Carbon	The carbon stock is calculated for the land-uses on the off-reserve area which is currently covered with old growth forest (for scenario 2) and with old growth and secondary forest (for scenario 3)	Average carbon contents (ton C/ha) per land-use: Urban, bare soil = 0; nonforested fallow = 15; food crops = 30; food crops intercropped with young cocoa = 50; 3–8 year old cocoa = 70; productive cocoa = 100; forested fallow = 130; timber and rubber = 135; secondary forest = 160; old growth = 200	Mediated estimations from Swallow <i>et al.</i> (2007), Wauters <i>et al.</i> (2008) and De Bruijn (2005)
Income	Profit from cocoa = productive cocoa area * average production per ha * net profit per ha (income minus costs fertilizer and pesticides) REDD income is calculated in the REDD payments sector	<p>The Ghanaian cocoa prices of 2007 and 2008 (US\$ 1.14 and 1.37/kg) are compared to global market prices to calculate the percentage going to the government (44%)</p> <p>Cocoa price is projected to 2030 following and extending the trend of the World Bank forecast to 2020 resulting in a 40% decrease in 20 years</p> <p>Average production per hectare: 11.8 bags (=767 kg)</p> <p>Costs are 20% of profit</p> <p>Cocoa profit contributes &gt; 90% of rural cash income</p> <p>Cocoa income is used as proxy for total rural cash income excluding cash from REDD We assume labor is not paid and the cost of this is not included in the model</p>	<p>Information from district official and cocoa farmer, and World Bank (2009a)</p> <p>World Bank (2009b)</p> <p>Data from Technoserve Extension Offices in the district</p> <p>Estimation district officials</p> <p>Expert judgment</p>
REDD payments	Total carbon payment is calculated by: CO <sub>2</sub> stock (tons) of land-uses in 20 years from now on land now covered with off-reserve old growth forest (scenario 2) and secondary forest (scenario 3) minus carbon stock old growth forest (scenario 2) and secondary forest (scenario 3) multiplied by the price farmers would receive per ton CO <sub>2</sub>	<p>We assume an international carbon price of US\$ 10/ton CO<sub>2</sub> paid by investors, We obtained this number mediating the average contracted price throughout 2007 and early 2008 on the Clean Development Mechanism market (US\$ 13.60/ton CO<sub>2</sub>) and the average price on the voluntary market (US\$ 4.40/ton CO<sub>2</sub>)</p> <p>Transaction costs of REDD are presumed high and thus we assume only 25% will reach the farmers (US\$ 2.5/ton CO<sub>2</sub>), We adapted this number from Indonesian transaction costs which can be as high as 80%</p> <p>We assume a 20-year contract with: 20% paid up front; large payments paid every 5-years (10%) and 20% paid after 20 years if there is contract compliance; and regular small payments in other years (2%)</p>	<p>Capoor and Ambrosi (2008) for CDM price, and Butler <i>et al.</i> (2009) for voluntary market price</p> <p>CarbonPositive (2009) for Indonesian transaction costs</p> <p>How REDD contracts will be constructed has yet to be determined. We assume a large up-front payment in order to attract sellers of carbon and provide finance for start-up costs of sellers</p>



**Figure 1** Total carbon stock in the off-reserve area for (a) area currently covered with old-growth forest under “business as usual” (scenario 1) and “avoided deforestation of old-growth forest” (scenario 2); and (b) area now covered with secondary and old-growth forest under “business as usual” and “avoided deforestation of standing secondary and old-growth forest” (scenario 3).

and at what carbon price this would not happen (Appendix S1). In general, discount rates are high among low-income farmers (Campbell *et al.* 2006). However, Richards & Asare (1999) argue discount rates to be low among Ghanaian cocoa farmers, since many see cocoa farming as a type of old age pension, suggesting a discount rate of 6%. We used discount rates of 6 and 20%.

Three scenarios were modeled. Scenario 1 explores business as usual: old-growth and secondary forest are converted into cocoa plantations extrapolating the linear trend for the period 2000–2007. Scenario 2 explores avoided deforestation of old-growth forest. In this scenario, we assume all large landholders with old-growth forest on their land opt to receive REDD payments and no old-growth forest is converted into cocoa plantations. Scenario 3 explores avoided deforestation of all forest. In this scenario, we assume all farmers with standing old-growth and secondary forest on their land opt to receive REDD payments and no forest is converted into cocoa plantations. Only degraded cocoa plantations and non-forested land is used for new cocoa plantations.

Payments are simulated only for forest outside reserves since the forest reserves are already under a national forest conservation strategy and are not available to local farmers. We assume an international carbon price of US\$10/ton CO<sub>2</sub> to be paid by investors (Table 1), of which 75% is lost to transaction costs (Table 1) and thus US\$ 2.5/ton CO<sub>2</sub> would be received by the farmer reducing emissions on his land. For the payments we as-

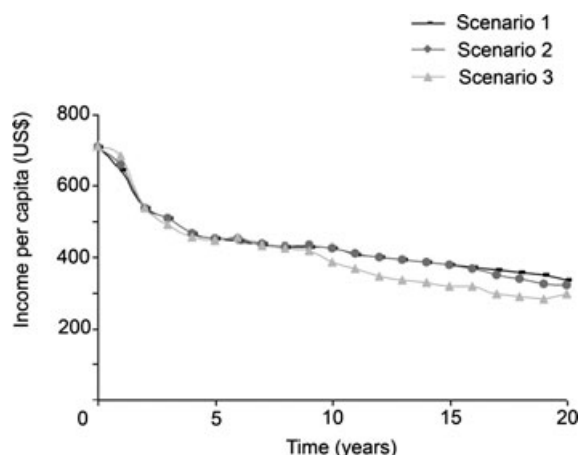
sumed a 20 year payment contract, with a high up-front payment because of the start-up costs involved in REDD (Table 1).

## Results

### Land use changes and carbon

For scenario 1, carbon stock declines rapidly over 20 years (Figure 1). These scenarios (Figure 1a and b) are used as the baseline for the calculation of REDD payments. The carbon stock on the land now covered with old-growth forests outside reserves decreases by 37% from 3 to 1.9 million ton C (Figure 1a) and for old-growth and secondary forest together the carbon stock decreases by 40% from 7.9 to 4.8 million ton C (Figure 1b). Already after 3 years, all old-growth forest outside the reserves is converted into cocoa plantation, excluding sacred forests. Once old-growth forest is gone, secondary forest cover decreases faster as it gives way to new cocoa plantations. The total cocoa area expands approximately 10% after 11 years to 220,000 ha after which there is no secondary forest or other land for further expansion. After 20 years the food crop area per household has decreased by 10% due to population growth and cocoa expansion.

Under scenario 2, the expansion of cocoa comes to an end after 7 years, when cocoa has increased by 4% to 212,000 ha. At the start of the simulation the farmers with old-growth forest shift their demand for new cocoa land to secondary forest resulting in the depletion of



**Figure 2** Income per capita for the rural population in the district under three scenarios: (1) business as usual, (2) no conversion of old-growth forest, and (3) no conversion of standing secondary and old-growth forest.

secondary forest after 6 years. Under scenario 2, 1.2 million ton C is prevented from being emitted compared to business as usual (Figure 1a).

Under scenario 3, after 1 year, all nonforested fallow land has been converted to cocoa plantations reaching their maximum cover of 205,000 ha. The rest of the simulation the cocoa area decreases as old cocoa turns into fallow land left unused for 3 years. The food crop area per household drops by 15% after 20 years because of the limitations placed on forest conversion. Some secondary forest regenerates into old-growth forest. Under scenario 3 carbon in the off-reserve area currently covered by old-growth and secondary forest increases from 7.9 to 8.3 million ton C (Figure 1b) and 3.5 million ton C is prevented from being emitted compared to business as usual.

### Rural income and opportunity costs

The average per capita income under scenario 1 decreases from US\$ 710 to 340 over 20 years for Wasa Amenfi West's rural population (Figure 2). This is partly due to the decrease in cocoa price, dropping by 40% after 20 years following the World Bank's forecast (Table 1). It is also due to the shortage of land for new cocoa plantations and declining soil fertility, while at the same time land has to be shared among the expanding future generation. It is likely that migration out of the district will increase in this situation, though this was not simulated.

Smallholders have no access to old-growth forest and are therefore not receiving payments for halting deforestation. Under scenario 2, average annual REDD payments vary between US\$ 18–180 per ha, while average annual cocoa net income varies between US\$ 388–563

per ha. For the first 7 years of the simulation large landholders have enough land without old-growth forest to continue cocoa expansion at the current rate. Since cocoa is simulated to become productive after 8 years, the cocoa planting restrictions after year seven only impact income after year 15 when it drops below income under business as usual (Figure 2).

Under scenario 3, average annual REDD payments vary between US\$ 16–159 per ha, while average annual cocoa net income varies between US\$ 388–563 per ha. Cocoa expansion is already restricted after 1 year, impacting income after 9 years (Figure 2). However already after 2 years, average per capita income under scenario 3 drops below business as usual caused by the lack of food crop land for smallholders. Smallholders are simulated to shorten their cocoa cycle, converting older productive cocoa to food crops, in order to maintain the minimum food crop plot of one ha per household.

The opportunity costs of cocoa production are not met by REDD payments. However, since REDD payments would be received immediately while cocoa starts producing after 8 years, discounting the income flows increases REDD's attractiveness. There is little to choose between the scenarios in terms of net present value (Table 2, first column), though scenario 3 appears to provide the least incentives. Scenario 2 becomes slightly more attractive to business as usual applying a high discount rate; big future losses in income can be compensated by a small up-front payment when discounting. The low level of net present value variation among the scenarios is largely due to the fact that limiting cocoa expansion affects income with an 8-year delay, the time for cocoa to start producing.

### Alternative assumptions

Changing some assumptions on cocoa and carbon prices in the model, result in the net present values given in Table 2 (the alternative assumptions columns). The outcomes appear sensitive to the discount rate applied, though scenario preferences do not change with altering cocoa prices. When applying a 20% discount rate, increasing the carbon price paid by investors from US\$ 10 to 15, net present values for scenario 1 and 3 are about equal and doubling the carbon price, scenario 3 even gives a slightly higher net present value.

### Contract breaking and the price of stopping deforestation

If the farmers conserving their old-growth forest (scenario 2) would merely aim at profit maximization they would break the contract after year five and continue the

**Table 2** Net present values (US\$) for 20 year income flows under the three scenarios with current and alternative model assumptions applying a 6 and 20% discount rate

		Net present value – 6% discount rate				Net present value – 20% discount rate			
		Alternative assumptions				Alternative assumptions			
		Cocoa price for farmer fixed at US\$1.46/kg (price 2009)	Cocoa price increasing with 40% over 20 years	Carbon price paid by investors US\$15	Carbon price paid by investors US\$20	Cocoa price for farmer fixed at US\$1.46/kg (price 2009)	Cocoa price increasing with 40% over 20 years	Carbon price paid by investors US\$15	Carbon price paid by investors US\$20
Scenario 1	5,169	7,455	8,677	5,169	5,169	2,405	3,270	3,608	2,405
Scenario 2	5,170	7,437	8,641	5,186	5,202	2,419	3,283	3,619	2,428
Scenario 3	4,922	7,013	8,092	4,974	5,026	2,377	3,198	3,512	2,405

conversion to cocoa. This scenario results in some delay in carbon emissions but not in net emission reduction or conservation of old-growth forest over 20 years. To stop the deforestation of old-growth forest, a carbon price of at least US\$ 55–60/ton CO<sub>2</sub> is needed. Deforestation of old-growth and degraded forest is stopped at a minimum of US\$ 70–75/ton CO<sub>2</sub>.

## Discussion

Assuming an annual REDD payment, farmers are likely to accept REDD initiatives, especially if a large up-front payment is planned as may occur with REDD funds pouring into new initiatives (Angelsen 2008, p. 128). But soon after the up-front payment is made, there may be a high incentive to break the contract, given the higher financial benefits from cocoa production. To keep avoiding deforestation after the contract period, payments should continue after 20 years increasing the price per ton CO<sub>2</sub>. If cocoa prices remain at current values or increase, opportunity costs of cocoa will be even higher and therefore carbon prices should be even more than US\$ 55/ton CO<sub>2</sub> to stop deforestation of old-growth forest. Price fluctuations in tropical agricultural commodities are high (e.g., World Bank 2009a and b), providing a difficult context for REDD which has to be based on long-term contracts.

If farmers opt for REDD this will likely widen the gap between rich and poor given that 90% of the carbon is stored in forest on large landholdings owned by <14% of the rural population. Furthermore, poor people who lease land may lose access to the land as large landholders may claim back their leased-out land for REDD purposes. The food crop area per capita decreases more under scenario 3 than under business as usual, and they may opt for cash cropping rather than growing enough food exposing households to greater food insecurity. If REDD has negative impacts on human wellbeing, and it increases

rural differentiation, then policy makers may not support REDD, given their overriding concern with development and not environmental issues. A potential source of conflict is the unclear tenure over carbon; agreements on access to carbon payments and benefit sharing need to be negotiated.

If REDD becomes an option it is likely that some landholders will opt for REDD and others won't, unlike our scenarios where all do. There may be forest patches with lower cocoa suitability and thus lower opportunity costs where REDD is more attractive (e.g., on steep slopes). However, in our simulation REDD payments are so far from competing with opportunity costs of cocoa that even low-productive areas may be preferred for cocoa than REDD.

In landscapes comparable to this study, with little remaining unprotected old-growth forest, high population pressure, and lucrative income from cash crop production, REDD payments based on current carbon prices would not outcompete agricultural production. REDD investments based on current carbon market conditions made in such landscapes would most likely be received with some enthusiasm, perhaps initially shift deforestation from old-growth to degraded forest, for the strategy to be abandoned after some years. Such an investment would not result in long-term reduction of carbon emissions. That high prices for cash crops (including biofuels) can undermine REDD strategies has also been shown in Asia (Butler *et al.* 2009), while in some parts of Africa, e.g., where shifting cultivation is practiced, REDD could be a more lucrative option than current land uses (e.g., Bellassen & Gitz 2008).

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## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Appendix S1** Full description of the method, model structure and dynamics.

Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

## References

- Angelsen, A. (2008) *Moving AHEAD with REDD: issues, options and implications*. CIFOR, Bogor, Indonesia.
- Bellassen, V., Gitz V. (2008) Reducing emissions from deforestation and degradation in Cameroon—assessing costs and benefits. *Ecol Econ* **68**, 336–344.
- Butler, R.A., Koh L.P., Ghazoul J. (2009) REDD in the red: palm oil could undermine carbon payment schemes. *Conserv Lett* **2**, 67–73.
- Campbell, B.M., Gordon I.J., Luckert M.K., Petheram L., Vetter S. (2006) In search of optimal stocking regimes in semi-arid grazing lands: one size does not fit all. *Ecol Econ* **60**, 75–85.
- Capoor, K., Ambrosi P. (2008) *State and trends of the carbon market 2008*. World Bank, Washington, DC.
- CarbonPositive. (2009) Indonesia reveals REDD revenue shares. Available from: URL <http://www.carbonpositive.net/viewarticle.aspx?articleID=1602>. Accessed 17 September 2009.
- De Bruijn, A. (2005) *Carbon dynamics simulation in Malinau Research Forest, Borneo, Indonesia*. Thesis, Wageningen University, The Netherlands.
- Förster, J. (2009) *The potential of reducing emissions from deforestation and degradation (REDD) in Western Ghana*. Thesis, University of Bayreuth, Germany.
- HPS (High Performance Systems). (1996) *STELLA and STELLA research software*. HPS, Hanover, NH.
- Kanninen, M., Murdiyarso D., Seymour F., Angelsen A., Wunder S., German, L. (2007) Do trees grow on money? The implications of deforestation research for policies to promote REDD. Center for International Forestry Research (CIFOR), Bogor, Indonesia.
- Lambin, E.F., Turner B.L., Geist H.J. *et al.* (2001) The causes of land-use and land-cover change: moving beyond the myths. *Glob Environ Change* **11**, 261–269.
- NRMP (Natural Resource Management Programme). (1999) Globally significant biodiversity areas 'fure head waters' and 'fure river forest reserves' in Wasa Amenfi West District gazetted by NRMP, Ghanaian Ministry of Lands Forests and Mines.
- Pagiola, S. (2007) Payments for environmental services in Costa Rica. *Ecol Econ* **65**, 712–724.
- Richards, M., Asare A. (1999) Economic Incentives for Cocoa Farmers to Tend Cocoa Trees in Southern Ghana. Unpublished Report for UK Department for International Development (DFID) Forestry Research Programme. Overseas Development Institute, London.
- Righelato, R., Spracklen D.V. (2007) Carbon mitigation by biofuels or by saving and restoring forests? *Science* **317**, 902.
- Sandker, M., Campbell B.M., Nzooz Z. *et al.* (2009) Exploring forest wildlife conservation scenarios in Central Africa. *Biodiversity Conserv* **18**, 2875–2892.
- Sandker, M., Suwarno A., Campbell B.M. (2007) Will forests remain in the face of oil palm expansion? Simulating change in Malinau, Indonesia. *Ecol Soc* **12**, 37.
- Swallow, B., Noordwijk M., van Dewi S. *et al.* (2007) Opportunities for avoided deforestation with sustainable benefits. An Interim Report by the ASB Partnership for the Tropical Forest Margins. Nairobi, Kenya.
- UNFCCC (United Nations Framework Convention on Climate Change). (2007) Decision 2/CP.13 Reducing emissions from deforestation in developing countries: approaches to stimulate action. Pages 8–11 in FCCC/CP/2007/6/Add.1. Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007, Addendum Part Two: Action taken by the Conference of the Parties at its thirteenth session. Bonn, Germany. Available from: <http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf#page=8>. Accessed 1 December 2009.
- Van Den Belt, M. (2004) *Mediated modeling. A system dynamics approach to environmental consensus building*. Washington DC, USA.
- Wauters, J.B., Coudert S., Grallien E., Jonard M., Ponette Q. (2008) Carbon stock in rubber tree plantations in Western Ghana and Mato Grosso (Brazil). *Forest Ecol Manage* **255**, 2347–2361.
- Wilson, G.A. (2007) *Multifunctional agriculture: a transition theory perspective*. Trowbridge, UK.
- World Bank. (2009a) Commodity price data (pink sheet). Available from: URL <http://go.worldbank.org/2O4NGVQC00>. Accessed 17 September 2009.
- World Bank. (2009b) Prospects for the global economy: commodity forecast. Available from: URL <http://go.worldbank.org/9VQJ4ACJZ0>. Accessed 17 September 2009.

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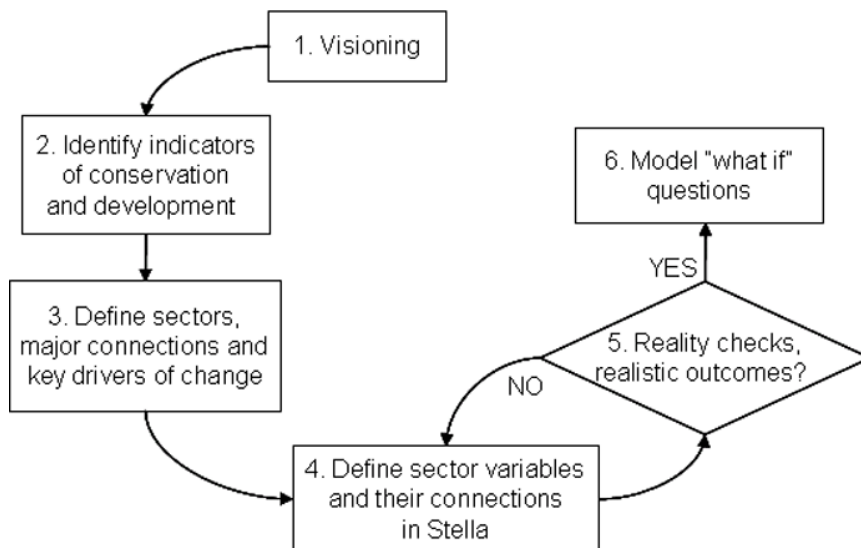
On dissertation page 103 / article page 115: the Wasa Amenfi West district area should be 3,465 km<sup>2</sup> instead of 34,646 km<sup>2</sup>

## **Appendix I. Full description of the method, model structure and dynamics**

In this appendix we give a full description of the steps taken in the participatory model building process and explain the basics of the model language STELLA. After this, we describe the full structure and dynamics of the model built of the Wasa Amenfi West district by providing a list of all variables and equations. Finally, we describe how we obtained the contract breaking year if we assume the farmer would make his decisions merely based on profit maximization (searching the highest net present value of income) and how we obtained the price at which deforestation can be stopped.

### **Steps taken in the participatory model building process**

We describe an idealized sequence of steps in the participatory modeling process (Fig. 1) although as in many multi-stakeholder processes there was some iteration and backtracking during the workshop.



**Figure 1.** Sequence of steps in participatory modeling process modified from Sandker *et al.* 2009

In the first step, we developed visions of the future around topics of interest. As a prelude to visioning, we encouraged participants to think about change by discussing historical events that affected conservation and development outcomes in the landscape (Wasa Amenfi West district). We examined underlying trends in ecological and socioeconomic variables. We then identified some potential major drivers of change, and developed positive

and negative scenarios from poverty and biodiversity perspectives. In so doing, we identified the key issues for modeling.

The second step consisted of identifying what model parameters we are interested in; their outcomes are plotted on graphs. For the scenario for Reducing Emissions from forest Degradation and Deforestation (REDD) this is the amount of carbon prevented from being emitted by deforestation and forest degradation, and the cash income for the farmers that preserve this carbon on their lands.

The third step consisted of conceptualizing the landscape; this involved defining the major sectors for the model, the spatial dimensions and the major connections between sectors. This step is conducted on paper or in STELLA's "map layer".

The fourth step was the detailed model building in STELLA. We defined the main variables (stocks and converters in model terms) in each sector and collected the initial values for these variables. We defined how these variables changed over time (adding flows to the stocks) and how variables influenced each other (adding action connectors). Small groups of stakeholders worked on different sectors after which they were presented and discussed as a group and linked together in one landscape model.

The fifth step consisted of reality checks, running the model under different conditions and exploring how simulations compared to what is known by stakeholders. The simulations often led to revisions of assumed variables and relationships and revealed the need for additional data; data which was collected in the beginning of 2009 by household surveys.

Once the model simulations were found to be realistic by all stakeholders, we moved to the final step of exploring scenarios and asking 'what if..' questions. Accordingly assumptions can be changed in the model, e.g. 'what happens to farmer income patterns if the carbon price is US\$ 20 instead of US\$ 10/ton CO<sub>2</sub>?'. On the basis of the simulation outcome (e.g. displayed in a graph) the participants discuss potential obstacles and likely farmer decisions.

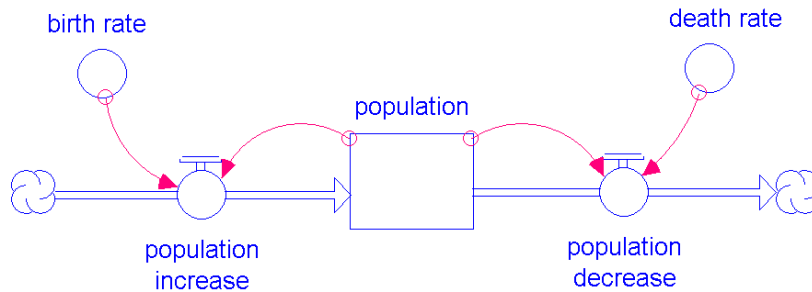
### **The modeling language STELLA**

The system dynamics model of the Wasa Amenfi West district was built using the software STELLA (HPS, 1996). STELLA's interface has three levels: the equation level, the model level and the interface level. The model level is quantitative but can be switched to qualitative (then referred to as map instead of model) to display only the relationships among variables without adding their values. The equation level gives the mathematical description (see 'Detailed description of model equations') of the elements constructed in the model level. The interface level gives an overview of the model sectors and their connectedness. The equation level is generally the least used, the



model is built at the model level and the interface level is used for navigation.

STELLA models are built using four basic elements of construction: 'stocks', 'flows', 'action connectors' and 'converters' (Figure 2).



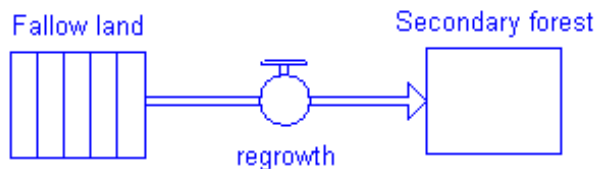
**Figure 2.** A STELLA model for population (in STELLA's model level)

Stocks (e.g. 'Population' in Figure 2) represent conditions within a system; they are a quantity of something with one single unit (e.g. km<sup>2</sup>, persons, m<sup>3</sup>). Stocks are represented with the following equation:

$$X(t) = X(t-dt) + (\text{Inflows} - \text{Outflows}) * dt$$

where  $t$  = time and  $dt$  = the time step

None of the stocks in the Wasa Amenfi West model are allowed to have a negative value. There are different stock variants, of which two are used in this model. We used the 'classic' stock, called a 'reservoir' ('Population' in Figure 2, and 'Secondary forest' in Figure 3), and a 'conveyor' to simulate aging ('Fallow land' in Figure 3).



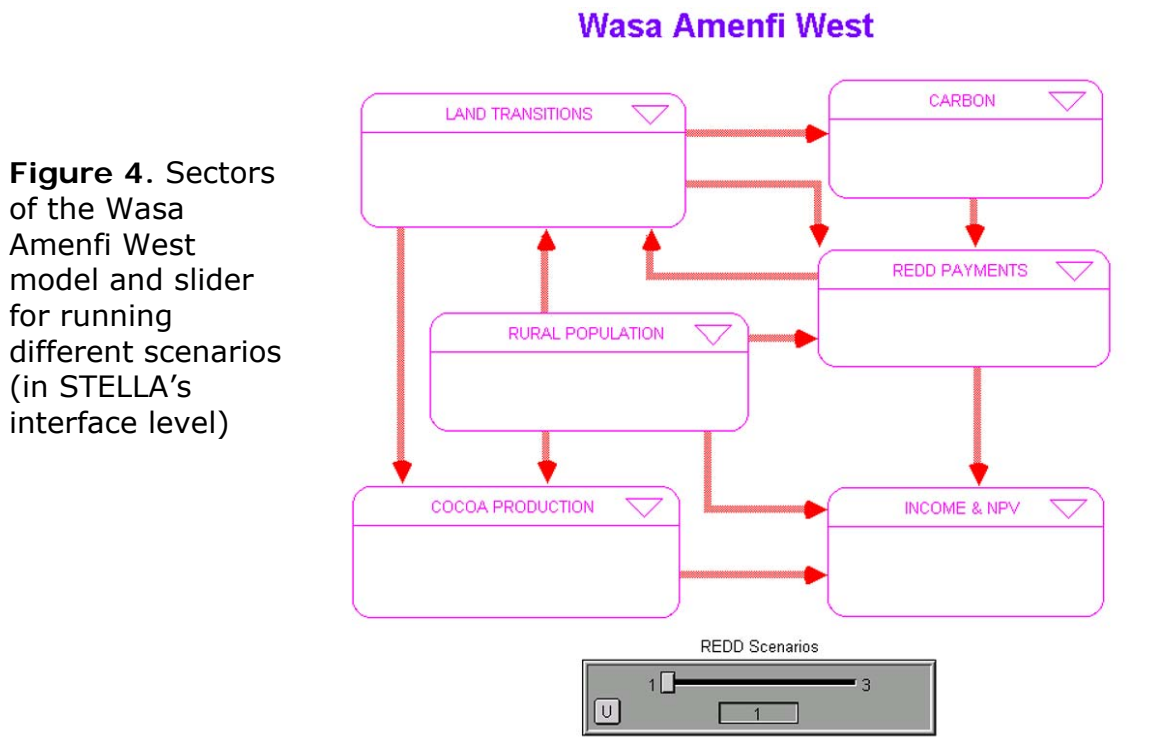
**Figure 3.** A STELLA model for re-growth of fallow land into forest using a conveyor

The initial value entered in the conveyor is considered to be of different ages spread equally over the transit time. For example, in the example of Figure 3 we entered a transition time for re-growth of 5 years; when  $t=0$  and the initial value of fallow land=100ha, then during the first 5 years of the simulation, 20 ha will grow into secondary forest each year. After the first transit time in the simulation has passed, the outflow equals the inflow with one transit time delay; in our example this would be outflow ( $t$ ) = inflow ( $t-5$ ).

Flows ('Population increase' and 'Population decrease' in Figure 2 and 'Regrowth' in Figure 3) represent the activities that cause conditions to

change and add dynamics to the values of stocks. Flows do not have a predetermined equation structure but have the same unit as the stock with which they are connected per time step (e.g. km<sup>2</sup>/year, persons/year). In a metaphor HPS (2003) suggests that if stocks are nouns and flows are verbs, then converters ('Birth rate' and 'Death rate' in Figure 2) are adverbs. Converters add information and are often used to define flows and convert their units correctly. They have no predetermined equation structure and can have single (e.g. ha, elephants) or combined units (e.g. elephants/ha; m<sup>3</sup>/year). Often they are constant values but their values can also be defined as functions or 'graphical functions'. When a converter is a graphical function its value can change in a non-linear manner over time or with the values of stocks, flows or other converters in the model. E.g. one can make a graphical function of Birth rate making its value depend on Population; we can enter a constant value until the population reaches a certain number after which we can lower the value of Birth rate with an S-shaped curve. The graphical function is designed by the modeler.

The last element of the STELLA language is the action connector (the arrows in Figure 1). Action connectors transport information from stocks, flows and converters to flows and converters. E.g. if the flow 'Population increase' is determined by 'Birth rate' x 'Population', then action connectors are needed from 'Birth rate' and 'Population' to 'Population increase'.



A landscape model is often sub-divided in different model sectors, just to make it easier to navigate the model and to keep a degree of overview when the model gets more complex. The sectors of the Wasa Amenfi West model

are displayed in Figure 4. The arrows between the sectors indicate information from the sector from which the arrow departs is used in the sector the arrow points at.

Located below the model sectors one can see a slider called 'REDD Scenarios' (Figure 4). A slider is a converter which can take different values. The slider in Figure 4 can take the value 1, 2 and 3. The incremental step is set at 1 so the slider in this example cannot take intermediate values (e.g. 1.5). Sliders are usually used so one can easily run different scenarios or to change the value of a parameter whose influence on the model outcomes we'd like to explore.

In the Ghana model the three scenarios explored are obtained by changing the slider 'REDD Scenarios' as follows:

REDD Scenarios= 1: 'Business as usual', forest is being converted to cocoa plantations

REDD Scenarios= 2: 'Avoided deforestation of old-growth forest', none of the current area covered with old-growth forest is converted

REDD Scenarios=3: 'Avoided deforestation of all forest', none of the current area covered with old-growth or secondary forest is converted

### **Detailed description of the model equations**

In this section the equations used to model the landscape are described per sector. The equations are ordered as stocks, flows and converters though some sectors only include converters (carbon, cocoa production, REDD payments and Income and net present value). The stocks, flows or converters which are underlined originate from a different sector (causing the arrows between the sectors in Figure 4).

#### *SECTOR: Rural population*

Only the rural population is included in this model since the urban population is not involved in REDD and will not affect deforestation much. Rural population increase is mainly caused by births in the district as the in- and out migration was expected to be minor. There might be a possible shift from rural people becoming urban (farmers changing to the service sector) and/or one might experience an increase in rural people migrating out of the district, especially with land becoming scarce. However this is not of major importance for the outcomes of REDD and was not included in the model. The rural households are divided into large landholders (LL) and smallholders (SH) because these are differently affected by REDD payments.

#### *Stocks:*

$$\text{LL\_households}(t) = \text{LL\_households}(t - dt) + \text{LL\_hh\_increase} - \text{LL\_hh\_decrease}$$

$$SH\_households(t) = SH\_households(t - dt) + SH\_hh\_increase - SH\_hh\_decrease$$

*Flows:*

$$\begin{aligned} LL\_hh\_increase &= Birth\_rate * LL\_households * dt \\ LL\_hh\_decrease &= Death\_rate * LL\_households * dt \\ SH\_hh\_increase &= Birth\_rate * SH\_households * dt \\ SH\_hh\_decrease &= Death\_rate * SH\_households * dt \end{aligned}$$

*Convertors:*

$$\begin{aligned} Birth\_rate &= 0.04 \\ Death\_rate &= 0.015 \\ Total\_hh &= LL\_households + SH\_households \\ Total\_rural\_population &= Total\_hh * 5 \\ Change\_in\_hh\_LL &= LL\_hh\_increase - LL\_hh\_decrease \\ Change\_in\_hh\_SH &= SH\_hh\_increase - SH\_hh\_decrease \end{aligned}$$

*SECTOR: Land transitions*

Deforestation in the landscape has occurred mainly outside forest reserves, driven by local farmers clearing for cocoa production. This land cover change dynamic is our main interest which is why this conversion is modeled in more detail. It is unclear whether timber and rubber plantations would increase or decrease to make way for cocoa; these areas are presumed to remain constant. The demand for new cocoa land is modeled in such a way that the cocoa area per household remains the same as long as there is enough land available. Thus deforestation is driven by population increase and by the demand for land replacing old cocoa plantations for which a fallow period is modeled.

*Large landholders' (LL) land:*

*Stocks:*

$$\begin{aligned} Old\_growth\_off\_reserve\_LL(t) &= Old\_growth\_off\_reserve(t - dt) + (Regeneration - Old\_growth\_into\_cocoa) * dt \\ Old\_growth\_off\_reserve(0) &= 11,400 \text{ ha} \\ Sec\_forest\_LL(t) &= Sec\_Forest\_LL(t - dt) + (Fallow\_to\_sec\_LL - Cocoa\_planting\_on\_sec\_LL - Regeneration) * dt \\ Sec\_forest\_LL(0) &= 24,406 \text{ ha} \\ Productive\_cocoa\_LL(t) &= Productive\_cocoa\_LL(t - dt) + (Cocoa\_over\_8yrsLL - Cocoa\_deterioration\_LL) * dt \\ Productive\_cocoa\_LL(0) &= 51,394 \text{ ha} \\ Food\_crop\_LL(t) &= Food\_crop\_LL(t - dt) + Crops\_on\_cocoa\_land\_LL * dt \\ Food\_crop\_LL(0) &= 9,946 \text{ ha} \end{aligned}$$

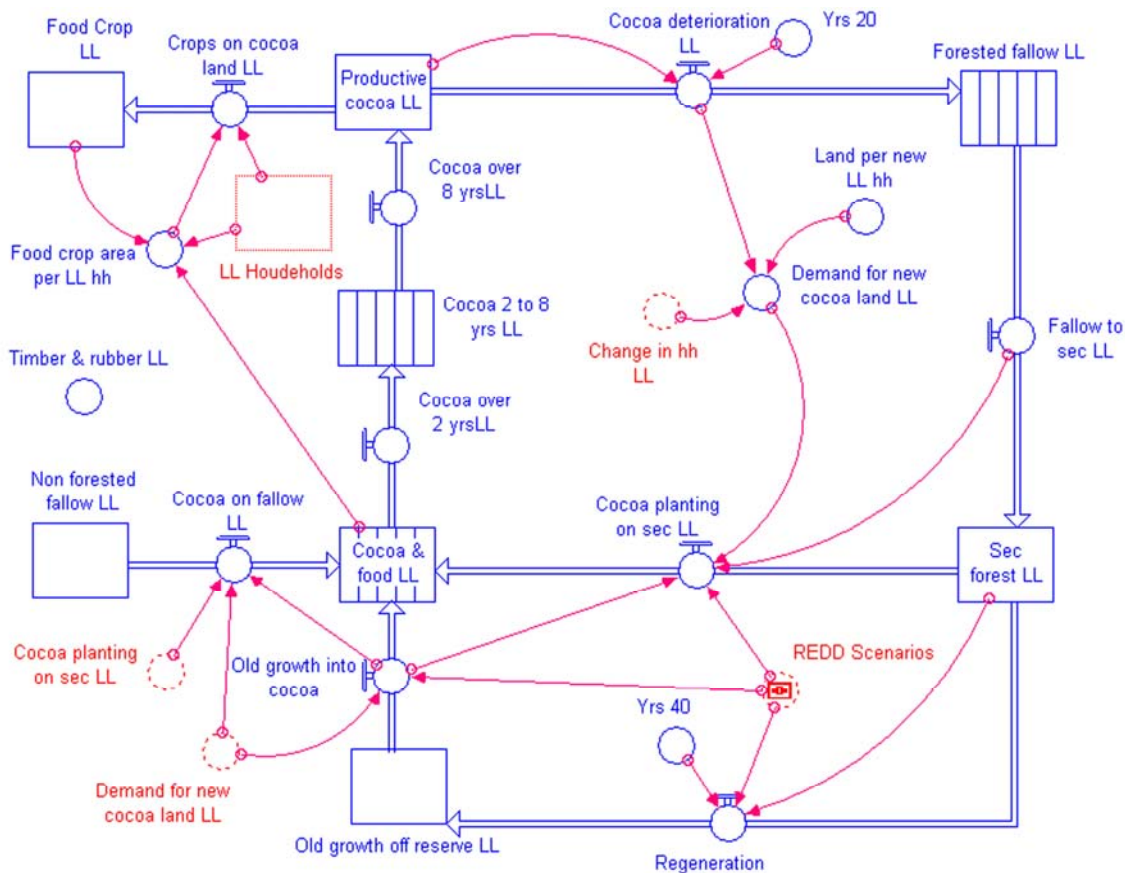
$\text{Non\_forested\_fallow\_LL}(t) = \text{Non\_forested\_fallow\_LL}(t - dt) - \text{Cocoa\_on\_fallow\_LL} * dt$   
 $\text{Non\_forested\_fallow\_LL}(0) = 3,661 \text{ ha}$

*Conveyor stocks:*

$\text{Cocoa\_}\&\_\text{food\_LL}(t) = \text{Cocoa\_}\&\_\text{food\_LL}(t - dt) + (\text{Cocoa\_planting\_on\_sec\_LL} + \text{Old\_growth\_into\_cocoa} + \text{Cocoa\_on\_fallow\_LL} - \text{Cocoa\_over\_2yrsLL}) * dt$   
 $\text{Cocoa\_}\&\_\text{food\_LL}(0) = 7342$   
 Transit time = 2 years (Conveyor outflow 'Fallow\_to\_sec\_LL')

$\text{Cocoa\_2\_to\_8\_yrs\_LL}(t) = \text{Cocoa\_2\_to\_8\_yrs\_LL}(t - dt) + (\text{Cocoa\_over\_2\_yrsLL} - \text{Cocoa\_over\_8\_yrsLL}) * dt$   
 $\text{Cocoa\_2\_to\_8\_yrs\_LL}(0) = 22842$   
 Transit time = 6 years (Conveyor outflow 'Cocoa\_over\_8\_yrsLL')

$\text{Forested\_fallow\_LL}(t) = \text{Forested\_fallow\_LL}(t - dt) + (\text{Cocoa\_deterioration\_LL} - \text{Fallow\_to\_sec\_LL}) * dt$   
 $\text{Forested\_fallow\_LL}(0) = 0$   
 Transit time = 3 years (Conveyor outflow 'Cocoa\_over\_2yrsLL')



**Figure 5.** Model for dynamics of land uses on large landholders' land (elements in dotted lines are model elements calculated in other model sectors and 'copied' to this sector maintaining its dynamics)

*Flows:*

Regeneration = if REDD\_Scenarios=3 then Sec\_forest\_LL/Yrs\_40 else 0  
Old\_growth\_into\_cocoa = if REDD\_Scenarios=1 then  
    Demand\_for\_new\_cocoa\_land\_LL\*0.9 else 0  
Fallow\_to\_sec\_LL = Conveyor outflow  
Cocoa\_planting\_on\_sec\_LL = if REDD\_Scenarios=3 then Fallow\_to\_sec\_LL  
    else Demand\_for\_new\_cocoa\_land\_LL-Old\_growth\_into\_cocoa  
Cocoa\_on\_fallow\_LL = Demand\_for\_new\_cocoa\_land\_LL -  
    Old\_growth\_into\_cocoa - Cocoa\_planting\_on\_sec\_LL  
Cocoa\_over\_2\_yrsLL= Conveyor outflow  
Cocoa\_over\_8\_yrsLL= Conveyor outflow  
Cocoa\_deterioration\_LL = Productive\_Cocoa\_LL(t)/Yrs\_20  
Crops\_on\_cocoa\_land\_LL = if Food\_crop\_area\_per\_LL\_hh <1 then (1-  
    Food\_crop\_area\_per\_LL\_hh) \* LL\_households(t) else 0

*Convertors:*

Demand\_for\_new\_cocoa\_land\_LL = Change in hh\_LL \*  
    Land\_per\_new\_LL\_hh + Cocoa\_deterioration\_LL  
Food\_crop\_per\_LL\_hh = (Food\_crop\_LL + Cocoa\_&\_food\_LL)/LL\_households  
Land\_per\_new\_LL\_hh = 21 ha  
    *This value is obtained by (Cocoa\_&\_food\_LL + Cocoa\_2\_to\_8\_yrs\_LL*  
    *+ Productive\_Cocoa\_LL + Food\_Crop\_only\_LL + Forested\_Fallow\_LL +*  
    *non\_forested\_fallow\_LL)/LL\_households at t=0*  
Yrs\_20 = 20 years  
Yrs\_40 = 40 years  
Timber\_&\_rubber\_LL = 6102 ha

*Smallholders' (SH) land:*

*Stocks:*

Sec\_forest\_SH(t) = Sec\_forest\_SH(t - dt) + (Fallow\_to\_sec\_SH -  
    Cocoa\_planting\_on\_sec\_SH) \* dt  
Sec\_forest\_SH(0) = 6,102 ha  
Productive\_cocoa\_SH(t) = Cocoa\_hh\_SH(t - dt) + (Cocoa\_over\_8yrsSH -  
    Cocoa\_deterioration\_SH - Old\_cocoa\_into\_food\_crop) \* dt  
Productive\_cocoa\_hh\_SH(0) = 77,091 ha  
Food\_crop\_SH(t) = Food\_crop\_SH(t - dt) + Crops\_on\_cocoa\_land\_SH \* dt  
Food\_crop\_SH(t) = 14,918 ha  
Non\_forested\_fallow\_SH(t) = Non\_forested\_fallow\_SH(t - dt) -  
    Cocoa\_on\_fallow\_SH \* dt

Conveyor stocks:

$$\text{Cocoa\_ \& food\_SH}(t) = \text{Cocoa\_ \& food\_SH}(t - dt) + (\text{Cocoa\_planting\_on\_sec\_SH} + \text{Cocoa\_on\_fallow\_SH} - \text{Cocoa\_over\_2yrsSH}) * dt$$

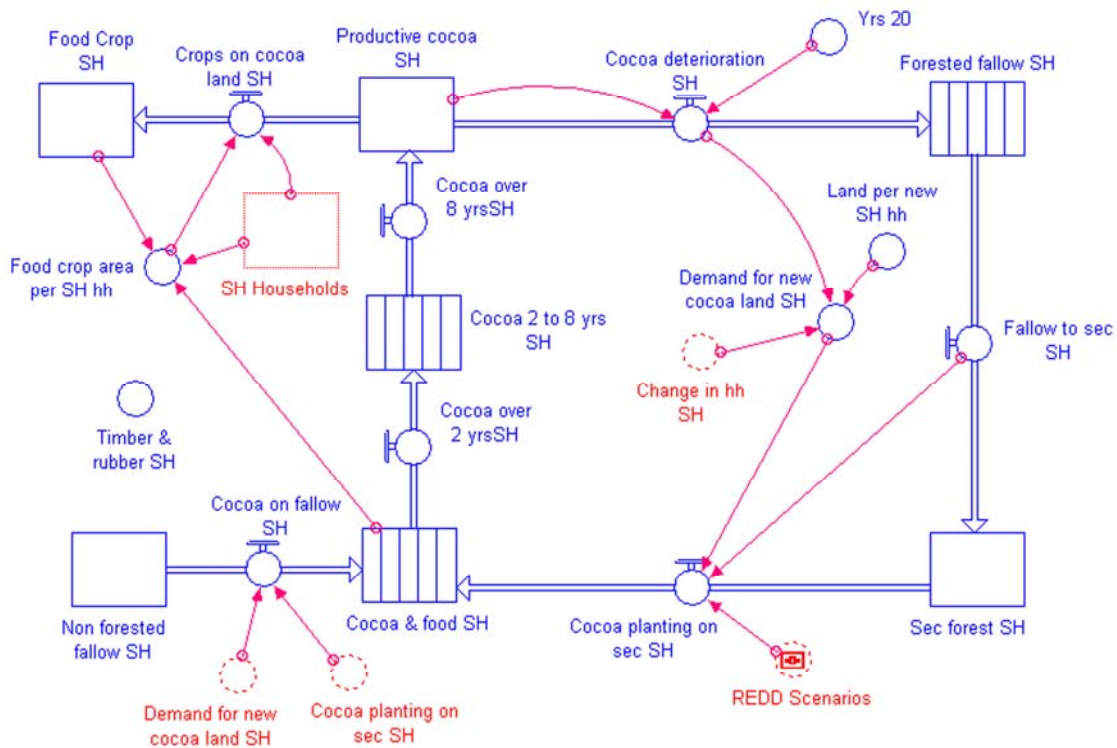
$$\text{Cocoa\_ \& food\_SH}(0) = 11013$$
 Transit time = 2 years (Conveyor outflow 'Cocoa\\_over\\_2\\_yrsSH')

$$\text{Cocoa\_2\_to\_8\_yrs\_SH}(t) = \text{Cocoa\_2\_to\_8\_yrs\_SH}(t - dt) + (\text{Cocoa\_over\_2\_yrsSH} - \text{Cocoa\_over\_8\_yrsSH}) * dt$$

$$\text{Cocoa\_2\_to\_8\_yrs\_SH} = 34263$$
 Transit time = 6 years (Conveyor outflow 'Cocoa\\_over\\_8\\_yrsSH')

$$\text{Forested\_fallow\_SH}(t) = \text{Forested\_fallow\_SH}(t - dt) + (\text{Cocoa\_deterioration\_SH} - \text{Fallow\_to\_sec\_SH}) * dt$$

$$\text{Forested\_fallow\_SH}(0) = 0$$
 Transit time = 3 years (Conveyor outflow 'Fallow\\_to\\_sec\\_SH')



**Figure 6.** Model for dynamics of land uses on smallholders' land

Flows:

$$\text{Fallow\_to\_sec\_SH} = \text{Conveyor outflow}$$

$$\text{Cocoa\_planting\_on\_sec\_SH} = \text{if REDD\_Scenarios}=3 \text{ then Fallow\_to\_sec\_SH}$$

$$\text{else Demand\_for\_new\_cocoa\_land\_SH}$$

$$\text{Cocoa\_on\_fallow\_SH} = \text{Demand\_for\_new\_cocoa\_land\_SH} - \text{Cocoa\_planting\_on\_sec\_SH}$$

Cocoa\_over\_2\_yrsSH = Conveyor outflow  
 Cocoa\_over\_8\_yrsSH = Conveyor outflow  
 Cocoa\_deterioration\_SH = Productive\_cocoa\_SH(t)/Yrs\_20  
 Crops\_on\_cocoa\_land\_SH = if Food\_crop\_area\_per\_SH\_hh < 1 then (1 -  
 Food\_crop\_area\_per\_SH\_hh) \* SH\_households(t) else 0

*Convertors:*

Demand\_for\_new\_cocoa\_land\_SH = Change in hh SH \* 5.2 +  
 Cocoa\_deterioration\_SH  
 Food\_crop\_area\_per\_SH\_hh =  
 (Cocoa\_&\_food\_SH + Food\_crop\_SH) / SH\_households(t)  
 Land\_per\_new\_SH\_hh = 5.1 ha  
*This value is obtained by (Cocoa\_&\_food\_SH + Cocoa\_2\_to\_8\_yrs\_SH  
 + Productive\_Cocoa\_SH + Food\_Crop\_only\_SH + Forested\_Fallow\_SH  
 + non\_forested\_fallow\_SH) / SH\_households at t=0*  
 Timber\_&\_rubber\_SH = 9,152 ha

*Remaining land:*

Forest\_reserve = 41,384 ha  
 Old\_growth\_sacred\_forest = 3,813 ha  
 Urban & bare soil = 6,102 ha

*SECTOR: Carbon*

In this sector, the amount of carbon is calculated for which a payment can be received. The business as usual scenario is used as the carbon baseline. All variables in this sector are convertors.

*Calculation of carbon (C) contents different land-uses:*

C\_old\_growth\_per\_ha = 200 ton C/ha  
 C\_secforest\_per\_ha = 160 ton C/ha  
 C\_timber\_&\_rubber\_per\_ha = 135 ton C/ha  
 C\_new\_cocoa\_per\_ha = 50 ton C/ha  
 C\_cocoa\_2to8\_per\_ha = 70 ton C/ha  
 C\_prodcocoa\_per\_ha = 100 ton C/ha  
 C\_forest\_fallow\_per\_ha = 130 ton C/ha  
 C\_nonforest\_fallow\_per\_ha = 15 ton C/ha  
 C\_food\_crop\_per\_ha = 30 ton C/ha  
 Total\_C\_old\_growth\_off\_reserve = C\_old\_growth\_per\_ha \*  
Old growth off reserve LL(t)  
 Total\_C\_sec\_forest\_LL = C\_secforest\_per\_ha \* Sec Forest LL(t)  
 Total\_C\_timber\_&\_rubber\_LL = C\_timber\_&\_rubber \* Timber & Rubber LL  
 Total\_C\_new\_cocoa\_LL = C\_new\_cocoa\_per\_ha \* Cocoa & food LL(t)  
 Total\_C\_cocoa\_2to8\_LL = C\_cocoa\_2to8\_per\_ha \* Cocoa 2 to 8 yrs LL(t)  
 Total\_C\_prodcocoa\_LL = C\_prodcocoa\_per\_ha \* Productive Cocoa LL(t)



$\text{Total\_C\_forest\_fallow\_LL} = \text{C\_forest\_fallow\_per\_ha} * \text{Forested Fallow LL(t)}$   
 $\text{Total\_C\_foodcrop\_LL} = \text{C\_food\_crop\_per\_ha} * \text{Food Crop LL(t)}$   
 $\text{Total\_C\_nonfor\_fallow\_LL} = \text{C\_non\_for\_fallow\_per\_ha} * \text{Non forested fallow LL(t)}$   
 $\text{Total\_C\_sec\_forest\_SH} = \text{C\_secforest\_per\_ha} * \text{Sec Forest SH(t)}$   
 $\text{Total\_C\_timber\_\&\_rubber\_SH} = \text{C\_timber\_\&\_rubber} * \text{Timber \& Rubber SH}$   
 $\text{Total\_C\_new\_cocoa\_SH} = \text{C\_new\_cocoa\_per\_ha} * \text{Cocoa \& food SH(t)}$   
 $\text{Total\_C\_cocoa\_2to8\_SH} = \text{C\_cocoa\_2to8\_per\_ha} * \text{Cocoa 2 to 8 yrs SH(t)}$   
 $\text{Total\_C\_prodcocoa\_SH} = \text{C\_prodcocoa\_per\_ha} * \text{Productive Cocoa SH(t)}$   
 $\text{Total\_C\_forest\_fallow\_SH} = \text{C\_forest\_fallow\_per\_ha} * \text{Forested Fallow SH(t)}$   
 $\text{Total\_C\_foodcrop\_SH} = \text{C\_food\_crop\_per\_ha} * \text{Food Crop only SH(t)}$   
 $\text{Total\_C\_nonfor\_fallow\_SH} = \text{C\_non\_for\_fallow\_per\_ha} * \text{Non forested fallow SH(t)}$

*Calculation of C contents for payment scenario 2:*

*Scenario 2 only concerns carbon payments to LL since old-growth forest is located on their land. For scenario 2, the amount of carbon for payment is obtained by calculating the carbon stock for the land-uses that have replaced old-growth forest after 20 years under business as usual and subtracting this value from the calculated carbon stock in the old-growth forest after 20 years (scenario 2). In these calculations we 'distillate' only the carbon changes on the land which is currently covered with old-growth forest from the total landscape carbon changes. Thus the carbon amount for the land uses replacing old-growth forest under business as usual is assessed by calculating the total landscape carbon changes on LL land after 20 years, minus the changes in carbon outside the current old-growth area after 20 years as explained in more detail here below.*

$\text{C\_cocoa\_sec\_fallowLL} = \text{Total\_C\_new\_cocoa\_LL} + \text{Total\_C\_Cocoa\_3to8\_LL} +$   
 $\text{Total\_C\_Prodcocoa\_LL} + \text{Total\_C\_for\_fallow\_LL} +$   
 $\text{Total\_C\_sec\_forest\_LL}$

$\text{Total\_C\_outside\_current\_area\_old\_growthLL} = \text{Graphical function of time}$   
 (year, value  $\text{Total\_C\_outside\_current\_area\_old\_growthLL}$ )  
 (0.00, 1.1e+007), (1.00, 1.1e+007), (2.00, 1e+007), (3.00, 1e+007),  
 (4.00, 9.9e+006), (5.00, 9.6e+006), (6.00, 9.4e+006), (7.00,  
 9.5e+006), (8.00, 9.6e+006), (9.00, 9.7e+006), (10.0, 9.8e+006),  
 (11.0, 9.8e+006), (12.0, 9.9e+006), (13.0, 1e+007), (14.0, 1e+007),  
 (15.0, 1e+007), (16.0, 1e+007), (17.0, 1e+007), (18.0, 1e+007),  
 (19.0, 1e+007), (20.0, 1e+007)

*The values in this graphical function are the carbon changes on the LL land excluding the carbon changes in the land currently covered with old-growth forest. The values are obtained from the values of C\_cocoa\_sec\_fallowLL running the model for 20 years under a business as usual scenario and multiplying the following flows by zero: Crops\_on\_cocoa\_land\_LL, Cocoa\_on\_fallow\_LL, Old\_growth\_into\_cocoa.*

*By giving these flows a value zero we calculate the carbon changes in the area outside the old-growth forest going through the different cocoa stages. We assume that the old-growth forest is only converted into cocoa, not into food crops.*

$$C\_cocoa\_sec\_fallow\_oldgrowthLL = Total\_C\_new\_cocoa\_LL + Total\_C\_Cocoa\_3to8\_LL + Total\_C\_Prodcocoa\_LL + Total\_C\_for\_fallow\_LL + Total\_C\_sec\_forest\_LL + Total\_C\_old\_growth$$

$$Total\_C\_scen\_1\_ \& \_2 = C\_cocoa\_sec\_fallow\_oldgrowthLL - Total\_C\_outside\_current\_area\_old\_growthLL$$

*We get the C-values for the area currently covered with old-growth for scenario 1 and 2 while multiplying the following flows by zero:*

*Crops\_on\_cocoa\_land\_LL, Cocoa\_on\_fallow\_LL*

$$Total\_C\_for\_paymentLL\_scen2 = 1,125,045 \text{ tonC}$$

*This value is obtained from the converter value Total\_C\_scen\_1\_&\_2 at t=20 when REDD Scenarios=2 minus the converter value Total\_C\_scen\_1\_&\_2 at t=20 when REDD Scenarios=1. The flows Crops\_on\_cocoa\_land\_LL and Cocoa\_on\_fallow\_LL are multiplied by zero since we want to calculate only carbon changes in the land currently covered with old-growth and we assume the land currently covered with old-growth forest will be converted to cocoa land, not into cropland.*

*Calculation of C contents for payment scenario 3:*

*For scenario 3, the amount of carbon for payment is obtained by calculating the carbon stock for the land-uses that replace old-growth and secondary forest after 20 years (business as usual) and subtracting this value from the calculated carbon stock in the area now covered with old-growth and secondary forest after 20 years (scenario 3). Under scenario 3 this area remains covered with secondary and old-growth forest and some secondary will grow into old-growth forest increasing carbon contents. In these calculations we 'distillate' only the carbon changes on the land which is currently covered with old-growth and secondary forest from the total landscape carbon changes. Thus the carbon amount for the land-uses replacing secondary and old-growth forest under business as usual is assessed by calculating the total landscape carbon changes on LL and SH land after 20 years, minus the changes in carbon outside the area currently covered with secondary and old-growth forest after 20 years as explained in more detail here below.*

$$C\_cocoa\_ \& \_fallowLL = Total\_C\_new\_cocoa\_LL + Total\_C\_Cocoa\_3to8\_LL + Total\_C\_Prodcocoa\_LL + Total\_C\_for\_fallow\_LL$$

$$Total\_C\_cocoa\_outside\_current\_area\_old\_growth\_ \& \_sec\_LL = \text{Graphical function of time (year, value}$$

*Total\_C\_cocoa\_outside\_current\_area\_old\_growth\_ \& \_sec\_LL*  
 (0.00, 7.1e+006), (1.00, 7.4e+006), (2.00, 7.6e+006), (3.00, 7.8e+006), (4.00, 7.8e+006), (5.00, 7.8e+006), (6.00, 7.7e+006), (7.00, 7.7e+006), (8.00, 7.7e+006), (9.00, 7.7e+006), (10.0,

7.7e+006), (11.0, 7.7e+006), (12.0, 7.7e+006), (13.0, 7.7e+006), (14.0, 7.7e+006), (15.0, 7.7e+006), (16.0, 7.7e+006), (17.0, 7.7e+006), (18.0, 7.7e+006), (19.0, 7.7e+006), (20.0, 7.7e+006)

*The values in this graphical function are obtained from the values of C\_cocoa\_&\_fallowLL running the model under a business as usual scenario and multiplying the following flows by zero:*

*Crops\_on\_cocoa\_land\_LL, Cocoa\_on\_fallow\_LL,*

*Old\_growth\_into\_cocoa, Cocoa\_planting\_on\_sec\_LL and by connecting the flow Fallow\_to\_sec\_LL to the stock Cocoa\_&\_food\_LL(t) instead of Sec\_forest\_LL(t).*

*By giving these flows a value zero we calculate the carbon changes in the current cocoa area going through the different ages. We assume that the secondary and old-growth forest is only converted into cocoa, not into food crops.*

$$\text{Total\_C\_land\_currently\_old\_growth\_\&\_sec\_LL} = \text{Total\_C\_new\_cocoa\_LL} + \text{Total\_C\_prodcocoa\_LL} + \text{Total\_C\_sec\_forest\_LL} + \text{Tot\_C\_old\_growth\_off\_reserve} + \text{Total\_C\_cocoa\_3to8\_LL} + \text{Total\_C\_forest\_fallow\_LL}$$

$$\text{Total\_C\_scen\_1\_\&\_3\_LL} = \text{Total\_C\_land\_currently\_old\_growth\_\&\_sec\_LL} - \text{Total\_C\_cocoa\_outside\_current\_area\_old\_growth\_\&\_sec\_LL}$$

*We get the C-values for the area currently covered with old-growth for scenario 1 and 3 while multiplying the following flows by zero:*

*Crops\_on\_cocoa\_land\_LL, Cocoa\_on\_fallow\_LL*

$$\text{Total\_C\_for\_paymentLL\_scen3} = 3,221,492 \text{ tonC}$$

*This value is obtained from the converter Total\_C\_scen\_1\_&\_3\_LL's value at t=20 when REDD Scenarios=3 minus the converter*

*Total\_C\_scen\_1\_&\_3\_LL's value at t=20 when REDD Scenarios=1. The flows Crops\_on\_cocoa\_land\_LL and Cocoa\_on\_fallow\_LL are multiplied by zero.*

$$\text{C\_cocoa\_\&\_fallowSH} = \text{Total\_C\_new\_cocoa\_SH} + \text{Total\_C\_Cocoa\_3to8\_SH} + \text{Total\_C\_Prodcocoa\_SH} + \text{Total\_C\_for\_fallow\_SH}$$

$$\text{Total\_C\_cocoa\_outside\_current\_area\_sec\_SH} = \text{Graphical function of time (year, value Total\_C\_cocoa\_outside\_current\_area\_sec\_SH)}$$

(0.00, 1.1e+007), (1.00, 1.1e+007), (2.00, 1.1e+007), (3.00, 1.2e+007), (4.00, 1.2e+007), (5.00, 1.2e+007), (6.00, 1.2e+007), (7.00, 1.2e+007), (8.00, 1.2e+007), (9.00, 1.2e+007), (10.0, 1.2e+007), (11.0, 1.1e+007), (12.0, 1.1e+007), (13.0, 1.1e+007), (14.0, 1.1e+007), (15.0, 1.1e+007), (16.0, 1.1e+007), (17.0, 1.1e+007), (18.0, 1.1e+007), (19.0, 1.1e+007), (20.0, 1.1e+007)

*The values in this graphical function are obtained from the values of C\_cocoa\_&\_fallowSH running the model under a business as usual scenario and multiplying the following flows by zero:*

*Crops\_on\_cocoa\_land\_SH, Cocoa\_on\_fallow\_SH,*

*Cocoa\_planting\_on\_sec\_SH and by connecting the flow*

*Fallow\_to\_sec\_SH to the stock Cocoa\_&\_food\_SH(t) instead of Sec\_forest\_SH(t).*

$$\text{Total\_C\_land\_currently\_sec\_SH} = \text{Total\_C\_new\_cocoa\_SH} + \text{Total\_C\_cocoa\_3to8\_SH} + \text{Total\_C\_prodcocoa\_SH} + \text{Total\_C\_sec\_forest\_SH} + \text{Total\_C\_forest\_fallow\_SH}$$

$$\text{Total\_C\_scen\_1\_\&\_3\_SH} = \text{Total\_C\_land\_currently\_sec\_SH} - \text{Total\_C\_cocoa\_outside\_current\_area\_sec\_SH}$$

$$\text{Total\_C\_for\_paymentSH\_scen3} = 403,237 \text{ tonC}$$

*This value is obtained from the converter Total\_C\_scen\_1\_\&\\_3\_SH's value at t=20 when REDD Scenarios= 3 minus the converter Total\_C\_scen\_1\_\&\\_3\_SH's value at t=20 when REDD Scenarios = 1. The flows Crops\_on\_cocoa\_land\_SH and Cocoa\_on\_fallow\_SH are multiplied by zero.*

#### SECTOR: Cocoa production

Production and income from cocoa plantations is simulated in this sector. Income from cocoa makes up for over 90% of the rural population's cash income (estimation district officials 2007) which is why we use cocoa income as a proxy for total cash income excluding REDD payments. All variables in this sector are convertors.

$$\text{Cocoa\_production\_per\_ha} = 11.8 \text{ bags (767 kg)}$$

$$\text{Price\_per\_bag predicted\_by\_World\_Bank} = \text{Graphical function of time (year, value Price\_predicted\_by\_World\_Bank)}$$

(0.00, 94.6), (1.00, 87.4), (2.00, 72.5), (3.00, 69.1), (4.00, 67.1), (5.00, 65.7), (6.00, 64.6), (7.00, 63.7), (8.00, 63.0), (9.00, 62.3), (10.0, 61.8), (11.0, 61.2), (12.0, 60.8), (13.0, 60.3), (14.0, 59.9), (15.0, 59.6), (16.0, 59.2), (17.0, 58.9), (18.0, 58.6), (19.0, 58.4), (20.0, 58.1)

$$\text{Profit\_ratio} = 0.8$$

$$\text{Total\_production\_LL} = \text{Cocoa\_production\_per\_ha} * \text{Productive Cocoa LL(t)}$$

$$\text{Total\_cash\_value\_cocoa\_LL} = \text{Total\_production\_LL} * \text{Price\_per\_bag}$$

$$\text{Total\_cocoa\_income\_LL} = \text{Total\_cash\_value\_cocoa\_LL} * \text{Profit\_ratio}$$

$$\text{Cocoa\_income\_per\_LL\_hh} = \text{Total\_cocoa\_profit\_LL} / \text{LL Houdeholds}$$

$$\text{Total\_production\_SH} = \text{Cocoa\_production\_per\_ha} * \text{Productive Cocoa SH(t)}$$

$$\text{Total\_cash\_value\_cocoa\_SH} = \text{Total\_production\_SH} * \text{Price\_per\_bag}$$

$$\text{Total\_cocoa\_income\_SH} = \text{Total\_cash\_value\_cocoa\_SH} * \text{profit\_ratio}$$

$$\text{Cocoa\_income\_per\_SH\_hh} = \text{Total\_cocoa\_profit\_SH} / \text{SH Households}$$

#### SECTOR: REDD payments

In this sector the payment to the farmers (LL and SH) is calculated. LL have old-growth and secondary forest on their land and thus receive carbon payments under both scenario 2 and 3. SH only have some secondary forest on their land so they only get a carbon payment under scenario 3.

$$\text{Conversion\_factor\_CO2\_to\_C} = 1/3.67$$

$$\text{Price\_tonCO2} = 10\text{US\$}$$

$$\text{Share\_to\_farmers} = 0.25$$

Contract\_payment\_share\_per\_year(t) = Graphical function of time (year, value Contract\_payment\_share\_per\_year)  
 (0.00, 0.00), (1.00, 0.2), (2.00, 0.02), (3.00, 0.02), (4.00, 0.02),  
 (5.00, 0.02), (6.00, 0.1), (7.00, 0.02), (8.00, 0.02), (9.00, 0.02),  
 (10.0, 0.02), (11.0, 0.1), (12.0, 0.02), (13.0, 0.02), (14.0, 0.02),  
 (15.0, 0.02), (16.0, 0.1), (17.0, 0.02), (18.0, 0.02), (19.0, 0.02),  
 (20.0, 0.2), (21.0, 0.00)  
 C\_due\_for\_payment\_scen\_2\_LL = if REDD\_Scenarios=2 then  
     Total C for payment scen2 else 0  
 C\_due\_for\_payment\_scen\_3\_LL = if REDD\_Scenarios=3 then  
     Total C for paymentLL scen3 else 0  
 Total\_gross\_scen2\_payment\_LL =  
 Price\_tonC\*C\_due\_for\_payment\_scen\_2\_LL  
 Total\_gross\_scen3\_payment\_LL =  
 Price\_tonC\*C\_due\_for\_payment\_scen\_3\_LL  
 Total\_net\_scen\_2\_REDD\_pay\_LL =  
 Total\_gross\_scen2\_payment\_LL\*Share\_to\_farmers  
 Total\_net\_scen\_3\_REDD\_pay\_LL =  
 Total\_gross\_scen3\_payment\_LL\*Share\_to\_farmers  
 Total\_annual\_REDD\_scen\_2\_LL =  
     Total\_net\_scen\_2\_REDD\_pay\_LL\*Contract\_payment\_share\_per\_year  
 Total\_annual\_REDD\_scen\_3\_LL =  
     Total\_net\_scen\_3\_REDD\_pay\_LL\*Contract\_payment\_share\_per\_year  
 Total\_annual\_REDD\_LL =  
     Total\_annual\_REDD\_scen\_3\_LL+Total\_annual\_REDD\_scen\_2\_LL  
 REDD\_per\_LL\_hh = Total\_annual\_REDD\_LL/LL Houdeholds  
 C\_due\_for\_payment\_SH = if REDD\_Scenarios=3 then  
     Total C for paymentSH scen3 else 0  
 Total\_gross\_REDD\_payement\_SH = Price\_tonC \* C\_due\_for\_payment\_SH  
 Total\_net\_REDD\_pay\_SH = Total\_gross\_REDD\_payement\_SH \*  
 Share\_to\_farmers  
 Total\_annual\_REDD\_SH = Total\_net\_REDD\_pay\_SH \*  
     Contract\_payment\_share\_per\_year  
 REDD\_per\_SH\_hh = Total\_annual\_REDD\_SH/SH Houdeholds

*SECTOR: Income & net present value*

In this sector we simulate total and per capita cash income for the rural population in the district over the next 20 years and the Net Present Value (NPV) of this per capita cash income. The NPV is the present value (PV) of a time series of cash flows. To obtain present values we discounted the cash income using a 20% discount rate.

The equations used for PV and NPV are:

$$PV(t) = \text{Cash per capita } (t)/(1+r)^t$$

$$NPV = \sum_{t=1}^{20} PV(t)$$

where  $r$  is the discount rate and  $t$ =time

All functions in this sector are convertors.

Total\_rural\_income = Total cocoa income LL + Total cocoa income SH +  
Total annual REDD LL + Total annual REDD SH

Income\_per\_capita(t) = Total rural income/Total rural population

PV\_rural\_income\_pp\_per\_year\_6%(t) = Income\_per\_capita(t)/1.06<sup>t</sup>

PV\_rural\_income\_pp\_per\_year\_20%(t) = Income\_per\_capita(t)/1.2<sup>t</sup>

NPV\_6% =  $\sum_{t=1}^{20} PV\_rural\_income\_pp\_per\_year\_6\%(t)$  *this is calculated after the simulation*

NPV\_20% =  $\sum_{t=1}^{20} PV\_rural\_income\_pp\_per\_year\_20\%(t)$  *this is calculated after the simulation*

The model can be downloaded at

[http://www.cifor.cgiar.org/conservation/\\_ref/research/research.2.5.htm](http://www.cifor.cgiar.org/conservation/_ref/research/research.2.5.htm)

To be able to open the model you need to have STELLA installed, with the following link a safe-disabled trial version can be downloaded

<http://www.iseesystems.com/community/downloads/STELLA/STELLADemo.aspx>

### **Contract breaking and price at which deforestation is stopped**

Farmer decision is approximated by NPV per capita of future income. We could not simulate this decision making directly in our model since the simulation at time t doesn't know yet what income will be in time t=1. Instead we calculated afterwards based on the simulation results at what time in the simulation farmers would likely break the contract. Each year, NPV was re-calculated for the following 20 years, so the simulation was run for 40 years in order to calculate the NPV in year 20. Under the REDD scenario we simulated avoided deforestation for the contract period but not after, so after 20 years farmers will convert the forest to cocoa. After one year of participation in a REDD scheme, a farmer will no longer be able to compare his NPV with NPV under the business as usual scenario. This because if after one year he breaks the REDD contract and starts planting cocoa again, his cocoa is planted one year later than under business as usual and will thus become productive one year later. In order to obtain the year in which the contract will be broken we entered the feature of contract breaking in the model to re-calculate the NPV under the new scenario including contract breaking and comparing this with the NPV of remaining in a REDD scheme. The price at which deforestation is stopped is the price at which the NPV of the REDD scenario is higher then the NPV under the REDD scenario with contract breaking throughout the 20 year contract period.

Contract breaking is entered in the model as follows:

Time\_contract\_breaking\_old\_growth = this year is entered by the modeler  
(for Scenario 2 and 3)

Time\_contract\_breaking\_sec\_forest = this year is entered by the modeler  
(for Scenario 3)

```

Contract_breaking_old_growth = if
    TIME<Time_contract_breaking_old_growth then 0 else
    Demand_for_new_cocoa_land_LL*0.9
Contract_breaking_sec_forest = if TIME<Time_contract_breaking_sec_forest
    then Fallow_to_sec_LL else Cocoa_planting_sec_LL
Old_growth_into_cocoa = if REDD_Scenarios=1 then
    Demand_for_new_cocoa_land_LL*0.9 else
    Contract_breaking_old_growth
Cocoa_planting_on_sec_LL = if REDD_Scenarios=2 then
    Contract_breaking_sec_forest else Cocoa_planting_sec_LL
Cocoa_planting_on_sec_SH = if REDD_Scenarios=2 then
    Contract_breaking_sec_forest_SH else Cocoa_planting_sec_SH
Total_annual_REDD_scen_2_LL = if
    TIME<Time_contract_breaking_old_growth then
    Total_net_scen_2_REDD_pay_LL*Contract_payment_share_per_year
    else 0
Total_annual_REDD_scen_3_LL = if
    TIME<Time_contract_breaking_sec_forest then
    Total_net_scen_3_REDD_pay_LL*Contract_payment_share_per_year
    else 0
Total_annual_REDD_SH = if TIME<Time_contract_breaking_sec_forest then
    Total_net_REDD_pay_SH*Contract_payment_share_per_year else 0

```

## REFERENCES

- HPS (High Performance Systems) (1996) *STELLA and STELLA Research Software*. High Performance Systems, Inc. Hanover NH.
- HPS (High Performance Systems) (2003) *An Introduction to Systems Thinking*
- Sandker, M., B. M. Campbell, Z. Nzooh, T. Sunderland, V. Amougou, L. Defo, and J. Sayer (2009) Exploring the effectiveness of integrated conservation and development interventions in a Central African forest landscape. *Biodiversity and Conservation* **18**: 2875-2892.



## Chapter 8

### **Logging or conservation concession: Exploring conservation and development outcomes in Dzanga-Sangha, Central African Republic**





# Logging or conservation concession: Exploring conservation and development outcomes in Dzanga-Sangha, Central African Republic

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## ABSTRACT

The Dzanga-Sangha landscape consists of a national park surrounded by production forest. It is subject to an integrated conservation and development project (ICDP). In collaboration with the ICDP personnel, a participatory model was constructed to explore wildlife conservation and industrial logging scenarios for the landscape. Three management options for the landscape's production forest were modelled: (I) 'predatory logging', exploitation by a logging company characterised by a lack of long-term plans for staying in the landscape, (II) sustainable exploitation by a certified logging company, or (III) conservation concession with no commercial timber harvesting. The simulation outcomes indicate the extreme difficulties to achieve progress on either conservation or development scenarios. Both logging scenarios give best outcomes for development of the local population. However, the depletion of bushmeat under the predatory logging scenario negatively impacts the BaAka-pygmy minority who strongly depend on hunting for their income. The model suggests that conservation and development outcomes are largely determined by the level of economic activity, both inside and outside the landscape. Large investments in the formal sector in the landscape without any measures for protecting wildlife (scenario I) leads to some species going nearly extinct, while investments in the formal sector including conservation measures (scenario II) gives best outcomes for maintaining wildlife populations. The conservation concession at simulated investment levels does not reduce poverty. Neither does it seem capable of maintaining wildlife populations since the landscape is already filled with settlers lacking economic opportunities as alternative to poaching.

**Keywords:** Congo Basin; ICDP; participatory modelling; poaching; STELLA; Tri-National de la Sangha

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## INTRODUCTION

The Congo basin forests constitute the second largest area of moist tropical forest in the world, after the Amazon, covering a total area of about two million km<sup>2</sup> (CBFP 2006). About 12 percent of this area is under protection (Laporte et al. 2007) while 76 percent consists of production forest (CBFP 2006). These production forests are often located in proximity to national parks, forming a buffer between the protected area and more intensively used agricultural areas. The Dzanga-Sangha landscape located in the south-western part of the Central African Republic (CAR) is typical of this situation. Clark et al. (2009) investigated the effect of logging on mammal populations in the proximity of this area and concluded that production forests, if managed appropriately can extend the effective habitat of many of Central Africa's most threatened species.

Despite its high biological diversity, the Congo basin ranks economically amongst the poorest regions of the world (Blom 2001). CAR has a gross national income of merely € 290 per capita and ranks amongst the lowest income countries (World Bank 2009). The forestry sector is of major importance to the CAR's economy; timber contributed 41 percent of the national export revenues in 2007 and the sector is, after the government, the most important provider of employment nationwide (Wasseige et al. 2009). In remote rural areas, logging companies are by far the most important providers of salaried jobs (Wasseige et al. 2009) and often take over the role of the state in providing services (e.g. electricity and hospitals) in the villages where they operate. For this reason, local people often see their arrival as an opportunity to advance local development. Logging concessions in the Congo Basin thus have a dual function buffering and extending protected areas while boosting the local economy. But the centres of development that are stimulated by forestry operations have also been linked to an upsurge in use of wildlife for bushmeat (Bennett 2004). Not all of the vast production forest in the Congo Basin is currently being logged; in 2007 only 36 percent was legally allocated as logging concessions. Africa's timber production is projected to increase substantially (FAO 2003) thus an increase in the number of licenses and area exploited is expected. The arrival of logging companies in these remote forest areas will affect the local economy and wildlife populations.

Ever since the creation of the national park in 1990, an integrated conservation and development project (ICDP) has been operating in the Dzanga-Sangha landscape. Discussions are on-going between the CAR government and proponents of the ICDP concerning the options for the management of the production forest. The most likely scenario is that a license will be issued to a logging company, for the extraction of timber under a rotation cycle. However, one conservation organization leading the ICDP has advocated making the area a 'conservation concession'. The concept is defined as follows by Rice (2003, p1): *'Under a conservation concession agreement, national authorities or local resource users agree to*

*protect natural ecosystems in exchange for a steady stream of structured compensation from conservationists or other investors'*. With conservation and development experts from the ICDP we constructed a systems dynamics model for the Dzanga-Sangha landscape to explore different management options for the production forest and their consequences for wildlife and for the local economy.

## METHODS

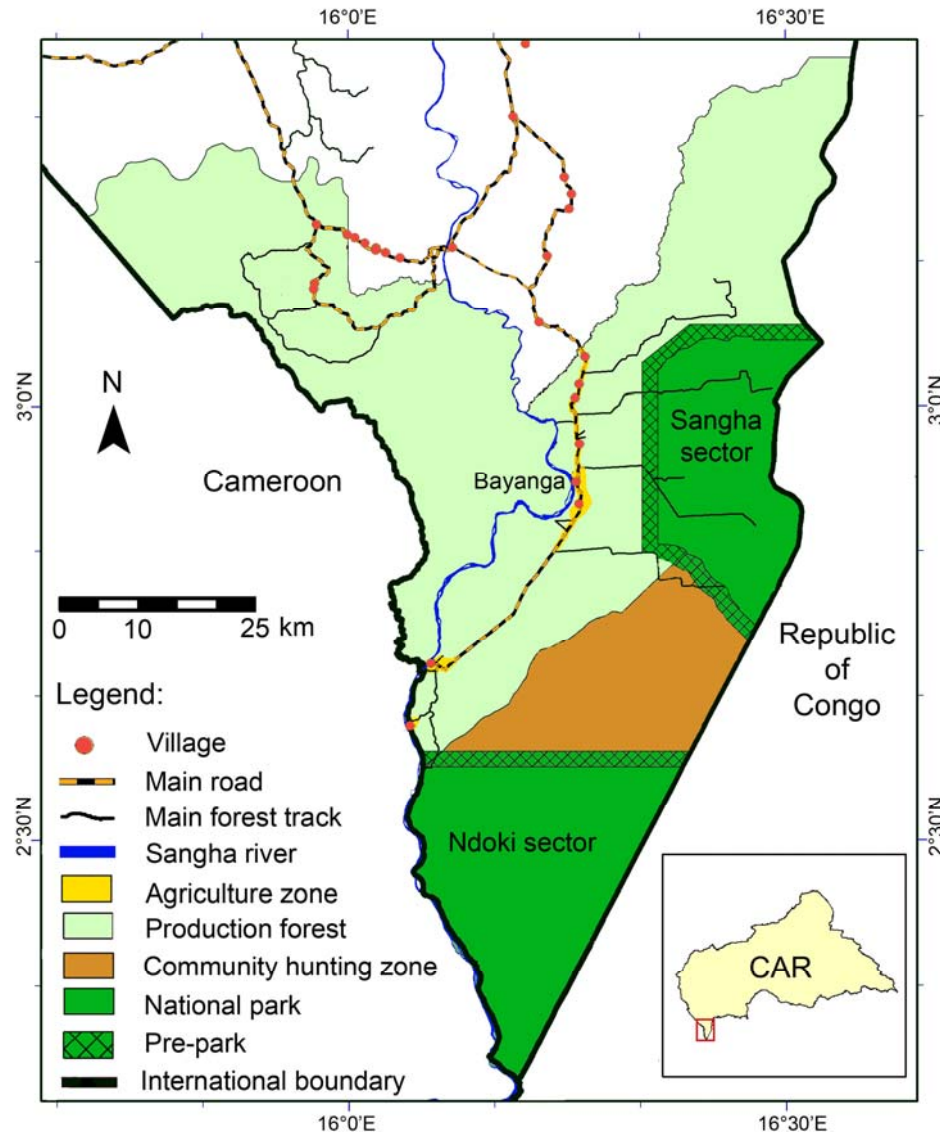
### *Conservation and development in the Dzanga-Sangha landscape*

Situated in the extreme south-west of the CAR, the Dzanga-Sangha landscape covers a total area of 4,643 km<sup>2</sup>. Of this area, 27 percent is made up by the national park (Sangha and Ndoki sector), 4 percent is pre-park (2 km-wide buffer zone around the parks), 55 percent is production forest (to be allocated to a logging concession), 13 percent is a communal hunting zone and 1 percent is reserved for agriculture (Fig 1). 70 percent of the production forest is at the same time reserved for safari hunting though at the moment all safari hunting companies have closed down.

The forest of Dzanga-Sangha constitutes an integral part of those sites termed critical for conservation of dense forests in the Afro-tropical region (Monza 1996). It hosts approximately 105 terrestrial mammal species, out of which 16 are primates, 14 are ungulates and 14 are carnivores (Blom 2001). The region has a remarkable high density of forest elephants (*Loxodonta cyclotis*) with 0.2-0.3 individuals per km<sup>2</sup> and of western-lowland gorillas (*Gorilla gorilla gorilla*) with 1.05 individuals per km<sup>2</sup> (Blake 2005). The region is important for Bongo antelopes (*Tragelaphus euryceros*) with an estimated density of 0.3 individuals per km<sup>2</sup> (Klauss-Hugi 1998). Hunting pressure is high in the landscape resulting in rapidly declining populations of several wildlife species (Blake 2005). The worsening wildlife situation in Bayanga is illustrated by the closure of the last active safari hunting company in 2007. It is unlikely that safari hunting will resume in the near future. The employment provided by the safari company at the time it was operational was rather limited (<10 permanent jobs) and safari tax revenues represented a tiny fraction of the forestry taxes (e.g. 0.25-1.5 percent of forestry taxes for the period 2000-2003). For this reason, safari hunting has not been included in the model.

The Dzanga-Sangha landscape had a population of about 6850 people (2 people / km<sup>2</sup>) in 2005, living in 12 villages (Kamiss 2006, 2007 GTZ census unpublished). Before the arrival of a logging company in 1972, Bayanga was a small fishing village (Kamiss 2006). The population at that time consisted of BaAka (pygmies, mainly hunter-gatherers) and Sangha Sangha (Bantus, mainly fishermen). These original people now make up about one third of the total population, the rest being Bantu migrants (Kamiss 2006). Principal income sources of the local population are agriculture, hunting, gathering and local sale of non-timber forest products (NTFPs, like *Gnetum spp*),

**Figure 1.**  
The Dzanga-Sangha  
landscape  
(modified  
from GTZ-  
GFA 2009)



fishing and employment in ecotourism and the ICDP project. Ecotourism is well developed in the landscape: in 2007, about 580 tourists visited the area generating 72 million FCFA (€ 110,000) of local revenue (Feiganangai 2003). Of this amount, about 12 percent is directly captured by local people through salaries (pers. com. Roth 2008). Though this amount may seem substantial, annual salary revenue generated by the logging company when it was operational was much higher, at 270 million FCFA (€ 411,600) (Czesnik 2007).

Bayanga -where the sawmill is located- is the largest village, home to 57 percent of the total population in the landscape. Though the sawmill has not been operating since 2004, previous logging activities have attracted many migrants into the landscape; roughly two thirds of the population is not original to the region (Kamiss 2006). Between 1972 and 2004, four different logging companies have exploited the logging concession in the Dzanga-

Sangha landscape. Most of the logging companies operated only for short periods, given that this is a remote area and the financial returns on logging are severely limited by the costs of extraction and marketing. The departure of these logging companies was often abrupt, leaving its local employees unemployed with several months of unpaid salaries. The intervals during which the concession remained closed usually ranged between one to four years. The majority of the workforce remained in the village or in mining camps just north of the landscape, hoping to be paid for their past work and hoping to secure employment in a new logging company (Noss 1995). However, with each re-opening only a fraction of the old workforce was usually re-employed and many new people arrived from outside the landscape (pers. com. Kamiss 2007). The 2004 sawmill closure resulted in an increase in households practicing agriculture from 39 to 76 percent (Kamiss 2006). Laid-off employers usually turn to hunting (Doungoubé 1990). Logging itself also augments hunting pressure through increased access to markets and hunting by family members of sawmill employees (Bennett 2004). However, with its history of logging around Bayanga the hunting pressure is already high in absence of logging activities.

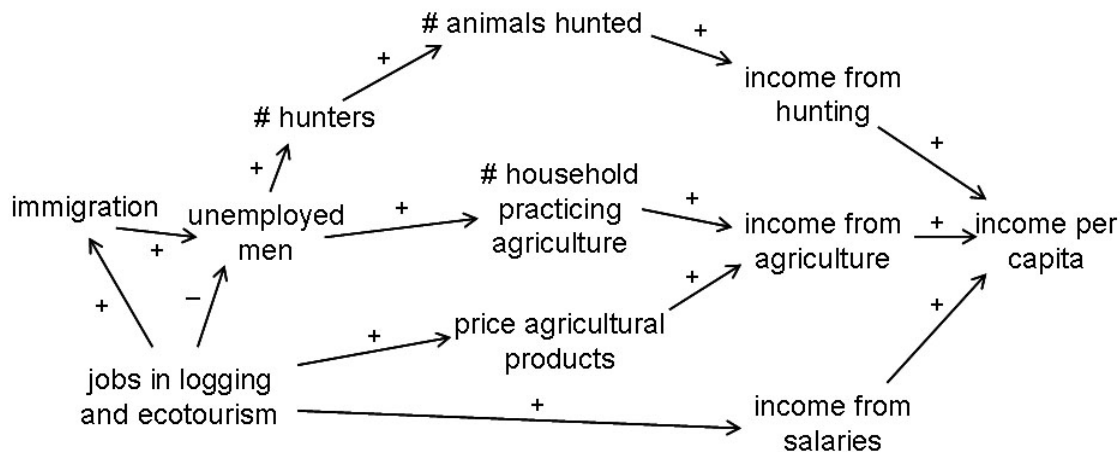
#### *Participatory modelling*

Between 2004 and 2009, under the guidance of model experts, an exploratory landscape model is built by non-model expert conservation and development actors working in the Dzanga-Sangha landscape. The objectives of participatory modelling comprise to stimulate the exchange of knowledge and visions between the actors, unravel complex interactions, identify drivers of change, understand trade-offs between conservation and development outcomes, and explore plausible future scenarios (Van den Belt 2004, [chapter 9](#)). The model has been developed in the user-friendly modelling language STELLA 8.0 (HPS 1996). STELLA is a system dynamics modelling language whose basic components are *stocks* (such as forest area, elephant population and annual budgets), *flows* (e.g. change from forest to agriculture or birth and death of elephants) and *convertors* that moderate these flows (including laws, interventions and price variations). The scenarios to be simulated with the model were defined during workshops with the conservation and development actors working in the Dzanga-Sangha landscape.

#### *The model structure*

The model reflects nature – society interactions. Visioning exercises like historical trend analysis (Sayer et al. 2007) were undertaken to identify trends of socio-economic and biological variables, as well as other crucial attributes of the landscape. These exercises helped to select the main stocks and flows for the model. We did not attempt for the model to be all-inclusive, rather the stakeholders were urged to select only those variables and interactions they considered most important for the outcomes of concern to the ICDP. This resulted in a model existing of 12 interconnected sectors (sub-

models), containing a total of 260 variables. Figure 2 gives a schematic representation of some –incomplete– relations between variables in the model determining per capita income. It demonstrates how many relations are ambiguous, e.g. investment in logging provides an alternative to poaching through employment but at the same time it attracts potential poachers through increased immigration. Many such relations are regulated through interventions either by the ICDP or by a certified logging company.



**Figure 2.** Schematic representation of relations between some variables in the model

The model sectors are 'human population', 'BaAka and Bantu households', 'forest elephant and duiker populations', 'hunting', 'local economy', 'employment', 'logging concession', 'eco-tourism', 'land-use', and 'interventions'. In 'human population' we model natural growth and immigration, the latter being partly driven by employment, partly by the bad socio-economic situation in the rest of the country. The sectors 'BaAka and Bantu households' simulate income generating activities. In the model, households get income from agriculture, fishing, hunting, NTFPs, employment and commerce. With exception of NTFP and fishing, the income contributions per household are all dynamic. Households are simulated to turn to poaching and agriculture in absence of formal employment (Fig 2). An increase in salaried jobs, on the other hand, results in agricultural products being sold at higher prices and commerce being stimulated. Income from hunting is driven by duiker and elephant hunting (modelled in the 'hunting' sector). Income from employment is mainly driven by logging and ecotourism investment. The 'hunting' sector furthermore simulates elephant poaching to be partly determined by the number large calibre guns, in its turn a function of roads, traffic and cash in the landscape (all increasing with logging activities), and controlled under the 'interventions' sector by the ICDP and the certified logging company. Duiker hunting is simulated to be mainly determined by the number of hunters and controlled by snare removal and surveillance (simulated in the sector 'interventions'). Both the number of duikers and elephants hunted decrease when its populations drop below a critical number. The variables and their relations in each model

sector are given in Table 1 which also gives the data sources. Furthermore, the model can be downloaded at:

<http://www.cifor.cgiar.org/conservation/ref/research/research.2.5.htm>

**Table 1.** The model's assumptions and data inputs

<b>Data</b>	<b>Source</b>
<b>Model sector: Human population</b>	
Total population= 7350 people in 2009 (2007 data projected to 2009 with an annual growth rate of 1.5%) of which 30% is BaAka, 70% is Bantu	2005 and 2007 GTZ census (unpublished)
Natural growth rate = 1.5%	Mediated from UN (2009)
Immigration rate= 1-3%. We assume a 1% fixed immigration due to the bad socio-economic situation in CAR. An additional 0-2% immigration depends on total investments in salaried jobs, 0 being current investment, 2% being 5 times the current investment	Local expert approximation
One-off immigration due to opening logging concession= 2000 Bantus. One-off outmigration due to closure logging concession (scenario I only)= 500 Bantus	Local expert approximation based on historical trend pers. com. Kamiss 2007
<b>Model sector: Land-uses</b>	
National park = 1,444 km <sup>2</sup> ; Communal hunting zone = 587 km <sup>2</sup> ; Logging concession = 2,571 km <sup>2</sup> ; Agriculture zone = 40 km <sup>2</sup> (but agriculture is not modelled to be restricted to this zone)	GIS measurements Dzanga-Sangha Project 2008
<b>Model sectors: BaAka and Bantu households</b>	
Average BaAka household size= 6.8	Results from 20 BaAka household questionnaires 2006
Average annual BaAka household cash income= 300,000FCFA (€460) of which now 49% comes from hunting, 31% from NTFPs, 11% from fishing, 5% from agriculture and 4% from employment in ecotourism	
Average Bantu household size= 7.5	Results from 30 Bantu household questionnaires 2006
Average annual Bantu household income= 900,000 FCFA(€1370) of which now 46% comes from agriculture, 23% from employment by the ICDP project and ecotourism, 16% from fishing, 11% from hunting and 4% from commerce	
Cash per household from NTFPs and fishing remains constant	Local expert approximation
The price of agricultural products (and thus income from agriculture) increases with the employment rate (maximum increase 50%)	
Households practicing agriculture is positively related to the number of unemployed men	Kamiss 2006
Income hunting BaAka= duiker income * (100/ Percentage duikers total bushmeat income BaAka)	Local expert approximation
Income hunting Bantu= duiker income * (100/ Percentage duikers total small bushmeat income Bantu) + elephant income	
Duiker income= (duikers hunted – wastage – auto-	

consumption) * average duiker price. For duikers hunted see hunting sector	
Elephant income= elephants hunted * price elephant (=390,000 FCFA). For elephants hunted see hunting sector	
Wastage= 10% (wastage snare hunting= 27% (Noss 1998) but now more home-made gun hunting)	
Percentage duikers total bushmeat income BaAka= 80-85%	
Percentage duikers total small bushmeat income Bantu= 90%	
Average price duiker= 2600 FCFA (weighted average of prices three duiker species; <i>C. monticola</i> = 1300 FCFA, <i>C. callipygus</i> = 4400 FCFA <i>C. dorsalis</i> = 5300 FCFA)	2006 household questionnaires
Income from commerce= %age of total investment in salaries (now 60% of total commerce) + other cash to commerce (constant)	2006 questionnaire results mediated with expert approximation
Other cash to commerce = 14,600 FCFA/household 10% of the investment in salaries goes directly to commerce	Garreau 1994
Model sector: <b>Logging concession</b>	
Average annual log production rate= 0.11m <sup>3</sup> /ha	Czesnik 2007
Number of logging concession employers= 430 at opening concession	Pago pers. com. 2007 (the ex-director of personal last active logging company)
Average annual salary logging company without certification= 614,000 FCFA (€936)	CIB management plan 2006
Average salary certified logging company= 1,085,000 FCFA (€1654)	
40% increase in production prospected in next 20 years for both certified and non-certified logging companies	
Future projection of number of employers and taxes to be paid increases with log production	Local expert approximation
Total forestry taxes exist of logging tax ( <i>taxe d'abattage</i> ) which is 7% of the logged value and a reforestation tax ( <i>taxe de reboisement</i> ) which is 11% of the exported log value (article 36, finance law 2001).	Czesnik 2007
Logging tax= 137 million FCFA, Reforestation tax= 70 million FCFA (Average for the period 2000-2003)	
Model sector: <b>Ecotourism</b>	
At current ecotourism provides 13 fulltime jobs and some temporary activities (equivalent to another 2 fulltime jobs)	Dzanga-Sangha project 2008
Average annual ecotourism fulltime salary = 576,000 FCFA(€878)	
The number of ecotourists remains unchanged under scenario I and II and increases five times in the first 10 years of the simulation under scenario III to remain fixed from year 10 to 20	Local expert approximation
Ecotourism starts to decrease when the number of elephants drops below 450 (45% of current elephant population)	
Model sector: <b>Local economy</b>	
Sums up the total investment in the formal sector	Calculated with model



Model sector: **Employment**

Calculates the employment rate by dividing the number of formal jobs by the total labour force (# of unemployed adult men)

Adult men= 12% of the total population

Model sector: **Forest elephant populations**

Populations in and outside the park are simulated separately using a logistic equation, starting with 1003 elephants (704 inside the park-299 outside the park).

Off-take by hunting is simulated in the 'hunting' sector

Birth rate= 3%

Natural death rate= 1%

Carrying capacity (in and outside park)= 2.5 elephant/km<sup>2</sup>

Sustainable off-take rate= 0.0045 elephant/km<sup>2</sup>/year or 20 elephants for the entire area per year

Model sector: **Duiker populations**

Duiker refers to the species *Cephalophus monticola*, *C. callipygus* and *C. dorsalis*

Populations in and outside the park are simulated separately using a logistic equation, starting with 196,420 duikers (86,050 inside the park-110,370 outside the park). Off-take by hunting: 'hunting' sector  
Reproduction rate (birth rate – natural death rate) = 0.43%

Carrying capacity = 110 duikers/km<sup>2</sup> (using maximum densities Noss as reference point)

Sustainable off-take rate= 3.9 duikers/km<sup>2</sup>/year

Model sector: **Hunting**

Number of BaAka hunters= 97% of the adult male - adult males with a job

Number of Bantu hunters= 30% of the adult male unemployed population and 20% of the adult male population under scenario II (hunting will be restricted under this scenario and is therefore expected to be a less attractive option)

Elephants hunted increases with number of immigrant hunters and number of large calibre guns and decreases with anti-poaching surveillances and when elephant density drops below 0.2/km<sup>2</sup>

Number of elephants hunted at the start of the simulation is 67/year

Duikers hunted increases with the number of hunters and decreases with snare removal and when the duiker density drops below 40/km<sup>2</sup>

Duiker hunting is calibrated with an approximate number of 115 duikers/hunter/year

~67% of elephants hunted are captured inside the national park

~20% of duikers hunted are captured inside the national park

Calculated with model

Noss 1998

Blake 2005 densities, projected to 2009 by local expert approximation  
Turkalo 2005  
Local expert approximation

Calculated with model

Data from Noss 1998 mediated with local expert judgement: mid-point data for Noss' density range is used, and maximum for Noss' reproduction rate

Calculated with model

2006 household questionnaires  
Noss 1998 mediated with local expert judgement

Local expert approximation

Estimation Bokoto 2007

Local expert approximation

Noss 1998

Extrapolation of elephant poaching observations  
Local expert approximation

The number of large calibre guns increases with the increase of traffic, roads and salaries in the landscape and are controlled by the certified company (see interventions sector). At the start of the simulation there are 15 large calibre guns in the landscape.	Approximation by park director ( <i>conservateur</i> ) 2007
Model sector: <b>Interventions</b> Anti-poaching investment is 178 FCFA/ha inside the park and 90 FCFA/ha outside the park Currently 55 people are employed by the ICDP, projected to go up to 69, 71 and 84 in 20 years for scenario 1, 2 and 3 respectively (ecoguard jobs increase with investment in ecotourism)	Local expert approximation
Anti-poaching surveillances and snare removal increase with ICDP budget (fixed in the simulation) plus the contribution of the certified logging company The certified logging company controls the traffic of large calibre guns and bushmeat	Observation from neighbouring certified companies

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#### *The data entered in the model*

Data was obtained from existing project monitoring and missing data (e.g. recent data on duiker population) was extracted from scientific publications and ongoing studies underway in the reserve (see Table 1). Additional information to fill some data gaps was gathered through 50 interviews held in April-June 2006 with the head of household (*chef de ménage*); 20 concern BaAka, 30 Bantu households. The interviewed households were randomly selected in three different villages (Bayanga, Bomandjokou and Mossapoula) characterized as: a village with a sawmill (though closed at the time of the interview, but with a higher concentration of migrant households), a village with employment from ecotourism and a village without access to formal employment. The questions focused on income generating activities, and number and species of animals hunted. Income per activity was approximated making the respondent estimate the total production of the household, the share sold and the price per product. When respondents had difficulties using numbers in their replies, marbles were used to quantify importance of activities. Given the small sample size and the possible large error with estimated values, the interview results are of indicative value only and we deemed it necessary to discuss and validate the results with local experts (Table 1). Remaining data gaps were filled by informed estimates obtained through discussions with local experts working in the area. Thus, the simulation results of this study are based on the best available information to us. We recommend further profound and solid research to fill knowledge gaps.

#### *Indicators of conservation and development outcomes in the landscape*

The state of key attributes indicating the status of conservation and development in the landscape were selected and plotted on graphs to visualize the consequences of the different scenarios for conservation and

development (simulation outcomes). Elephant and duiker populations were selected as proxies indicating the general state of conservation. Elephants have low reproduction rates and their hunting is prohibited; they are mainly poached with large calibre guns. Duikers have high reproduction rates and their hunting is legal under certain conditions; they are mainly captured with cable snares or hunted with small home-made guns. They form the most important source of bushmeat; the 2006 household surveys revealed of the small animals hunted 9 out of 10 were duikers. Noss (1998) collected data on bushmeat hunting in Bayanga in 1994 and concluded at that time hunting levels were likely to be unsustainable for duikers. When simulating the situation from 1994 to today, based on Noss' approximated hunting pressure, mid-range duiker densities, and maximum reproduction rates, there would be no duikers left outside the protected area. However, 16 years after Noss' study, bushmeat markets are still abundantly supplied with duikers, and 2006-2008 mapping of hunting zones by the ICDP (Dzanga-Sangha project unpublished) showed hunting areas still to be in the proximity of the villages providing little evidence of their depletion. Furthermore, the 2006 household questionnaires (Table 1) indicated the number of duikers hunted per hunter to be almost the same as the number found by Noss. This is why we have chosen rather high values in the possible range Noss' study gives for duiker density and reproduction rate (Table 1).

Household cash income was used as a proxy indicating the state of local development. Though this only gives a rough approximation in a situation where subsistence income is of great importance, the actors building the model still thought this was the best indicator to approximate the development situation of local people. Since about half of the cash captured by BaAka comes from bushmeat (2006 household surveys, Table 1), monetary income does reflect their access to this important forest product.

The outcomes of the simulation often led to discussions amongst stakeholders and revisions of the model until consensus was reached on plausible future scenarios. Considering the process adopted for the elaboration and revision of the latter, the results presented in this article do not represent precise predictions but are indicative and should serve as a basis for reflection and discussion, concerning the future of the Dzanga-Sangha and similar landscapes.

### *Scenario descriptions*

#### Scenario I: 'Predatory Logging' (business as usual)

This scenario simulates logging companies characterised by a lack of long-term plans for staying in the landscape and minimal investments in the local salaries, infrastructure and facilities. The continuous arrival and departure of logging companies simulate an extension of what the landscape has experienced since 1972. We simulated the opening of the sawmill attracting many job seekers and their families (2000 people) while with a closure we

expect only some of them to leave (500 people). The simulation assumes opening of the sawmill in year 2 and 13, and closure in year 10 and 18.

#### Scenario II: Logging by Certified Company

This scenario simulates the re-opening of the sawmill by a company obtaining Forest Stewardship Council (FSC) certification. We assume their sustainable exploitation practice to result in a long-term forestry enterprise, thus no closure is simulated. This feature was confirmed by Desmet (personal communication 2009) of the neighbouring logging company CIB who claimed that without their FSC certificate the company would have most likely collapsed due to the financial crisis. The FSC certificate furthermore requires the company to provide basic services in the villages located in the concession, to pay higher salaries and put resources into controlling poaching (FSC 2007).

#### Scenario III: Conservation Concession (no logging)

This scenario simulates the production forest in the Dzanga-Sangha landscape as a conservation concession. Following the earlier given definition of Rice (2003) of a conservation concession, we assume the compensation the conservation investor pays to the state would be equivalent to the taxes and royalties paid by a traditional concessionaire, amounting on average 207 million FCFA/year (€ 316,000) for the period 2000-2003 (Czesnik 2007). We believe this would be the minimum investment of a conservation concession that would be approved by the government, since ideally a conservation concession should also compensate for the foregone salaries of the logging company personnel. We assume ecotourism to develop under this scenario with the number of eco-tourists increasing to five times the current number after 10 years.

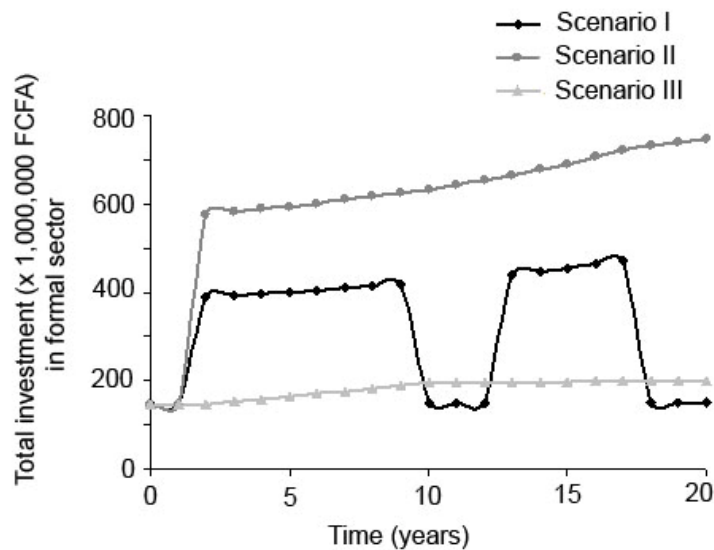
## RESULTS

### *Local economy and population dynamics*

The cash investment in the formal sector is substantial under both logging scenarios (Fig 3). With each closure of the logging company under scenario I, the investment drops below the conservation concession scenario (III) the difference being made by the larger investment in ecotourism employment under scenario III.

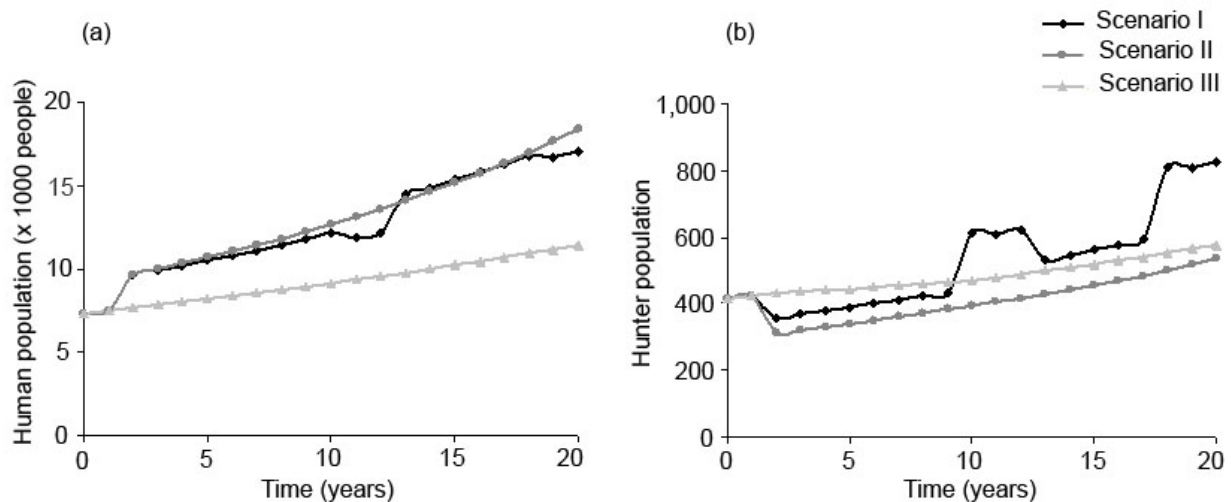
The human population increases substantially under all scenarios (Fig 4a). Due to the politically unstable and economically weak situation in the CAR, immigration into the landscape is expected to be high even in the absence of opportunities for paid labour. Under the conservation concession scenario, the population increases with an annual growth rate of 2.5 percent. Scenario II has the highest population growth attracted by the large cash investment in the formal sector (Fig 3). Though the cash investment under scenario I is much lower than under scenario II, population size is comparable due to the recurring cycle of opening and closing; with each opening (year 2 and 13)

attracting more people than those leaving after each closure (year 10 and 18).



**Figure 3.** Investment in the formal sector (salaries from ecotourism, the ICDP and the logging concession) under the three scenarios explored (I: predatory logging, II: certified logging, III: conservation concession)

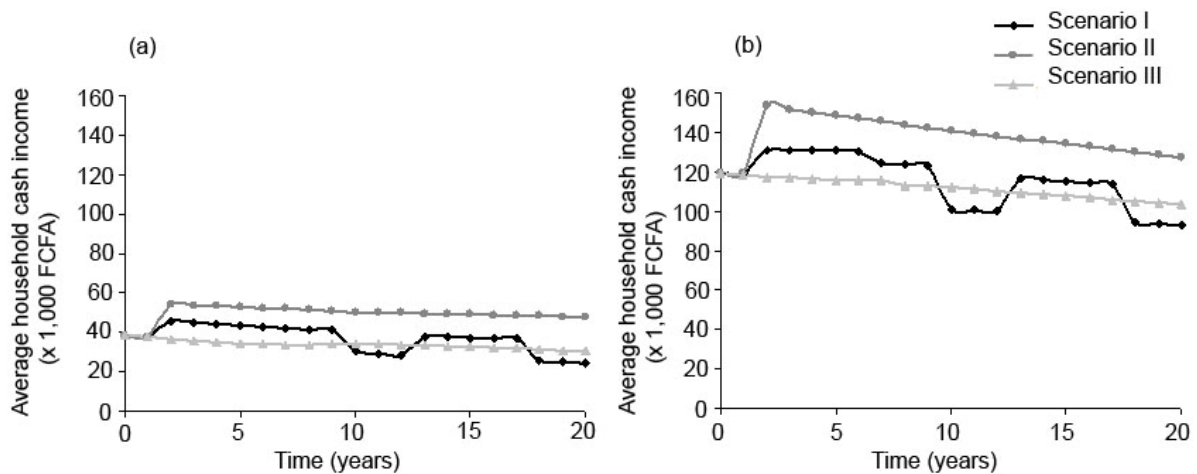
The number of hunters (Fig 4b) is calculated as a percentage of the unemployed male population in the landscape (Table 1). The number of hunters falls back when people are employed by the company after re-opening (year 2 and 13). The number of hunters increases substantially more though each time the predatory logging company shuts down (year 10 and 18) due to the simulation of laid-off workers turning to poaching.



**Figure 4.** Total human population (a) and number of hunters (b) in the Dzanga-Sangha landscape under the three scenarios explored (I: predatory logging, II: certified logging, III: conservation concession)

BaAka are poorer than Bantu in monetary terms, capturing about one third of the cash a Bantu captures per capita (Table 1 and Fig 5). BaAka cash income shows a downward trend which is mainly due to the declining duiker population. Their access to bushmeat diminishes which currently contributes

50 percent of their cash income (2006 household surveys, Table 1). Though the BaAka only capture 5-10 percent of the jobs in the logging concessions this affects their per capita cash income quite dramatically since they are less in number and because their average per capita cash income is quite low (Fig 5a). Giving average cash income, Figure 5a hides a larger income differentiation for BaAka under scenario I with only some capturing the benefits (salaried jobs) but all suffering the costs (reduced access to bushmeat). Bantu cash income also shows a downward trend but this is due to the high increase in population mainly due to immigration and thus the investments in the formal sector are divided over a larger number of people lowering the per capita cash capture. Even though the cash investment in the formal sector is continuously increasing under scenario II (Fig 3), the migrant inflow is larger than the creation of new jobs at the logging concession resulting in the cash per capita decreasing slightly.

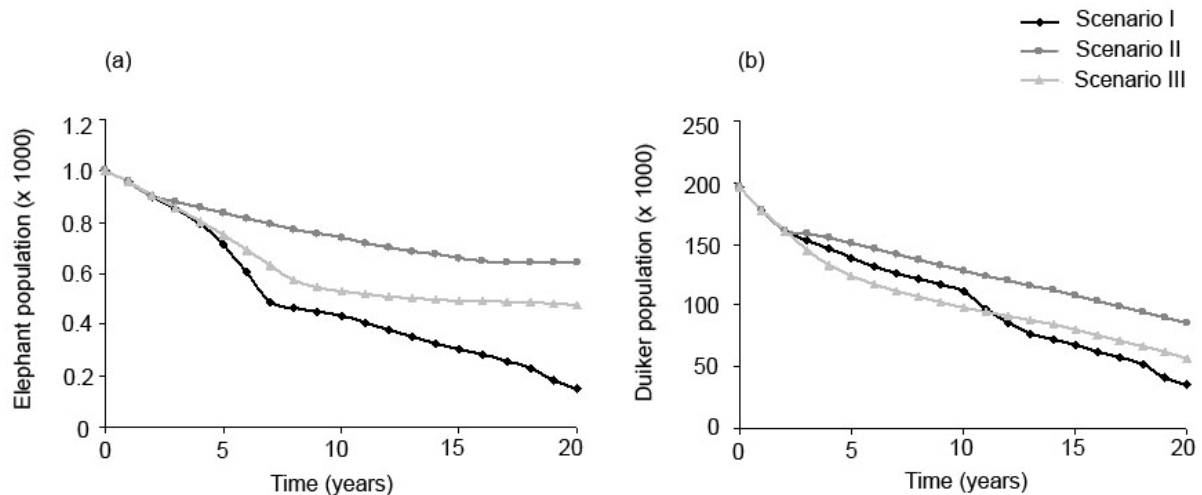


**Figure 5.** Average annual per capita cash income for (a) BaAka pygmies and (b) Bantus under the three scenarios explored (I: predatory logging, II: certified logging, III: conservation concession)

### *Wildlife populations*

Under the predatory logging and conservation concession scenarios, the simulated elephant population declines by 85 and 50 percent respectively after 20 years (Fig 6a). Such dramatic losses have been seen in the past in the landscape when the elephant population decreased by 70 percent from 2855 individuals in the 1980's (Carroll 1986) to 869 individuals in 2004 (Blake 2005). In year 7 of the simulation, under scenario I the elephant density inside the park drops below  $0.2/\text{km}^2$  resulting in a decreasing hunting success from this moment onwards (Fig 6a). In year 10 under scenario I, the elephant population declines faster due to the increase in poachers (Fig 4b) being a result of the closure of the logging company. The same feature is seen with the closure in year 18 under scenario I, though the elephant population is already so weak hunting elephants has become quite difficult. Though scenario II results to be the best option to conserve the elephant population, this still entails a 35% decline in elephants.

The duiker population (Fig 6b) is strongly related to the number of hunters (Fig 4b) under the three scenarios. For the first ten years of the simulation, the conservation concession gives worst results for the duiker population because of the lack of alternative income generating activities for the local population of which as a result a large share dedicates to bushmeat hunting. The closures of the logging concession in year 10 and 18 (scenario I) result in a sudden increase in duiker hunting and thus a sudden decrease in duiker population (Fig 6b) as people compensate forgone income from their lost jobs with bushmeat hunting. Already at the start of the simulation, the duiker population is slightly below 40 animals/km<sup>2</sup> so the hunting success diminishes linearly with the decrease in duiker density. Again scenario II results in best outcomes for duikers which still results in duiker densities dropping more than half the current values.



**Figure 6.** Total number of forest elephants (a) and duikers (b) in the Dzangha-Sangha reserve under the three scenarios explored (I: predatory logging, II: certified logging, III: conservation concession)

The predatory logging scenario bares a more dramatic effect on elephants than duikers in comparison to the other scenarios. We modelled this scenario to be accompanied by an increased import of large calibre guns used for elephant poaching through the opening of roads and the increased traffic and because the employers will have more money to purchase guns (in line with findings of Bennett 2004). With a certified logging company though, we expect the company to establish control points on the roads limiting the transport of guns and bushmeat, and to close logging roads that are no longer used. This is being done by neighbouring certified companies in Cameroon and Congo.

#### *Sensitivity analyses*

A sensitivity analysis showed that wildlife population outcomes are sensitive to levels of human migration, and duiker population outcomes are sensitive

to duiker density and reproduction rate. If instead of the assumed 1 – 3 percent immigration rate, we assume an out-migration rate of 2 percent e.g. as a result of economic opportunities in the town of Berberati or Bangui, the elephant population would be 12–70 percent higher at the end of the simulation. Assuming this out-migration under the scenario of a certified logging company, the elephant population would be comparable to the current population size after 20 years. Using minimal duiker densities with maximum reproduction rates as given by Noss (1998) results in similar downward population trends when comparing the three scenarios, only they would go extinct under scenario I and III after 19 and 20 years respectively, while under scenario II a small population of around 10,000 duikers would remain after 20 years. Assuming minimum densities and reproduction rates from Noss (1998) results in minimal differences between the scenarios and duikers going extinct under all scenarios.

## **DISCUSSION**

### *Local and national economy*

Overall, peoples' incomes declines in the absence of a major entrepreneur/employer like a logging company, mainly because the landscape lacks the economic activities needed to support the increasing human population. Bushmeat hunting doesn't seem able to provide a sustainable cash flow for the increasing local population. Current modelled hunting levels are unsustainable (Fig 5b) and hunting pressure from outside the area might increase in the future as improved roads provide better access to the landscape. Agricultural production is not likely to provide an income alternative either for a large proportion of the people. The Dzanga-Sangha landscape has mainly ferrallitic soils which are rapidly impoverished by slash-and-burn and when not altering cycles of cassava cultivation with other crops (Kokamy-Yambere 2007) as is the current practice. This, together with the administrative restrictions placed on agricultural expansion, limits the potential of agriculture to become a major income source. We didn't model soil fertility declines and didn't restrict agricultural expansion to remain within the small administrative agriculture zone. A separate modelling exercise showed when applying an agricultural rotation, agricultural expansion, as needed to keep agricultural production at current levels, would already be restricted by the limits of the agriculture zone within the next five years. If the boundaries of the agriculture zone are not revised and the current practice of continued mono-cropping continues, household income might decline more dramatically than suggested by the simulation results.

The sensitivity of the data to human migration levels in and out of the landscape illustrates the importance for rural areas of growth in the national economy (Frost et al. 2007), as this reduces pressure on natural resources. At the same time, national development also brings new conservation challenges for rural areas because of increased access through infrastructure development (Laurence 2006). If on the other hand the socio-political turmoil



in the country continues, and little economic opportunities surge, the Dzanga-Sangha landscape is a likely refuge for people who will make a living with some bushmeat hunting, agriculture and other activities. If in such a situation the flow of people coming to Dzanga-Sangha is even larger than the 1-3% immigration modelled, this would give very pessimistic outcomes for the landscapes' wildlife populations.

#### *Conservation concession*

The current conservation concession scenario assumes a compensation of forgone forestry taxes of € 316,000/year or € 1.23 per ha/year (Table 1). The Cameroonian government was unable to find investors ever since 2001 willing to pay € 1.4 per ha for 830,000 ha of almost entirely intact forest bordering a national park as a conservation concession (The Economist 2008 and personal observation Sandker 2009). Likewise, the Peruvian government tried to auction off 800,000ha forest as a conservation concession but could not find investors willing to pay between € 0.7-2.8 per ha (Hardner & Rice 2002). The Dzanga-Sangha concession concerns largely logged-over forest so it might be overly optimistic to assume investors will be found for the simulated € 1.2 per ha/year.

According to Karsenty (2007), opportunity costs of forgone wages for the Cameroonian 830,000ha would be as much as € 6.4 million per year (€ 7.8 per ha) additional to the taxes and royalties paid. Even if investors would be willing to pay the € 316,000 in the CAR, with the current situation of bad governance, direct payments to the government will do little for the local population.

One could argue ecotourism could provide economic opportunities to the local population (though ecotourism could probably be as well developed under the certified logging scenario). Under our most optimistic scenario (assuming a 400 percent increase in tourists), ecotourism could contribute € 55,850 to the local economy whereas the logging concession contributes between € 364,100 and € 885,200. A willingness-to-pay study in the Dzanga-Sangha landscape (Tieguhong 2009) revealed tourists are willing to pay about 1.8 times more than they currently spend, but even doubling the revenue from ecotourism it would still contribute less to the local economy than logging would. Furthermore, a large share of the population living far from the project may have no access to income from ecotourism. Often income from ecotourism cannot compete with income from more destructive activities (Oates 1999). Perhaps carbon payments could increase the investment in forest conservation, though research by World Growth (2009) found the value of carbon credits at best brings in only a quarter of what can be secured from more effective economic use of forest land by developing countries.

### *Hunting*

The logging activities might lead to a larger increase in hunting pressure than we modelled because of intensified commercial hunting through increased traffic and increased cash income in the villages and bushmeat demand from the concession workers. This is likely to alter the difference between scenario I and II, but we do not expect this to change the overall trends under the three scenarios.

### *Elephants*

One ecologist working in the landscape believed that the decrease in elephant population could be even more dramatic than the simulation results suggest. We assumed elephant hunting would become less successful once the elephant density drops below 0.2 elephants per km<sup>2</sup>, but since elephants concentrate on forest clearings (*salines*) hunting success might start decreasing at a lower elephant density. Furthermore, the number of elephants might decrease more drastically than simulated in the three scenarios if the elephants migrate to neighbouring Congo or Cameroon. Blake (2005) mentions that elephants move out of dangerous areas.

### *Duikers*

Van Vliet and Nasi (2008) report how different methods to approximate duiker densities result in highly variable results. Noss (1998) compared his own findings based on line transect surveys and net hunt encounters with those of other studies using different methods to approximate duiker densities (i.e. radio-telemetry, pellet and track counts). He indicates that densities of *C. monticola* could vary in a range of 11 – 79 animals/km<sup>2</sup> in the community hunting zone of the Dzanga-Sangha landscape according to different methods used to approximate duiker density. The density range he gives for *C. callipygus* and *C. dorsalis* shows an even larger variation, with highest approximated densities being 25 to 30 times the most conservative estimates. As explained under the method section, based on the hunting off-take rates in combination with duikers apparently still being abundant, we have used a high reproduction rate and relatively high densities for duikers in the model (Table 1). When interpreting the results one should consider the great uncertainty concerning duiker density. This study seeks in the first place to assess a realistic trend in duiker population. For a precise prediction of duiker densities we would recommend a more in-depth study on duikers.

Given the large variation in possible duiker densities, Noss (1998) was not certain whether hunt off-takes in 1994 were unsustainable for *C. monticola* and *C. dorsalis*. He did find hunting of *C. callipygus* to be at unsustainable levels even assuming the most optimistic density and reproduction figures. When comparing Noss' (1998) data gathered in 1994 on snare-captured duiker species with the most hunted species according to the 50 household

interviews in 2006, we observe that the capture of *C. monticola* has doubled in proportion to *C. callipygus*. Furthermore, the share of *C. dorsalis* (consisting of 10 percent in kg of the duiker captured in 1994) has gone down almost three times (3.6 percent in kg of total hunted kg in 2006). A study carried out by Van Vliet et al. (2007) comparing duiker inventories in Gabon in the 1980's and 2006 demonstrated that *C. dorsalis* has become locally extinct as a result of hunting pressure. Thus the relative decrease of *C. dorsalis* compared to the other duiker species in 2006 might reflect local depletion of this species due to over-hunting. We hypothesize that as the result of the depletion of one species of duiker, other species of duiker (notably *C. monticola* with its high reproduction rate) might increase as they have a higher carrying capacity and are exposed to less inter-species competition. These are however speculative findings since the data of Noss and the 2006 survey data were assessed in different ways, the standard hunting method for small animals has altered between 1994 and 2006 with small home-made guns gaining in popularity, and the household hunting estimates from the 2006 questionnaires are thought to be too rough to allow drawing any solid conclusions from it. We recommend further research to be done to test the hypothesis we pose. In any case, if a resilient animal like the duiker shows a dramatic decline, it is quite likely that other less resilient small animals will locally disappear with high hunting pressure.

## CONCLUSION

The simulation results oblige one to temper expectations on best outcomes for wildlife conservation and local development in the Dzanga-Sangha landscape. The most optimistic scenario outcomes suggest even minimal wildlife losses to be quite dramatic for the 20 years to come, while the income situation for local people only improves little. On a positive note, there does appear to be room for synergies, with scenario II giving the best, or least bad, outcomes for both conservation and development.

Contrary to the suggestion of Niesten & Rice (2004), the simulation results suggest that at current investment levels conservation concessions do not have the potential to provide economic development. In the situation of the Dzanga-Sangha landscape the conservation concession is not capable of maintaining wildlife populations since the landscape is already filled with settlers lacking alternative income generating activities. Economic development outside the landscape, and economic investments in the landscape (notably logging or mining) have major consequences for wildlife densities as they determine the extent of human migration in and out of the landscape and determine the economic alternatives for the people living in the landscape. External economic investments have a higher impact on the size of wildlife populations than current conservation interventions. A key criticism of past integrated conservation and development initiatives has been their failure to recognise the importance of external forces whose impact dwarfs that of the on-site interventions of conservation agencies (McShane & Wells 2004). It seems that in situations like the Dzanga-Sangha

landscape, an important role of the ICDP is that of negotiating and informing the actors of the consequences of their choices of the credentials of logging companies. This choice will be the main determinant of conservation and development outcomes for the landscape.

The results of this study suggest that rather than seeking to expand the protected area networks in the Congo Basin, both wildlife conservation and local development outcomes are better served by an appropriate balance between sustainable use and protection of the forest. This study therefore illustrates the importance of initiatives like Forest Law Enforcement, Governance and Trade (FLEGT), promoting timber certification and the allocation of Reducing Emissions from Deforestation and forest Degradation (REDD) funding to sustainable management as well as protection.

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## REFERENCES

- Bennett, E.L. 2004. *Seeing the Wildlife and the Trees. Improving Timber Certification to Conserve Tropical Forest Wildlife*. World Bank, Washington DC, USA.
- Blake, S. 2005. *Long term system for monitoring the illegal killing of elephants (MIKE). Central African forests: Final report on population surveys 2003 – 2004*. Report. CITES MIKE Programme, Washington DC, USA.
- Blom, A. 2001. *Ecological and economic impacts of gorilla-based tourism in Dzanga-Sangha, Central African Republic*. PhD thesis. Wageningen: Wageningen University. The Netherlands.
- Carroll, R.W. 1986. *The status, distribution and density of the lowland gorilla (Savage and Wyman), Forest elephant and associated dense forest fauna in southwestern Central African Republic*. Research towards the establishment of a Reserve for their protection. PhD thesis. Yale: Yale University School of forestry and environmental studies, UK.
- CBFP (Congo Basin Forest Partnership), 2006. *Les forêts du Bassin du Congo-Les états des forêts 2006*. Report. Kinshasa: CBFP, DRC.
- Clark, C.J., J.R. Poulsen, R. Malonga and P.E. Elkan. 2009. Logging Concessions Can Extend the Conservation Estate for Central African Tropical Forests. *Conservation Biology* **23**(5): 1281-1293.
- Czesnik, F. 2007 *Mission d'appui-conseil financier pour le renforcement de la coopération avec la Commune de Bayanga*. Rapport de mission. Bayanga: GFA Consulting Group and Dzanga-Sangha Project, CAR.

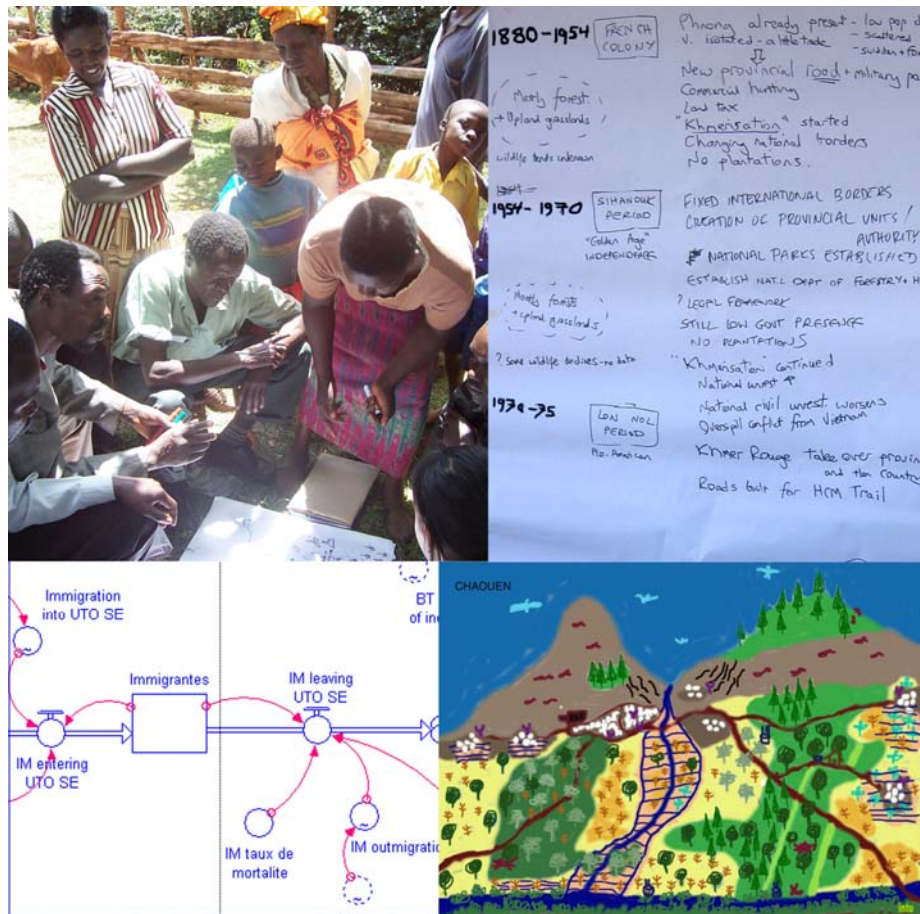
- Doungoubé, G. 1990. *Central African Republic: the Dzanga-Sangha Dense Forest Reserve*. Pages 75-79 in A. Kiss (ed.). *Living with wildlife: wildlife resource management with local participation in Africa*. Washington DC: World Bank.
- FAO (Food and Agriculture Organization of the United Nations). 2003. *African Forests: A view to 2020*. Forestry Outlook Study for Africa. Report. Rome: European Commission (EC)/African Development Bank/FAO, Italy.
- Feiganangai, N. 2003. *L'écotourisme à Dzanga Sangha – un exemple de valorisation économique de la conservation des ressources naturelles*. Rapport de stage ISDR de Mbaiki. Bangui: Bangui University, CAR.
- Frost, P., B. Campbell, M. Luckert, M. Mutamba, A. Mandondo and W. Kozanayi. 2007. In Search of Improved Rural Livelihoods in Semi-Arid Regions through Local Management of Natural Resources: Lessons from Case Studies in Zimbabwe. *World Development* **35**(11):1961-1974.
- FSC (Forest Stewardship Council). 2007. *Système de certification Forest Stewardship Council: Référentiel de gestion forestière adapté pour le Cameroun*. Report. Yaoundé: RF03 FSC GF Cameroun version 1.3. Bureau Veritas Certification/Eurocertifor, Cameroon.
- Garreau, J.M. 1994. *Enquête sur le revenu des ménages à Bayanga et Moussapoula*. Rapport. Bayanga: Dzanga-Sangha Project, CAR.
- Hardner J. and Rice R. 2002. Rethinking green consumerism. *Scientific American* 287: 89-95
- HPS (High Performance Systems). 1996. *STELLA and STELLA Research Software*. High Performance Systems (now Isee systems). Hanover NH, USA.
- Kamiss, A. 2006. *Recensement de la populations des villages de la Réserve Spéciale de Dzanga Sangha au des année 2005*. Rapport. Bayanga: Dzanga-Sangha Project, CAR.
- Karsenty, A. 2007. *Overview of Industrial Forest Concessions and Concession-based Industry in Central and West Africa and Considerations of Alternatives*. Report. Montpellier: CIRAD, France.
- Klauss-Hugi, C.S. 1998. *Home range, feeding behavior and social organization of the Bongo (Tragelaphus euryceros) In Central African Republic*. PhD thesis. Zurich, Switzerland.
- Kokamy-Yambere, S., E. Bango, P. Doko, and R. Kanimbia. 2007. *Rapport de Prospection Pedologique et de Cartographie des Terroirs Agricoles Villageois dans la Commune de Yobe-Sangha*. Report. Bayanga: GFA Consulting Group, CAR.
- Laporte, T.N., A. Jared, A.J. Stabach, R. Grosch, S.T. Lin and J.S. Goetz. 2007. Expansion of Industrial logging in Central Africa. *Science* **316**: 1451.
- Laurance, W.F., B.M. Croes, L. Tchignoumba, S.A. Lahm, A. Alonso, M.E. Lee, P. Campbell and C. Ondzeano. 2006. Impacts of Roads and Hunting on Central African Rainforest Mammals. *Conservation Biology* **20** (4): 1251-1261.

- McShane T. and Wells M. (eds) 2004. *Getting biodiversity projects to work: towards more effective conservation and development*. Columbia University Press, New York, USA.
- Monza, J.P. de. 1996. *Conservation de la forêt tropicale humide*. Report. Yaoundé: International Union for Conservation of Nature (IUCN), Cameroon.
- Nielsen, E. and Rice, R. 2004. Sustainable forest management and conservation incentive agreements. *International Forestry Review* **6**: 56– 60.
- Noss, A.J. 1998. The impact of cable snare hunting on wildlife population in the forests of the Central Africa. *Conservation Biology* **12**(2): 390-398.
- Noss, A.J. 1995. *Duikers, cables and nets: a cultural ecology of hunting in a central African forest*. PhD thesis. Gainesville: University of Florida, USA.
- Oates J.F. 1999. *Myth and reality in the rain forest: how conservation strategies are failing West Africa*. University of California Press, Berkeley, USA.
- Rice, R. 2003. *Conservation Concessions - Concept Description*. Vth World Parks Congress: Sustainable Finance Stream. Durban: Conservation International, South Africa.
- Sayer, J., B. Campbell, L. Petheram, M. Aldrich, M. Ruiz-Perez, D. Endamana, Z. Nzooh-Dongmo, L. Defo, S. Mariki, N. Doggart, and N. Burgess. 2007. Assessing environment and development outcomes in conservation landscapes. *Biodiversity and Conservation* **16**:2677-2694.
- The Economist, 2008. *The price of conservation-the unkindest cut. Cameroon wants to sell a forest, but conservationists don't want to buy it*. The Economist.
- Tieguhong, J.C. 2009. *Ecotourism for sustainable development: economic valuation of recreational potentials of protected areas in the Congo Basin*. PhD thesis. Pietermaritzburg: University of KwaZulu-Natal, South Africa.
- Turkalo, A. 2005. *Rapport d'activité*. Report. Bayanga: Projet Dzanga Sangha, CAR.
- UN (United Nations) 2009. *World Population Prospects: The 2008 Revision*. UN Department of Social and Economic Affairs, New York, USA.
- Van den Belt, M. 2004. *Mediated modeling. A system dynamics approach to environmental consensus building*, Washington, DC.
- Van Vliet, N. and R. Nasi. 2008. Why do models fail to assess properly the sustainability of duiker (*Cephalophus spp.*) hunting in Central Africa? *Oryx* **42**:392–399.
- Van Vliet, N., R. Nasi, L. Emmons, F. Feer, P. Mbazza and M. Bourgarel. 2007. Evidence for the local depletion of bay duiker *Cephalophus dorsalis*, within the Ipassa Man and Biosphere Reserve, north-east Gabon. *African Journal of Ecology* **45**(3): 440-443.
- Wasseige, C. de, D. Devers, P. de Marcken, R. Eba'a-Atyi, R. Nasi and P. Mayaux. (eds) 2009. *Les Forêts du Bassin du Congo – Etat des Forêts 2008*. Report. Office des publications de l'Union européenne.

- World Bank. 2009. *Gross national income per capita 2008, Atlas method and PPP*. World Bank, Washington DC, USA.
- World Growth. 2009. *Forestry and the Poor: How forestry reduces poverty*. World Growth Report.

## Chapter 9

### The role of participatory modeling in landscape approaches to reconcile conservation and development



Map right under created by Intu Boedhihartono



*Research*, part of a Special Feature on [Navigating Trade-offs: Working for Conservation and Development Outcomes](#)

## The Role of Participatory Modeling in Landscape Approaches to Reconcile Conservation and Development

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**ABSTRACT.** Conservation organizations are increasingly turning to landscape approaches to achieve a balance between conservation and development goals. We use six case studies in Africa and Asia to explore the role of participatory modeling with stakeholders as one of the steps towards implementing a landscape approach. The modeling was enthusiastically embraced by some stakeholders and led to impact in some cases. Different stakeholders valued the modeling exercise differently. Noteworthy was the difference between those stakeholders connected to the policy process and scientists; the presence of the former in the modeling activities is key to achieving policy impacts, and the latter were most critical of participatory modeling. Valued aspects of the modeling included stimulating cross-sector strategic thinking, and helping participants to confront the real drivers of change and to recognize trade-offs. The modeling was generally considered to be successful in building shared understanding of issues. This understanding was gained mainly in the discussions held in the process of building the model rather than in the model outputs. The model itself reflects but a few of the main elements of the usually rich discussions that preceded its finalization. Problems emerged when models became too complex. Key lessons for participatory modeling are the need for good facilitation in order to maintain a balance between “models as stories” and technical modeling, and the importance of inviting the appropriate stakeholders to achieve impact.

**Key Words:** *conservation and development; landscape approach; multiple stakeholders; natural resource policy; participatory modeling; systems modeling*

### INTRODUCTION

Integrated conservation and development projects emerged in the 1970s and represent major investments by conservation organizations. However, their effectiveness is seriously questioned (McShane and Wells 2003, Garnett et al. 2007). A new wave of investment is now emerging in “landscape approaches” as a way to integrate conservation and development (Sayer and Campbell 2004, Sayer and Maginnis 2005).

Landscapes are considered as mosaics of land cover types that provide environmental services and development opportunities for the multiple needs of diverse stakeholders. A landscape approach seeks

to understand landscape dynamics and the desired changes from different viewpoints, the aim being to identify interventions and policies that will achieve the stated goals of stakeholders. Constituting a forum for stakeholder negotiations is a fundamental first step in taking a landscape approach (Sayer and Maginnis 2005).

“Facilitated”, “mediated”, “group”, or “participatory” modeling are terms used for building models with non-modelers under the guidance of a skilled modeler. Participatory modeling has been used in a wide range of situations, including business (Vennix 1996, Vennix et al. 1996), fisheries (Otto and Struben 2004), and environmental decision-making (e.g., Van den Belt et al. 1998, Vanclay et

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al. 2006). A wide range of model types have been used in participatory modeling, including Bayesian or belief networks (Lynam et al. 2002), agent based modeling (Bousquet and Le Page 2004, Castella et al. 2005) and system dynamics modeling (Van den Belt 2004, Sandker et al. 2007).

Although models are widely used to predict and plan, participatory models serve to explore options and enrich debate. Rouwette et al. (2002) and Lynam et al. (2007) reviewed different cases where participatory modeling was used, and concluded that it improves communication between stakeholders and this increases understanding of complex systems. Akkermans and Vennix (1997) found that five out of six case studies used participatory modeling successfully to create insights and build consensus. This is confirmed by Bousquet et al. (2007) and Castella et al. (2007), who claim that building models with multi-stakeholder groups who have different perceptions and objectives helps build a shared understanding of problems. García-Barrios et al. (2008) report that modeling is particularly effective in stimulating cross-sector strategic thinking, and in helping participants confront the real drivers of change and recognize non-linearities and trade-offs. The modeling process helps participants step back and look beyond their own world view to the holistic landscape picture. All of these characteristics help in the implementation of a landscape approach.

In this paper, we examine several case studies where participatory system dynamics modeling was applied to environmental management challenges, and explore how it contributed to promoting a landscape approach. The case studies are drawn from landscapes where conservation and development goals were mutually sought. More specifically, we examine whether participatory modeling helped in conceptualizing the landscape and its dynamics, in exploring possible interventions, and in facilitating discussions among multiple stakeholders. We also present lessons for using participatory modeling.

## METHODS

### Background to the case studies

The case study sites all have extraordinary biodiversity values. The Tri National de la Sangha, which stretches between Cameroon, the Central

African Republic, and the Republic of Congo (hereafter TNS), and Malinau (Indonesia) have vast areas of largely undisturbed rainforest. The TNS houses significant populations of forest elephant (*Loxodonta cyclotis*), lowland gorilla (*Gorilla gorilla gorilla*), and chimpanzee (*Pan troglodytes troglodytes*). Malinau's tropical rainforests are among the world's internationally recognized biodiversity "hotspots" (Mittermeier et al. 2004). Wasa Amenfi West (Ghana), where rainforest is surrounded by agroforests, is also a biodiversity hotspot. The Chilimo Forest (Ethiopia) is a National Forest Priority Area and represents one of the few remnants of dry Afro-montane forests that used to cover the central plateau of Ethiopia. Namaqualand (South Africa) forms part of the Succulent Karoo biodiversity hotspot, which is one of only two arid regions in the world to qualify as such. The Subtropical Thicket Biome (South Africa) forms part of the Maputaland-Pondoland-Albany biodiversity hotspot (Steenkamp et al. 2004) and displays high levels of plant endemism, along with populations of African elephant (*Loxodonta africana*) and endangered rhinoceros (*Diceros bicornis michaeli* and *Diceros bicornis bicornis*).

Some of these landscapes have been subject to recent rapid transformation. In Malinau, many small-scale logging permits were issued as a result of decentralization. In Chilimo, deforestation increased significantly when state control weakened after 1991. These landscapes were selected for this paper because of their high biodiversity values and high levels of poverty, and because all had projects with conservation and development goals. Despite this commonality, the landscapes are highly diverse in their social-ecological contexts and stakeholder makeup. In some of the models, participants included governance as part of the system, notably in the TNS model where governance drastically affected outcomes landscape wide. In other landscapes, the governance component in the model was restricted to implications of specific policies. The characteristics of the landscapes, and the modeling approaches applied in each are described in Table 1.

### Model building approach and objective

In all landscapes, alternative scenarios were simulated to explore the trade-offs between conservation and development (see Table 1). Our approach to participatory modeling builds upon the

**Table 1.** Landscape characteristics and details of the modeling approach for each of the six case studies.

Landscape characteristics					Modeling approach			
Total area (km <sup>2</sup> )	Forest cover (%)	Population pressure (pers-on/km <sup>2</sup> )	Cash income per capita (US\$/annum)	Land use pressures	Objective	Steps in process to produce models	Stakeholder engagement	No. of variables in the model
<b>Malinau, Indonesia</b>								
42,000	>90	2	180	Logging and development of biofuel plantations	Explore impact on livelihoods and biodiversity of proposed conversion of forest to oil palm plantations (Sandker et al. 2007)	Workshop (2001), many small workshops, training course on modeling, continuing until 2007	District officials, researchers, representatives of community organizations	297
<b>Wasa Amenfi, Ghana</b>								
3,465	~25	55	600	Deforestation for cocoa plantations	Explore whether carbon payments can halt the conversion of primary and secondary forest into cocoa plantations (Sandker et al. 2010)	Workshop (2008)	District officials, local and international conservation agency staff (International Union for Conservation of Nature - IUCN), logging company representative, landholder and researchers	178
<b>Tri National de la Sangha, Central Africa</b>								
35,000	>90	4	250	Wildlife poaching; to a lesser extent logging	Intended to focus on livelihood outcomes from conservation initiatives but came to focus on governance and corruption impacts (Sandker et al. 2009)	Five annual workshops, policy briefings, continuing until 2009	Conservation agency staff (IUCN, World Wildlife Fund, Wildlife Conservation Society), regional conservation bodies, researchers (20–25 persons per workshop)	584
<b>Chilimo, Ethiopia</b>								
220	<30	60	40	High timber extraction, grazing, farming	Explore joint forest management versus state control (Kassa et al. 2009)	Training course (2005), policy workshops	20 staff from a forestry college, graduate students, staff of non-governmental organizations (NGOs), local officials, policy advisors	486
<b>Subtropical Thicket Biome, South Africa</b>								
3,686	Not naturally fully covered with forest	73	2085	Urban development, irrigated farming, over-grazing, alien plant invasion	Explore different mechanisms to schedule conservation actions	Work with PhD student to define model (2003)	None for the modeling part of the project	538

(con'd)

#### Namaqualand, South Africa

50,000	Not naturally fully covered with forest	4	285	Unsustainable farming, mining, illegal trade in succulents (Hofmann and Rohde 2007)	Explore different mixes of commercial, communal, and conservation land uses, and estimate opportunity costs of conservation on communal lands (James et al. 2005)	Workshop (2004)	Officers from agencies involved in conservation and agriculture, NGOs, researchers	526
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concept of the “throw-away” model: computer-implemented models that are built in a short time to explore a particular problem and are then “discarded” (Sayer and Campbell 2004). This approach is similar to that proposed for scoping models (Van den Belt et al. 1998, Van den Belt 2004, Sandker et al. 2008). The objective of these models is to explore links between the major components of landscape systems and simulate possible trends in environmental and livelihood outcomes over time. The term “throw-away model” stresses the utility of the model in facilitating brainstorming and discussions rather than its use as a formal predictive tool. The process of building the model in a participatory manner is therefore more important than the model produced. King and Kraemer (1993) doubt the usefulness of models with high predictive value in policy making processes. Decisions made that involve multi-stakeholder processes usually go deeper into the social realm where predictions are far from accurate.

In our approach, we collaboratively identify and build scenarios, where the modeled scenarios “tell the story” of envisaged future changes across a landscape. The intention of scenario building is to consider a variety of possible futures rather than to focus on the accurate prediction of a single best outcome (Bennett et al. 2003, Peterson et al. 2003). Ultimately, the objective of the model building exercise is to improve the performance of local stakeholders in identifying interventions that are likely to have the greatest impact on them. In some cases, the objective is also to inform more distant stakeholders at the national, regional, and international levels.

#### Stakeholders

These case studies typically aim to help stakeholders find solutions to their conservation and development challenges. Local stakeholders are primarily local landowners, and managers in

government and in local and international non-governmental organizations (NGOs). As part of the process in the TNS, several sessions were held with stakeholders at a policy level (donors, parliamentarians, regional agencies). Policy level dialogue was also part of the Chilimo and Malinau processes.

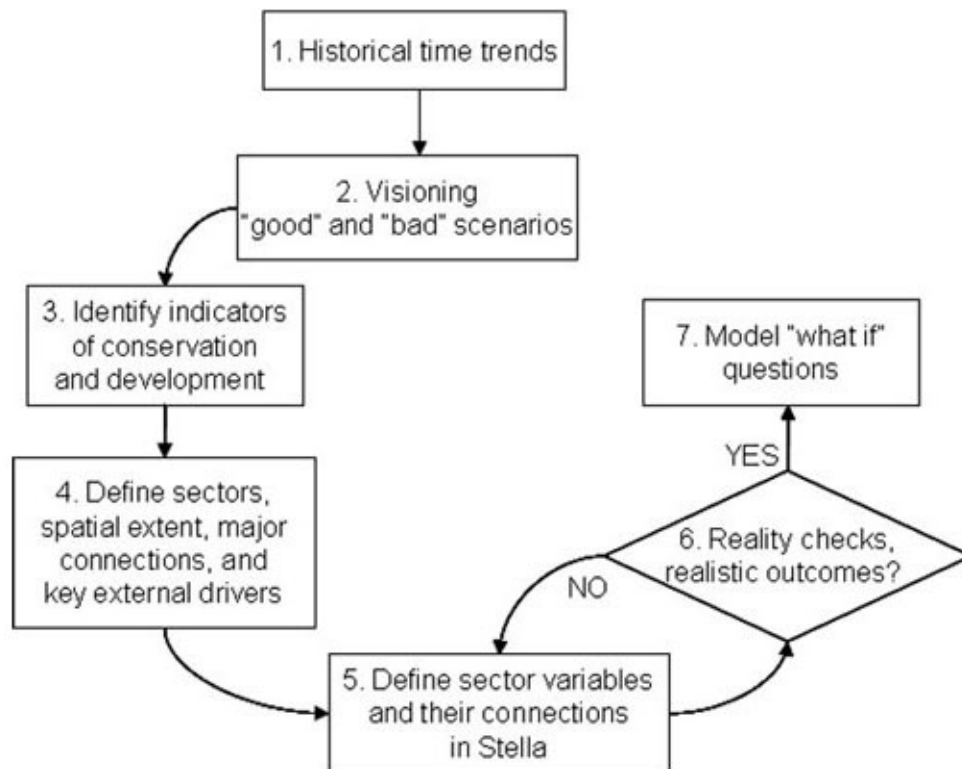
#### Model building steps

The approaches adopted in the six case studies were similar. In all cases, we used the systems dynamic modeling software STELLA. This is a stock-and-flow modeling language with a user-friendly icon-based interface. Most commonly, a workshop was held with a diverse range of stakeholders (Table 1), at which a number of activities were facilitated to promote discussion of desirable conservation and development outcomes at the landscape scale (Fig. 1). We often started with historical time trends as a precursor to visioning so as to create awareness of current trends in the landscape and to provoke discussion about the events that triggered changes in the landscape in the past and which might do so in the future. The visioning exercises took several forms: brainstorming on possible future scenarios, identifying “undesired” and “desired” scenarios from different stakeholders’ perspectives, identifying the major drivers of change, and discussing possible interventions.

The next step was to identify indicators of conservation and development, which generally became variables in the landscape model, later to be plotted on graphs to display the simulated outcomes under different scenarios. Examples included “household income”, “village development budget”, “elephant population”, and “forest cover”. This was typically accomplished by using flip charts and flash cards.

The next step was to define the different sectors (sub-models) of the landscape, for example “rural population dynamics”, “land-use changes”, and

**Fig. 1.** Schematic representation of steps taken in the participatory modeling process (modified from Sandker et al. 2009).



“wildlife populations”. Different groups of participants then worked independently to build these sectors under the guidance of specialist modelers. Landscape stakeholders selected the sectors and their elements, including all that they believed were affecting conservation and development outcomes in the landscape. Variables in the sectors were defined and parameterized using data from reports, literature, or expert estimates. The dynamics of the system were added by indicating how variables influence each other, based on the earlier discussions about the main drivers of change. A reality check was typically conducted where the model was run and simulated outcomes for specific variables were checked against known trends or participant expectations, which often led to further changes to the model.

Sectors were then linked to run the complete model. The modeling process often resulted in changes in focus as understanding of the system emerged. This often led to new sectors being added to the model while others became obsolete. The modeling group

then explored the potential impacts of different interventions. This allowed participants to ask “what if” questions and served as a reality check for what may be achieved with different interventions.

### Time investment

In some case studies, long-term engagement was possible. This was the case for the TNS (four annual meetings) and Malinau (seven years of engagement with district stakeholders) where the model was revised and updated at each successive meeting. At the other extreme, in the Subtropical Thicket Biome case study, the model was prepared by researchers with the intention of using it in multi-stakeholder forums, but the plan was terminated and the model was not further developed. In Wasa Amenfi, Chilimo, and Namaqualand, models were built at a single workshop. Wasa Amenfi was the shortest workshop, and the model was built in only five days but engagement through email discussions continued for several months. At Chilimo, a 10-day training program was held for lecturers and



researchers, which included engagement with other local stakeholders. In Namaqualand, a 7-day workshop was held, and the model was refined over the next 12 months.

### **Evaluation of the participatory modeling case studies**

The value of the participatory modeling cases was assessed through a questionnaire survey of the participants. Twenty-three participants from the six case studies participated in the questionnaire. The participants were grouped into four types of stakeholders: scientists, local/national NGO staff, international NGO staff, and persons closely connected to the policy process. The questions were based on reported qualities from participatory modeling experiences (Akkermans and Vennix 1997, Costanza and Ruth 1998, Rouwette et al. 2002, Van den Belt 2004, Beall 2007). The questions were grouped into four categories that described participatory modeling: (1) “process”: the participatory process of building the model and the thinking and discussion it provoked; (2) “structure”: the actual model and the more technical aspects of the model building; (3) “outputs”: the simulated indicator outputs featured in graphs or tables; and (4) “impact”: the impact of the modeling exercise and how the modeling results were used after the model session. The questionnaire had six questions on process, six on structure, six on outputs, and five on impacts (Appendix 1). The questions were structured as Likert statements (Babbie 1989) that were scored from one to five, with one representing a very low perceived value while five represented a high perceived value. The average scores for each case are presented in Appendix 1. The matrix of landscapes and their average scores for the four model building characteristics, and the matrix of stakeholders and their average scores were analyzed using Principal Component Analysis (PCA).

## **RESULTS AND DISCUSSION**

### **Modeling characteristics**

Average scores from the participants for the different characteristics of participatory modeling are shown in Figure 2. The highest scores were given to process, whereas impact scored the lowest. The latter characteristic also has the highest standard deviation, indicating a great variety of views about the potential impact of the modeling exercises.

These results are in line with the expectations of the throw-away model approach, where the functioning and outputs of the model are less relevant than the process of discussion, interpretation, and consensus building.

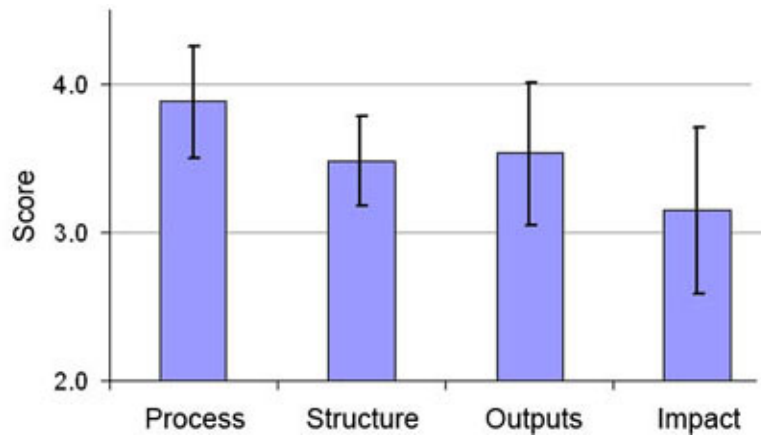
### **Modeling results in the different landscapes**

The PCA results of the average landscape scores for the four different modeling characteristics (process, structure, outputs, and impact) are shown in Figure 3. The PCA divides the landscapes into three groups: (1) Subtropical Thicket Biome and Namaqualand, (2) Malinau, Chilimo and Wasa Amenfi, and (3) TNS. The X-axis is largely a gradient from low (left) to high (right) scores. The Subtropical Thicket Biome and Namaqualand modeling exercises scored poorly, though in Namaqualand, the modeling process added some value. Malinau, Wasa Amenfi, and Chilimo are landscapes where the modeling was rated highly for all modeling characteristics. The TNS scored high on process, structure, and outputs, but scored poorly on impact. It is noteworthy that the highest scoring case studies concerned models with the fewest number of variables (Fig. 3, Table 1). The Y-axis differentiates between high and low impact. This seems to indicate that process, structure, and outputs are closely related but that other factors influence whether impact is achieved.

The initial model developed by experts for the Subtropical Thicket Biome was highly complex. This raised several problems. The time taken to build the model (about two person-months) was too much in relation to the need to act quickly in the project context. Also, the data needs were too great and the model would have been difficult to explain to the landowners who were the principle stakeholders. In the end, the model was abandoned. The model in this case had become too expert-driven. In Namaqualand, the model was also excessively complex – a simple model would have sufficed. The participatory modeling proved a distraction from the real objective of simply supplying local stakeholders with better information that could have been obtained through other methods.

In the TNS, the modeling gained high scores on process, structure, and outputs, but there was no impact. The explanation of the performance of the

**Fig. 2.** Average scores for the four characteristics of the model building exercise derived from the questionnaire survey.



TNS model lies partly beyond the questionnaire results. The model outputs suggested governance was the main problem in the landscape, and little impact was possible without reducing corruption within local government. This considerable challenge lay beyond the mandate of the stakeholders present at the modeling workshop (mainly conservation NGOs) or would put their relationships with government at risk.

In the Malinau, Wasa Amenfi, and Chilimo landscapes, participatory modeling resulted in or came close to having positive impacts. A primary reason why these cases had positive impacts was due to the presence of participants who had strong links to policy makers. This was most obvious in Chilimo where discussions and policy meetings after the modeling exercise resulted in a change in national legislation. For Chilimo, one of the participants was already engaged in policy dialogue with national level actors as the government was revisiting its forest proclamation. The results of the modeling exercise were systematically used to inform the policy formulation process, which led to the inclusion of a law that was relevant to joint management of protected forests (Kassa et al. 2009). In Malinau, the model results were presented and discussed with the district head; the discussions around the model were partially responsible for turning his attention to carbon payment schemes. The experience in Wasa Amenfi served as a lesson on the feasibility of reducing emissions from deforestation and forest degradation (REDD) in

comparable landscapes on a global level (Sandker et al. 2010), and the results could contribute to national level negotiations on REDD.

### Modeling results for different stakeholders

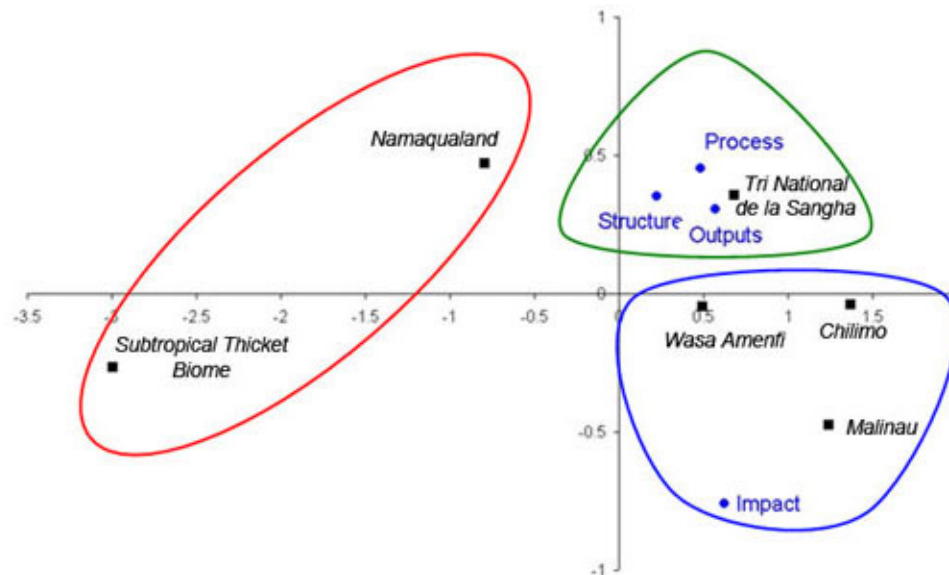
The PCA results of the average scores for the different types of participants for the four different modeling characteristics are provided in Figure 4. Each stakeholder type was placed in a distinct group. Again, the X-axis is explained mainly by the overall scores provided by the stakeholders. Scientists are clearly differentiated from the rest; they gave the lowest overall scores (3.3). At the other extreme, stakeholders with connections to the policy process gave the highest overall scores (3.8), and were especially positive in relation to impact. National NGO staff were especially positive about model structure. International NGO staff, located in the middle, gave high scores to most of the characteristics.

## THE LIMITATIONS OF PARTICIPATORY MODELING

### Complexity of models

STELLA is a simple, icon-based modeling language, and therefore is relatively accessible to non-professionals. Most participants confirmed this

**Fig. 3.** PCA of average scores for each of the four characteristics of participatory modeling for each landscape.



by ranking the user-friendliness of STELLA with a medium to high score (Appendix 1: 2.1). One participant commented “participative workshops are the best strength of STELLA since it is conceptually easy to learn compared to other modeling languages”. However, the lowest of all values was given to “the ease to run or alter the model” (Appendix 1: 2.2). Even though it is a relatively simple modeling language, non-modelers experience technical constraints in mastering STELLA. If all the elements of a landscape are included, the model can become highly complex and is no longer easily understood by all stakeholders. Complexity is inherent in the use of system dynamics modeling and forms the biggest limitation to the modeling being a participatory process. We therefore believe the success of participatory modeling depends on the presence of a skilled facilitator. Without good facilitation, the model likely passes into the realm of a high-tech simulation tool and loses its value as a means to stimulate participation and exchange among participants.

### Modeling that is “narrow” in scope

The model structure and outputs gained lower scores than the model building process (Fig. 2). One participant in the Ghana modeling session

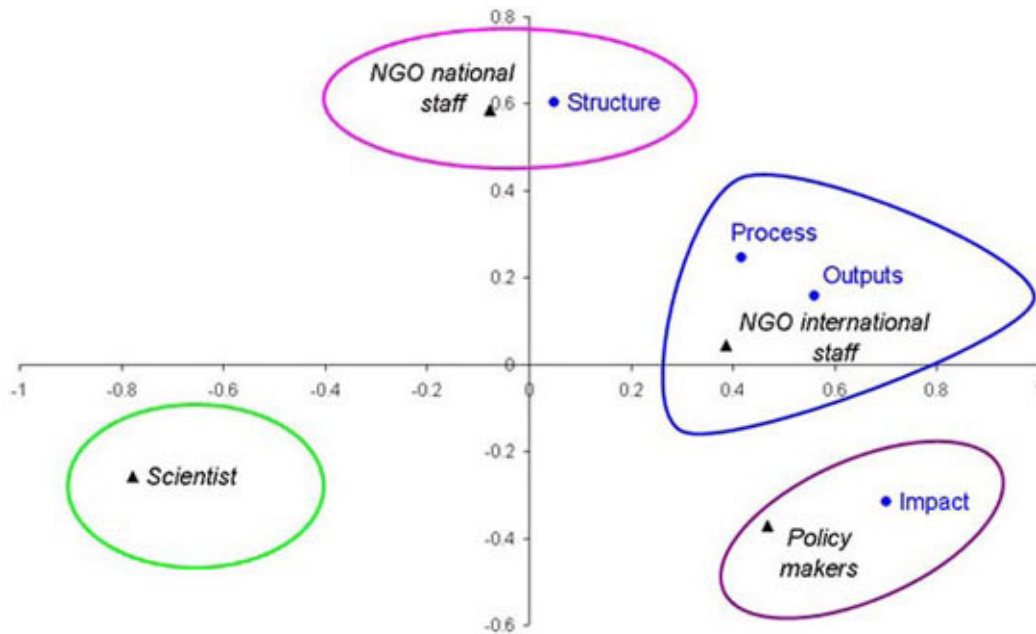
commented “a multi-dimensional discussion turned into a model with a one-track mind”. While the discussion provoked by the model building process was broad, only a small number of options were selected for simulation.

### Difficulty to achieve impact

Changing the way in which people think is a slow and difficult process. In a study by Pala and Vennix (2005) that evaluated whether students’ understanding of basic system dynamics concepts improved after they took a system dynamics course, the authors suggested that “...it is possible that our students only enrich (i.e., add information to existing conceptual structures) their ideas rather than revising (i.e., changing their beliefs or presuppositions) them.” This seems to hold for most of our participants. They gave medium to high scores for “enhancing out-of-discipline thinking” and “focusing on most relevant problems” (Appendix 1: 1.5 and 1.6), but gave lower scores for their ability to apply model outcomes to their daily activities (Appendix 1: 4.2 and 4.3).



**Fig. 4.** PCA of average scores for each stakeholder group for the four characteristics of participatory modeling.



## THE STRENGTHS OF PARTICIPATORY MODELING

### Better understanding

Early stages of model development often revealed a lack of shared understanding of problems among stakeholders. With the exception of the Namaqualand and Subtropical Thicket Biome case studies, high scores were given to the modeling exercise's value in increasing understanding of the landscape (Appendix 1: 1.1) and problems at hand (Appendix 1: 1.2). One participant commented that the modeling exercise was "an interesting approach that helps to connect the dots". Several participants also praised the model's capacity to help identify what data should be collected to increase the understanding of the landscape: "It made clear where data is still lacking, which I find a crucial element of planning new activities."

### Increasing dialogue

One of the key needs of a landscape approach is to facilitate multi-stakeholder discussion and negotiation. The participants gave the modeling process moderate to high scores in building consensus on

how to proceed (Appendix 1: 1.3) and creating awareness of different viewpoints (Appendix 1: 1.4). One participant mentioned she thought the enriching discussion was not a product of the model but rather of the facilitator's guidance, indicating good facilitation is key if the modeling process is to produce insightful exchange.

Some participants noted that awareness of different viewpoints was restricted because not all stakeholders were included in the modeling exercise. We found it difficult to adequately involve a sufficiently wide cross-section of local landowners and managers because time demands on stakeholders involved in the modeling process often proved excessive. Participation generally extended only as far as officers of NGOs and government agencies.

### Enhancing out-of-discipline thinking

Most participants concluded that they were stimulated to think outside their own discipline (Appendix 1: 1.5). In a number of the case studies, the participants were largely conservationists with a biophysical background. They had a clear view and knowledge of conservation dynamics and how

they affected these, but their view of development appeared superficial and incomplete (where the gaps were filled by development NGO participants). Despite the development rhetoric of many of the conservation organizations, the models often showed that conservation programs had little positive impact on local livelihoods. The models challenged them to better address the issues influencing the livelihoods of local people.

### **Confronting the drivers of change**

Most participants believed that participatory modeling was helpful in ensuring focus on the most relevant problems (Appendix 1: 1.6). When building quantitative models, assumptions must be made explicit because they have to be spelled out in scenarios, supported with data, and embodied in the equations used to build the model. The model outputs sometimes resulted in confronting findings – e.g., in the TNS, NGOs realized that the impacts of their current activities on local livelihoods would be negligible unless corruption was confronted (Sandker et al. 2009). This formed the basis for lively debate and a realization that shifts in strategies for investing conservation funds were needed. In Chilimo, where joint forest management is considered to be successful, participants identified future constraints to the system and issues that need to be addressed to sustain the interventions. Malinau comprises a region of extreme change – here, the focus of discussions was on the new challenges and opportunities that are likely to unfold from major external investments.

### **Formulation of strategy and policy**

Initially, it was believed by those leading the participatory modeling process that the models would be most useful for the participants within their landscapes. The models did contribute to understanding, did help in the exchange viewpoints, and did stimulate out-of-discipline thinking (Appendix 1: 1.1, 1.4, 1.5). However, mean impact scores were low. The best cases of success were outside the landscape. Outputs from the models, usually extremely simplified, can be used to communicate with external stakeholders, including people not involved in the modeling process. This is illustrated by the previously mentioned use of model outputs for the TNS, Chilimo, and Malinau to present certain points of view to policy makers.

## **LESSONS LEARNED FOR IMPLEMENTING EFFECTIVE PARTICIPATORY MODELING**

### **Select the appropriate tools**

It is essential to have sound reasons for embarking upon participatory modeling. In the Subtropical Thicket Biome case study, participatory modeling was probably not the appropriate approach. It may have been more effective to develop a GIS-based decision support system combined with expert judgment to choose the best mix of conservation options. In the Namaqualand case, participatory modeling was also probably inappropriate – simple spreadsheets could have been used to compare scenarios, and could have been used as the basis for discussion in stakeholder and policy forums. Vennix (1996: 106) states “...system dynamics is appropriate in situations where (a) the problem is dynamically complex because of underlying feedback processes, and (b) one looks for robust long term solutions.” In the Subtropical Thicket Biome and Namaqualand cases, stakeholders were beyond the phase where the problem had to be well defined and the underlying causes explored. Rather, they were in the planning phase of detailed information gathering to make a better comparison between different options. For an overview of what approach to use in what situation, we refer to Chapter 4 in Vennix (1996).

### **Invite the right stakeholders**

For the modeling to help in the exchange of different viewpoints, a sufficiently broad range of stakeholders should be involved in the model building process. Participants with good connections to policy makers should be invited to ensure the modeling results in impact.

### **Modeling is just one of various instruments in the toolkit**

Participants noted a limitation of participatory modeling. They mentioned that it was “narrow” since it selected only one or a few options for deeper exploration. Hisschemöller et al. (2001) state “Since models are only capable of analyzing well-structured problems, models are necessary but not sufficient tools to identify and define the problem to be evaluated...”. Modeling should be seen as one of a broader set of tools that help to implement a landscape approach.

Another limitation arises from processes that are extremely difficult to simulate. Many proponents of modeling advocate the use of soft system variables (“e.g., degree of social cohesion”) (Sterman 1991, Vanclay et al. 2006), but we have found that stakeholders are highly skeptical of including such variables (Sandker et al. 2008).

### **Value of the process**

Some of the most interesting insights and the more valuable discussions of possible scenarios came before the detailed modeling. Thus, the visioning phase is crucial. One participant commented “The modeling is good for helping the process of identifying possible strategies and policies. However, the future remains subject to uncertainty and therefore scenarios should be seen as an additional source of information but not as a prediction of reality.” This view is in accordance with the concept of a throw-away model.

### **Facilitation**

Good facilitation helps ensure stakeholders engage meaningfully with each other and the model does not become overly complex. In addition, the facilitator has an important role in encouraging participants to challenge conventional wisdom. Facilitation does not stop at the end of a modeling workshop. The most significant impacts have come where the facilitator has remained involved over several years and so has been able to update and adapt the model to address emerging problems. Participatory modeling can form a key input during processes of change, for identifying opportunities and constraints (Cowling et al. 2008).

### **Dealing with time constraints**

It was often challenging to realize all mentioned objectives of participatory modeling given stakeholders’ time constraints. If the modeling goes too slowly, you risk not getting to the bottom of the problem and limiting the outcomes to knowledge exchange. If the modeling goes too quickly, you risk losing comprehension by some stakeholders who consequently might feel little ownership of the model, which often results in little uptake of its outcomes. Ideally, as explained by Beall (2007), the modeling is realized on different places along the “hands on” continuum, from an active use of the modeling software by the participants to more technical model “fixing” by the facilitator, who in

the absence of the participants, translates stakeholder views into the model. It is therefore important to have a series of meetings, with the facilitator advancing the model in between them. In case of the TNS, for example, the governance issue came up only in the third meeting.

### **Keeping the model as simple as possible**

Building participatory models reveals a problem common to modeling generally – that of balancing simplicity against accuracy. Scientists feel a need to develop a highly complex model to capture the immense complexity of social-ecological systems because they are often uncomfortable with uncertainty (Knight et al. 2006). There is a perception that the greater the detail, the greater the value in exploring scenarios. In our case, the highest overall scores were given to models with the lowest number of variables, so complexity does not necessarily lead to a more useful model. One participant gave low scores to the degree of reality in the model and its outputs, commenting “due to the complexity and the frequent lack of data of sufficient quality, the model is merely good to give very rough indications; the big trends are probably right though”. This is exactly the aim of the throw-away model – to gain understanding of general system functioning. It is not suitable for precise predictions. It is also unrealistic to expect stakeholders to commit long periods of time to modeling. Some of the more successful participatory modeling exercises, the exercise in Ghana for example, were completed within 3-5 days. A balance needs to be found between those improvements to the model that are essential for the exploration of scenarios and those that yield only marginal improvements in outputs.

### **CONCLUSION**

Process came out as the most valued aspect of participatory modeling, which suggests that the approach of the throw-away model was valued by the participants. These findings concur with Vennix (1996: 98) who reports “...most insights are gained during rather than after the model building process.” Specifically, the modeling process was valued in its ability to stimulate information exchange and strategy discussions.

In most case studies, a wide range of disciplines were involved from the outset, and disciplinary

issues were not the biggest challenge. Challenges related more to reconciling the diverse views of the stakeholders involved (scientists, staff of local and international NGOs, stakeholders with connections to the policy process) than to the disciplinary mix. The evaluation results demonstrate that engaging stakeholders is not a simple process because different stakeholders sometimes have wide-ranging perspectives on what is valuable in the participatory process. Scientists typically were more critical of the modeling, while stakeholders with policy connections valued the model's role in informing decision makers. King and Kraemer (1993) discuss the division between scientists and policy makers and the low uptake by policy makers of 'scientific' modeling results (referring to predictive models of physical processes of the environment). Participatory modeling is apparently better able to reach policy audiences, though it may lack some credibility with scientists.

It takes careful judgment to determine when participatory modeling can be usefully applied. Strong facilitation of the modeling process is essential to keep the focus on "models as stories" rather than models becoming the end in themselves. Participatory modeling is not a panacea for solving the difficult problems of reconciling conservation and development at landscape scales. However, with skilled facilitation, models can be powerful tools to help stakeholders better understand the dynamics of landscapes and improve their decision making and investments in natural resource management. Therefore, they certainly help in taking a landscape approach.

Responses to this article can be read online at:  
<http://www.ecologyandsociety.org/vol15/iss2/art13/responses/>

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### LITERATURE CITED

- Akkermans, H. A., and J. A. M. Vennix.** 1997. Clients' opinions on group model-building: an exploratory study. *System Dynamics Review* 13:3–31.
- Babbie, E.** 1989. *The practice of social research*. Fifth edition. Wadsworth Publishing Company, Belmont, California, USA.
- Beall, A. M.** 2007. *Participatory environmental modeling and system dynamics: integrating natural resource science and social concerns*. Dissertation. Washington State University, Washington, USA.
- Bennett, E. M., S. R. Carpenter, G. D. Peterson, G. S. Cumming, M. Zurek, and P. Pingali.** 2003. Why global scenarios need ecology. *Frontiers in Ecology and Environment* 1:322–329.
- Bousquet, F., J.-C. Castella, G. Trébuil, C. Barnaud, S. Boissau, and S. P. Kam.** 2007. Using multi-agent systems in a companion modeling approach for agroecosystem management in South-east Asia. *Outlook on Agriculture* 36(1):57–62.
- Bousquet, F., and C. Le Page.** 2004. Multi-agent simulations and ecosystem management: a review. *Ecological Modelling* 176:313–332.
- Castella, J.-C., S. P. Kam, D. D. Quang, P. H. Verburg, and C. T. Hoanh.** 2007. Combining top-down and bottom-up modelling approaches of land use/cover change to support public policies: application to sustainable management of natural resources in Northern Vietnam. *Land Use Policy* 24(3):531–545.
- Castella, J.-C., T. N. Trung, and S. Boissau.** 2005. Participatory simulation of land-use changes in the northern mountains of Vietnam: the combined use of an agent-based model, a role-playing game, and a Geographic Information System. *Ecology and Society* 10:27. [online] URL: <http://www.ecologyandsociety.org/vol10/iss1/art27/>.
- Costanza, R., and M. Ruth.** 1998. Using dynamic modeling to scope environmental problems and build consensus. *Environmental Management* 22:183–195.



- Cowling R. M., B. Egoh, A. T. Knight, P. O'Farrel, B. Reyers, M. Rouget, D. Roux, A. Welz, and A. Wilhelm-Rechman.** 2008. An operational model for mainstreaming ecosystem services for implementation. *Proceedings of the National Academy of Science* 105(28):9483–9488.
- García-Barrios, L. E., E. N. Speelman, and M. S. Pimm.** 2008. An educational simulation tool for negotiating sustainable natural resource management strategies among stakeholders with conflicting interests. *Ecological Modelling* 210:115–126.
- Garnett, S. T., J. Sayer, and J. du Toit.** 2007. Improving the effectiveness of interventions to balance conservation and development: a conceptual framework. *Ecology and Society* 12(1): 2. [online] URL: <http://www.ecologyandsociety.org/vol12/iss1/art2/>.
- Hisschemöller, M., R. S. J. Tol, and P. Vellinga.** 2001. The relevance of participatory approaches in integrated environmental assessment. *Integrated Assessment* 2:57–72.
- Hoffman, M. T., and R. F. Rohde.** 2007. From pastoralism to tourism: the historical impact of changing land use practices in Namaqualand. *Journal of Arid Environments* 70(4):641–658.
- James, I., M. T. Hoffman, R. M. Cowling, R. Roberts, B. M. Campbell, R. Boumans, and N. Allsopp.** 2005. *Valuing Namaqualand's natural resources: the costs and benefits of communal, commercial and conservation land use practices in Namaqualand incorporating ecological, economic and social values*. Leslie Hill Institute for Plant Conservation, University of Cape Town and Terrestrial Ecology Research Unit, Nelson Mandela Metropolitan University.
- Kassa, H., B. Campbell, M. Sandewall, M. Kebede, Y. Tesfaye, G. Dessie, A. Seifu, M. Tadesse, E. Garedew, and K. Sandewall.** 2009. Building future scenarios and uncovering persisting challenges of participatory forest management in Chilimo Forest, Central Ethiopia. *Journal of Environmental Management* 90:1004–1013.
- King, J. L., and K. L. Kraemer.** 1993. Models, facts, and the policy process: the political ecology of estimated truth. Pages 353–360 in M. F. Goodchild, B. O. Parks, and L. T. Steyaert, editors. *Environmental Modeling with GIS*. Oxford University Press, New York, USA.
- Knight, A. T., A. Driver, R. M. Cowling, K. Maze, A. F. Boshoff, M. A. Botha, J. G. Castley, P. G. Desmet, P. S. Goodman, A. T. Lombard, K. MacKinnon, S. M. Pierce, M. Rouget, R. Sims-Castley, W. I. Stewart, and A. von Hase.** 2006. Designing systematic conservation assessments that promote effective implementation: best practice from South Africa. *Conservation Biology* 20(3):739–750.
- Lynam, T., F. Bousquet, C. Le Page, P. d'Aquino, O. Barreteau, F. Chinembiri, and B. Mombeshora.** 2002. Adapting science to adaptive managers: spidergrams, belief models, and multi-agent systems modeling. *Conservation Ecology* 5:24.
- Lynam, T., W. de Jong, D. Sheil, T. Kusumanto, and K. Evans.** 2007. A review of tools for incorporating community knowledge, preferences, and values into decision making in natural resources management. *Ecology and Society* 12:5. [online] URL: <http://www.ecologyandsociety.org/vol12/iss1/art5/>.
- McShane, T. O., and M. P. Wells.** 2003. *Getting biodiversity projects to work: towards more effective conservation and development*. Columbia University Press, New York, New York, USA.
- Mittermeier, R. A., M. Hoffmann, J. D. Pilgrim, T. B. Brooks, C. G. Mittermeier, J. L. Lamoreux, and G. da Fonseca,** editors. 2004. *Hotspots revisited: Earth's biologically richest and most endangered ecoregions*. Cemex, Mexico City, Mexico.
- Otto, P., and J. Struben.** 2004. Gloucester fishery: insights from a group modeling intervention. *System Dynamics Review* 20:287–312.
- Pala, Ö., and J. A. M. Vennix.** 2005. Effect of system dynamics on systems thinking inventory task performance. *System Dynamics Review* 21:147–172.
- Peterson, G. D., G. Cumming, and S. R. Carpenter.** 2003. Scenario planning: a tool for conservation in an uncertain world. *Conservation Biology* 17:358–366.

**Rouwette, E. A. J. A., J. A. M. Vennix, and T. van Mullekom.** 2002. Group model building effectiveness: a review of assessment studies. *System Dynamics Review* 18:5–45.

**Sandker, M., B. M. Campbell, Z. Nzooh, T. Sunderland, V. Amougou, L. Defo, and J. Sayer.** 2009. Exploring the effectiveness of integrated conservation and development interventions in a Central African forest landscape. *Biodiversity and Conservation* 18:2875–2892.

**Sandker, M., B. Campbell, and A. Suwarno.** 2008. What are participatory scoping models? *Ecology and Society* 13(1):r2. [online] URL: <http://www.ecologyandsociety.org/vol13/iss1/resp2/>.

**Sandker, M., S. K. Nyame, J. Förster, N. Collier, G. Shepherd, D. Yeboah, D. Ezzine-de Blas, M. Machwitz, S. Vaatainen, E. Garedew, G. Etoga, C. Ehringhaus, J. Anati, O. D. K. Quarm, and B. M. Campbell.** 2010. REDD payments as incentive for reducing forest loss: a case from Ghana. *Conservation Letters* 3:114–121.

**Sandker, M., A. Suwarno, and B. M. Campbell.** 2007. Will forests remain in the face of oil palm expansion? Simulating change in Malinau, Indonesia. *Ecology and Society* 12(2):37. [online] URL: <http://www.ecologyandsociety.org/vol12/iss2/art37/>.

**Sayer, J., and B. Campbell.** 2004. *The science of sustainable development: local livelihoods and the global environment*. Cambridge University Press, Cambridge, UK.

**Sayer, J. A., and S. Maginnis,** editors. 2005. *Forests in landscapes. Ecosystem approaches to sustainability*. Earthscan, London, UK.

**Snabe, B., and A. Grossler.** 2006. System dynamics modelling for strategy implementation – case study and issues. *Systems Research and Behavioral Science* 23(4):467–481.

**Steenkamp Y., A. E. van Wyk, J. E. Victor, D. B. Hoare, A. P. Dold, R. M. Cowling, and G. F. Smith.** 2004. Maputaland-Pondoland-Albany Hotspot. Pages 218–229 in R. A. Mittermeier, M. Hoffmann, J. D. Pilgrim, T. B. Brooks, C. G. Mittermeier, J. L. Lamoreux, and G. da Fonseca, editors. 2004.

*Hotspots revisited: Earth's biologically richest and most endangered ecoregions*. Cemex, Mexico City.

**Sterman, J. D.** 1991. A skeptic's guide to computer models. Pages 209–229 in G. O. Barney, W. Kreutzer, and M. J. Garrett, editors. *Managing a nation: the microcomputer software catalog*. Westview Press, Boulder, Colorado, USA.

**Sterman, J. D.,** editor. 2000. *Business dynamics – systems thinking and modeling for a complex world*. Irwin/McGraw-Hill, Boston, Massachusetts, USA.

**Vanclay, J. K., R. Prabhu, and F. Sinclair.** 2006. *Realizing community futures: a practical guide to harnessing natural resources*. Earthscan, London, UK.

**Van den Belt, M.** 2004. *Mediated modelling: a systems dynamic approach to environmental consensus building*. Island Press, Washington, D. C., USA.

**Van den Belt, M., L. Deutsch, and A. Jansson.** 1998. A consensus-based simulation model for management in the Patagonia coastal zone. *Ecological Modelling* 110:79–103.

**Vennix, J. A. M.** 1996. *Group model building: facilitating team learning using system dynamics*. John Wiley & Sons Ltd, Chichester, UK.

**Vennix, J. A. M., H. A. Akkermans, and E. A. J. A. Rouwette.** 1996. Group model-building to facilitate organizational change: an exploratory study. *System Dynamics Review* 12:39–58.

**APPENDIX 1.** The questions for each of the four characteristics describing participatory modeling with mean scores by case study.

	Value of participatory modeling in terms of:	Malinau	Wasa Amenfi	TNS†	Chilimo	Subtropical Thicket Biome	Namaqualand	Mean scores
1. Model building process	1. understanding/ conceptualization of system	4	4	4	5	3	4	<b>4.3</b>
	2. getting a common understanding of problems at hand	4	4	4	4	1	4	<b>3.7</b>
	3. building consensus on way forward	4	4	4	5	1	4	<b>3.6</b>
	4. creating awareness of different viewpoints	4	4	4	5	2	3	<b>3.9</b>
	5. enhancing out-of-discipline thinking	4	4	4	5	4	5	<b>4.2</b>
	6. focusing on most relevant problems	4	3	3	4	2	4	<b>3.5</b>
	<b>Mean score "process"</b>	<b>4.1</b>	<b>3.8</b>	<b>4.1</b>	<b>4.4</b>	<b>2.1</b>	<b>3.6</b>	<b>3.9</b>
2. Model structure	1. the user-friendliness of the Stella software	4	4	3	4	4	4	<b>3.7</b>
	2. the ease to run or alter the model	3	4	3	3	2	2	<b>3.0</b>
	3. the sense of ownership of model	4	4	4	4	4	3	<b>3.6</b>
	4. the degree to which the model approaches reality	3	3	4	4	2	4	<b>3.3</b>
	5. the completeness of the model	4	3	4	3	2	4	<b>3.6</b>

(con'd)

	6. capturing complexity	4	3	4	4	3	3	<b>3.6</b>
	<b>Mean score "structure"</b>	<b>3.4</b>	<b>3.6</b>	<b>3.7</b>	<b>3.5</b>	<b>2.6</b>	<b>3.2</b>	<b>3.5</b>
3. Model outputs	1. the degree to which model outputs are believable	3	3	4	4	3	4	<b>3.3</b>
	2. identifying best options for impact (optimization)	5	3	4	4	1	4	<b>3.5</b>
	3. formulation of strategy	4	4	3	4	2	3	<b>3.3</b>
	4. supporting decision making	4	3	3	4	1	3	<b>3.0</b>
	5. supporting policy formulation	4	4	4	5	2	3	<b>4.0</b>
	6. communicating strategy	4	4	3	4	1	3	<b>3.4</b>
	<b>Mean score "outputs"</b>	<b>3.9</b>	<b>3.6</b>	<b>3.7</b>	<b>4.1</b>	<b>1.5</b>	<b>3.0</b>	<b>3.5</b>
4. Impact after model-ing	1. improving performance of interventions	4	3	3	3	2	2	<b>2.9</b>
	2. actual changing the focus of interventions	4	4	3	4	1	2	<b>3.1</b>
	3. actual changing the strategy	4	3	2	4	1	3	<b>2.9</b>
	4. actual use in policy formulation	4	4	1	4	2	2	<b>2.6</b>
	5. actual use to communicate strategy	4	3	3	4	1	2	<b>3.2</b>
	<b>Mean score "impact"</b>	<b>4.1</b>	<b>3.3</b>	<b>2.9</b>	<b>3.8</b>	<b>1.3</b>	<b>2.1</b>	<b>3.1</b>

† Tri National de la Sangha (TNS), which stretches between Cameroon, the Central African Republic, and the Republic of Congo





## Chapter 10

### Trade-offs between Biodiversity Conservation and Economic Development in five Tropical Forest Landscapes



# Trade-offs between Biodiversity Conservation and Economic Development in five Tropical Forest Landscapes

Marieke Sandker<sup>1</sup>, Manuel Ruiz-Pérez<sup>1</sup> and Bruce M. Campbell<sup>2</sup>

## ABSTRACT

This study explores how conservation and development are inter-linked and quantifies their reciprocal trade-offs. It identifies interventions which hold a promise to improve both conservation and development outcomes. The study finds that development trajectories can either be at the cost of conservation or can benefit conservation, but in all cases sustained poverty negatively affects conservation in the long term. All Reducing Emissions from Deforestation and forest Degradation (REDD) implementation scenarios come at a cost of development and the financial benefits of payments for environmental services (PES) are not sufficient to make up for lost opportunities to earn cash. However, environmental service benefits and subsistence income enhance the attractiveness of conservation scenarios to local people and PES may provide the extra cash incentive to tip the balance for such a scenario. The paper also stresses the importance of external factors (like industrial investments and the development of the national economy) in largely determining landscape scale outcomes, and suggests a negotiating and visioning role for conservation agencies.

**Keywords:** deforestation; ICDP; participatory modelling; PES; poverty; protected areas; REDD.

## INTRODUCTION

Conservation and development are strongly related in tropical forest landscapes. For some decades now, integrated conservation and development projects (ICDPs) have been attempting to improve conservation and development outcomes simultaneously but worldwide they have been criticised for lack of progress (Christensen 2004; Kremen *et al.* 1994; Wells *et al.* 1999). To identify interventions contributing to this dual objective, one needs to have a good understanding of how conservation and development are related. If trade-offs occur between conservation and development outcomes we need to quantify them to see whether they can be overcome. Perhaps the best known representation of the large-scale and long-term relation between conservation and development is given by the environmental Kuznets curve. This relation assumes an inverse U-curve, where moving out of absolute poverty first comes with environmental degradation and only after a substantial increase in wealth is this

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degradation halted, and in some cases, turned into environmental restoration (e.g. reforestation). This environmental degradation response to increased wealth would imply ICDPs in developing country situations are largely attempting to do the impossible. However, the large scale in the Kuznets curve refers to a national level response, while ICDPs work at landscape levels. While it is uncertain whether this relationship holds for many developing nations, it is even more of an unknown whether it would hold at a landscape scale.

This study visualizes trajectories of conservation and development outcomes under different scenarios for five forest landscapes. For each of the landscapes a business as usual scenario is defined as the most likely scenario to happen in absence of new conservation or integrated conservation and development approaches. For each landscape, we also included an alternative scenario based on the introduction of a new strategy or approach to conservation (and development). For the Indonesian and West-African landscape, Reducing Emissions from Deforestation and forest Degradation (REDD) implementation strategies are explored, while for the Central African landscapes we explore better governance of timber and wildlife royalties, and forest certification. Simulation results for conservation and development indicators after 20 years from now are compared for each of the scenarios. We attempt to assess whether moving out of poverty goes at the cost of the environment to assess the chances of success for ICDPs. We quantify trade-offs occurring between conservation and development outcomes in forest landscapes and we also explore whether payments for environmental services (PES) can overcome these trade-offs. Finally, we try to identify interventions which hold the potential to improve both conservation and development outcomes.

## **METHODS**

### **The study locations**

We compared the current conservation and development indicator scores in five tropical forest landscapes and more importantly, we compared the likely future trajectories for conservation and development outcomes under a range of selected scenarios. The five landscapes (Table 1) are located in South-East Asia, and Central and West Africa: Malinau district, East-Kalimantan, Central Indonesia; Kaimana district, Papua, East Indonesia; the SE Technical Operational Unit, SE Cameroon; the Dzanga-Sangha landscape, SW Central African Republic (CAR), and Wasa Amenfi district, SW Ghana.

The common criteria for the selected landscapes are that they all have forests with great biodiversity, of which part is protected in national parks or forest reserves. In all of them projects or the government are attempting to improve conservation and development and all have some form of conflict between conservation and development interests.

**Table 1.** Characteristics of the five landscapes studied

	Kalimantan	Papua	Cameroon	CAR	Ghana
Total population	65,200	42,600	140,646	7,346	161,825
Total area (km <sup>2</sup> )	42,621	17,298	36,066	4,672	3,465
People/km <sup>2</sup>	1.5	2.5	3.9	1.6	46.7
Forest cover	99	95	97	99	25
Primary forest cover (including logged-over primary forest)	96	95	90	99	16
Per capita cash income (US\$)	250	205	270	215	625
Purchasing Power Parity* (international \$) per capita	690	565	500	395	1145
Data source	<a href="#">Chapter 5</a>	<a href="#">Chapter 4</a>	<a href="#">Chapter 6</a>	<a href="#">Chapter 8</a>	<a href="#">Chapter 7</a>

\*To convert cash income to PPP we used the 2007 conversion factor (WB 2009) for South-Asia (Kalimantan and Papua) and Sub-Saharan Africa (Cameroon, CAR and Ghana).

## Indicators of Conservation and Development

To quantify trade-offs between conservation and development we selected indicators of both. Forest cover (indicating quantity of forest) and primary forest cover (indicating quality of forest) percentages are used to approximate conservation outcomes. Average per capita cash income is used to indicate economic development outcomes, which is converted to purchasing power parity (PPP) in order to compare among the different geographical locations. Some conservationists see wildlife hunting for food as a more immediate threat to biodiversity conservation rather than deforestation (Wilkie *et al.* 2005). We suggest this is largely so in Central Africa but doesn't hold for countries like Indonesia where forests are replaced at large scales by other land-uses. For the Central African landscapes we included relative changes in forest elephant (*Loxodonta cyclotis*) and duiker (*Cephalophus spp*) populations to approximate conservation outcomes. No data on wildlife populations were available to us for any of the other landscapes.

## Scenario exploration

The scenarios are defined during participatory modelling sessions with local actors working in the landscapes and at the national or regional level. The modelling platform used was the system dynamics software STELLA, and with the participants a model was built of the landscape including all features related to conservation and development outcomes and their interactions. For more information on the model building process, the model structure and data input we would like to refer to the chapters mentioned in Table 1. For each location, three scenarios were explored: 1. business as usual (BAU), 2. an alternative scenario, 3. an alternative scenario including payments for environmental services to be received by the local population (Table 2). The business as usual scenarios selected are not necessarily a projection of historical trends but correspond with the most likely scenario to happen

according to participants considering changes seen and anticipated for the region. The alternative scenarios are scenarios with new approaches to conservation and/or development. In the Indonesian and Ghanaian landscapes, we explored the implementation of Reducing Emissions from Deforestation and forest Degradation (REDD) strategies (Table 2). In the Central African landscapes, deforestation is not a real issue now and isn't projected to be a major issue under the BAU scenarios, which is why we selected better governance ([Chapter 6](#)) and forest certification ([Chapter 8](#)) as alternative scenarios. When including PES under the alternative scenarios we assume local people to receive 20% of REDD payments, while under the alternative scenario without PES we assume the entire REDD payment to be consumed at central and district government level. We included a wildlife payment for the Central African landscapes following a REDD-design: wildlife population baselines are constructed for elephant and duiker populations based on a scenario without interventions (obtained with the model). If fewer animals are poached than under the baseline the difference in population size is paid for using the Cameroonian safari hunting fees per animal (Table 2). Some assumptions in the original models have been altered to have more coherence when comparing the different geographical locations. E.g. we altered the duiker density in CAR to get the density assessed with a similar method as in Cameroon and regarding REDD the carbon price paid on the international market is set equal for all locations (Table 2).

**Table 2.** Scenario description with main assumptions for the different landscapes

Landscape	Scenario	Assumptions
Kalimantan	BAU	500,000ha of forest are converted to plantation over 20 years Annual timber and plantation salaries are 10 and 12 mln Rp respectively Oil palm requires 0.2 worker/ha, for more assumptions see <a href="#">Chapter 5</a>
	Alternative scenario	REDD: A REDD strategy will be implemented resulting in plantation development to be restricted to 100,000ha over 20 years; local people don't receive a share of the REDD payment
	Alternative scenario with PES	BAU scenario is used to calculate total amount of carbon prevented from being emitted; CO <sub>2</sub> price= 10US\$; the scenario assumes a 20-year REDD contract with an equal annual pay; local people receive 20% of the REDD payment
Papua	BAU	600,000ha of forest are converted to plantation over 20 years Annual timber and plantation salaries are 10 and 12 mln Rp respectively Oil palm requires 0.2 worker/ha, for more assumptions see <a href="#">Chapter 4</a>
	Alternative scenario	A REDD strategy will be implemented resulting in plantation development to be restricted to 108,000ha over 20 years; local people don't receive a share of the REDD payment
	Alternative scenario with PES	BAU scenario is used to calculate total amount of carbon prevented from being emitted; CO <sub>2</sub> price= 10US\$; REDD contract lasts 20 years, and an equal amount is paid each year.
Cameroon	BAU	Prolongation of current trend: bad governance and high levels of poaching, ICDP invests in anti-poaching only, see <a href="#">Chapter 6</a>

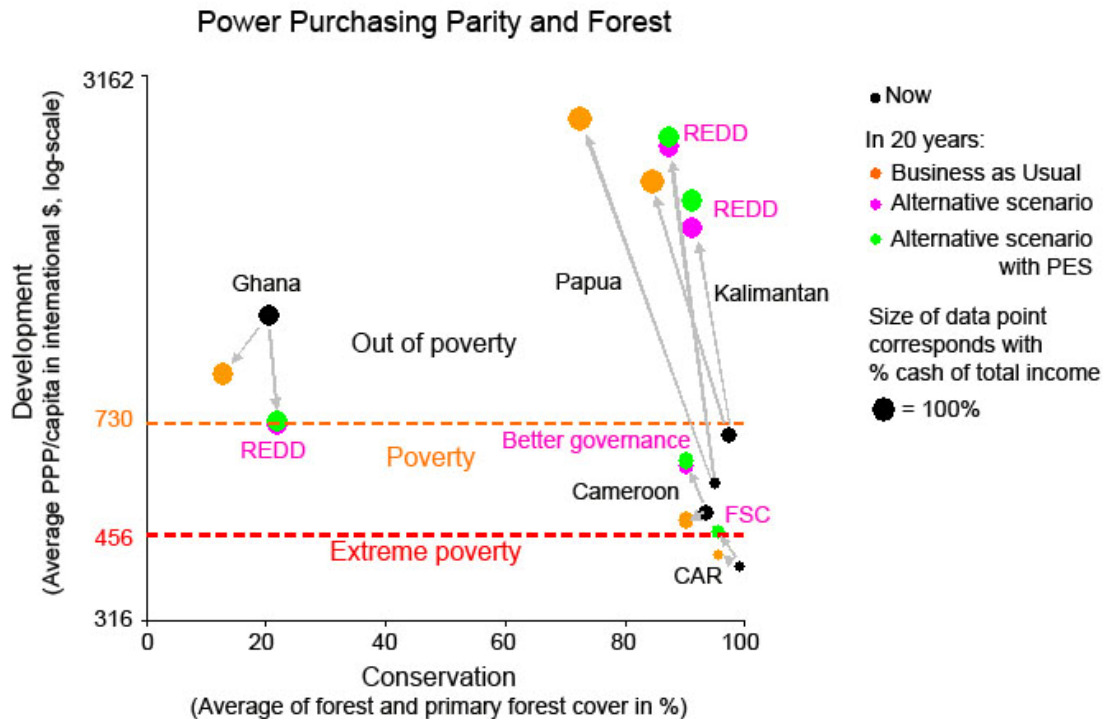
	Alternative scenario	Better governance: ICDP invests in improvement of redistributing and managing timber and wildlife royalties, see <a href="#">Chapter 6</a>
	Alternative scenario with PES	BAU scenario without ICDP is used to calculate total number of elephants and duikers prevented from being lost after 20 years; prices per animal are derived from safari hunting fees set by the Cameroonian government, being US\$185/elephant and US\$37/duiker; Duiker price is approximated since it concerns various species; PES contract lasts 20 years, and an equal amount is paid each year, all goes to local people in the form of an anti-poaching salary.
CAR	BAU	Prolongation of current trend: Re-opening of sawmill in the landscape run by a company showing low social responsibility and no long-term management plan, see <a href="#">Chapter 8</a> . We use minimum duiker density estimations by Noss (1998), and maximum reproduction rate approximation.
	Alternative scenario	FSC: re-opening of the (currently closed) sawmill by a company obtaining Forest Stewardship Council (FSC) certification, showing high social responsibility, see <a href="#">Chapter 8</a>
	Alternative scenario with PES	Worst case BAU scenario (complete extinction elephant and duiker) is used to calculate total number of elephants and duikers prevented from being lost after 20 years; prices per animal are derived from safari hunting fees set by the Cameroonian government, being US\$185/elephant and US\$37/duiker; Duiker price is approximated since it concerns various species; PES contract lasts 20 years, and an equal amount is paid each year, all goes to local people in the form of an anti-poaching salary.
Ghana	BAU	Prolongation of current trend: Cocoa expansion at the cost of forest, see <a href="#">Chapter 7</a>
	Alternative scenario	A REDD strategy will be implemented resulting in no more forest to be converted to cocoa.
	Alternative scenario with PES	BAU scenario is used to calculate total amount of carbon prevented from being emitted; CO <sub>2</sub> price= 10US\$; REDD contract lasts 20 years, and an equal amount is paid each year, all goes to local people.
All	All	We used the same PPP factor for the 20 year income projection though it is likely this will change, notably with fast development in South-Asia PPP might decrease.

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## RESULTS

When comparing the data point sizes in Figure 1, one notices that moving out of poverty coincides with moving into a cash economy. The Ghanaian landscape is already a cash economy now with around 90% of income being cash.

For the Ghanaian landscape, future PPP is unlikely to decrease as shown in Figure 1. Rather these outcomes indicate the landscape's future economy will depend less on natural resources while off-farm employment and urbanization will increase. In the landscape in Kalimantan people are already almost out of poverty. Their income situation improved greatly over the past decade when decentralization resulted in an enormous cash inflow into the sparsely populated district from mining and logging royalties resulting in a 'boom' effect on the previously small capital town (Moeliono *et al.* 2008).



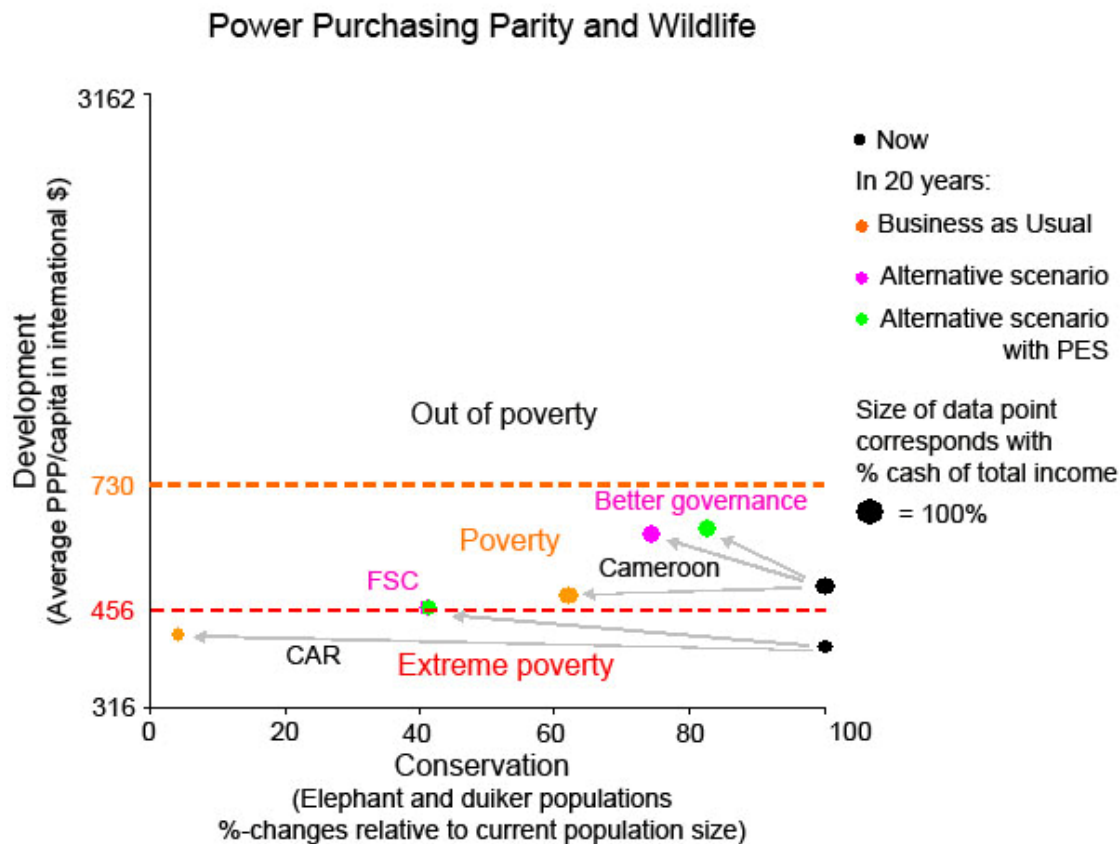
**Figure 1.** Changes in (primary) forest cover and purchasing power parity (PPP) under different scenarios (described in Table 2)

Most marked changes are expected in Papua moving out of poverty to become the wealthiest landscape in 20 years under business as usual with a 99% cash economy. However, these average numbers hide vast income disparities which are likely to occur under this industrial plantation scenario, and loss of many environmental benefits. The larger suitability for plantations in Kaimana-Papua compared to Malinau-Kalimantan explains why economic development is projected to be vaster under business as usual.

Figure 1 demonstrates that trade-offs occur between conservation and development; improved conservation outcomes under the alternative scenarios come at a cost for local incomes which are not as high as under business as usual (with the exception of the Central African landscapes). In none of the simulations, PES were able to overcome these trade-offs in cash terms. However, the development outcomes in Figure 1 hide the large range of negative consequences of large scale plantation investments, like great income disparity, pollution and perhaps even conflict ([Chapter 4](#) and [5](#)). Preoccupation for these negative impacts, plus the fear of a 'boom and bust' scenario, where the natural capital is consumed providing a one-time, unsustainable money inflow, might result in local people being more attracted to the alternative scenario. It is in such a situation, where subsistence income and (long-term) benefits from environmental services for local people makes the scenario more attractive, that PES could tip the balance and incentivize to opt for a scenario they already like.



Considering (primary) forest cover as indicator for conservation gives similar outcomes under the business as usual and alternative scenarios for Cameroon and CAR, where conservation outcomes are better approximated with wildlife indicators (Figure 2).



**Figure 2.** Changes in wildlife populations and purchasing power parity (PPP) under different scenario

Figure 1 and 2 show that an improved income situation either coincides with best conservation outcomes (see Cameroon and CAR), or coincides with worst conservation outcomes (see Papua and Kalimantan). However, Figure 2 suggests that a deteriorating income situation or a maintained situation of extreme poverty comes with negative long-term impacts on conservation outcomes. Business as usual in Indonesia means great economic development going at the cost of natural resources. Business as usual in Central Africa means some wildlife species will go nearly extinct, while people remain (extremely) poor. Though the Central African scenarios may seem the most pessimistic, at the same time they hold the largest potential for synergies between conservation and development through efforts like improved governance or timber certification. However, especially the governance issue is difficult to resolve and even these scenarios giving best outcomes result in great wildlife losses. A potentially more notable difference in development and conservation outcomes would be obtained if the national

economy was boosted. Chapter 8 discusses such a development and finds that if this would result in a 2% outmigration rate, with people moving to cities for salaried jobs, under the FSC scenario the elephant population could be maintained at its current size.

The wildlife PES scheme for the Central African landscapes results in a per capita payment which changes little for people's income situation, yet poor people might be incentivized with a small amount of extra cash, especially since these scenarios already come with (cash) benefits for local people.

## **DISCUSSION**

### **Causes of deforestation**

With the exception of Ghana, small scale agriculture is not the main driver of deforestation and forest degradation in the studied landscapes. Rather this is driven by commercial plantation and logging companies. These findings concur with those of Ickowitz (2006).

### **Income and deforestation**

Investments in the landscape coinciding with forest deterioration and/or loss influence local people's income either positively through inflow of cash in royalties and salaried jobs, negatively through increased pollution and depletion of wildlife and forest products, or, as in most cases, in ambiguous ways. These findings from our landscape studies give similar results as studies on this relation at the national scale. Several studies (Kaimowitz & Angelsen 1998; Thomas *et al* 2000; Koop & Tole 1999) have tested the hypothesis of a Kuznets curve relation between poverty alleviation and deforestation. Though this correlation is found to be positive in some cases (Kaimowitz & Angelsen 1998, Thomas *et al.* 2000), in all cases it is statistically insignificant providing weak empirical evidence for their causal relationship at the national level. There seems to be no one-size-fits-all explanation for conservation and development interactions and responses can be ambiguous. Wunder (2001) explains this ambiguity stating poverty is extremely complex and multidimensional and in many cases its links with deforestation are indirect.

### **Bushmeat consumption and income**

The relation between bushmeat consumption and wealth doesn't seem to be explained by the Kuznets-curve either. Studies among poor populations found in some cases that an increase in wealth was negatively related with bushmeat consumption (Albrechtsen *et al.* 2006), in others it was positively related (Wilkie *et al.* 2005), and Apaza *et al.* (2002) found earnings bore no association with wildlife consumption. Godoy *et al.* (2006) explain these different responses by categorizing bushmeat in the different locations of these studies as an inferior, normal or luxury good. In the Central African

landscapes bushmeat is preferred over other meat sources (Wilkie & Carpenter 1999) so one would expect an increase in income to result in increased bushmeat consumption, resulting in worst conservation of wildlife populations. However, we found the contrary in our explored scenarios; in the Cameroonian and CAR landscape, the scenarios resulting in highest income give at the same time best conservation outcomes for wildlife populations. This is explained by the assumption in the alternative scenarios that local people will protect their natural resources if these provide them with extra income. Local people receive benefits related to their surrounding natural resources through improved governance of wildlife and timber royalties (Cameroon) or through the implementation of FSC certification standards (CAR). A *status quo* of the current situation, i.e. people remaining poor, is unlikely to maintain viable wildlife populations since actual hunting levels are thought to be unsustainable (Noss 1998).

### **National economic development and conservation**

In Cameroon, unless an enormous long-term flow of funds for conservation could be assured, conservation outcomes would not be sustainable if the governance situation in the region were not improved ([Chapter 6](#)). Macroeconomic development of the national economy strongly influences conservation and rural development. In some cases, external factors even determine conservation outcomes, rendering local management institutions obsolete (Fisher *et al.* 2010). Increased opportunities outside the forest and urbanization trends can reduce the pressure on forest resources. For example, all scenarios for the CAR landscape result in substantial wildlife losses ([Chapter 8](#)), which is explained by the lack of alternative income opportunities for the local population other than bushmeat hunting. The stagnant CAR economy, together with a turbulent socio-political situation in the rest of the country, leads to a lack of income opportunities outside the forest. The result is low migration out of forest landscapes – currently only 38% of the CAR population is urban while in neighbouring country Cameroon it is 55% (UN 2006). In addition, the forest acts as a social safety net, thus bringing people into forested landscapes. According to Brandon (2001) 'getting the politics right' is the swiftest and most direct way to influence the links between poverty, land use and biodiversity loss. Culas (2007) and Heath and Binswanger (1996) confirm the important role of the overall policy framework. They mention environmental policies and institutions empowering local people exercise a much more critical impact on the sustainability of natural resource use than measures such as limiting economic development (because it is presumed to be destructive) or reducing population pressure in forested landscapes.

### **Payments for Environmental Services**

Tropical forest is often regarded as being invaluable for humanity or, when assessed in monetary terms, is highly valued, e.g. Costanza *et al.* (1997). Despite this high valuation, our findings concur with those of Karsenty

(2007) in that often conservation payments don't come close to real opportunity costs. PES are unlikely to reverse economical drivers of deforestation or degradation since these are very hard to out-compete with PES payments, as is shown by the scenario outcomes for the Ghanaian landscape. Furthermore, in a situation with high opportunity costs, as Karsenty (2007) argues, 'low-cost conservation' is a potential threat to the development wishes of poor people. In its turn, according to our findings, a population remaining in a situation of poverty provides an unsustainable pressure on natural resources, so on the long term such 'low-cost conservation' could be counter-effective. Frost *et al.* (2007) claim wide ranging investments and large infusions of capital are needed to significantly reduce poverty, and that 'without significant external changes, not much can be done to improve on what local people are already doing for themselves'. Some PES 'hand-outs' for conservation will thus not alleviate poverty, and a *status quo* in development will not reduce pressure on natural resources.

Our results suggest PES will only be effective if they reinforce intrinsic motivations. This way they can enhance the attractiveness of an already much appreciated scenario by local people, where local people themselves value the ecological services and prefer to preserve these. For example, in Malinau district, Kalimantan, local people would settle with much less than the opportunity costs for preserving their community forest (Wunder *et al.* 2008).

### **Decision making processes**

Unfortunately, decisions are often not made on the basis of best outcomes for local people, even when decision-making power has been decentralised. A very obvious example occurs in the Cameroonian landscape where local leaders show little concern towards improving the situation for the poorest people in their administrative unit. The previous mayor in the landscape siphoned off most of the timber royalties destined to finance development projects. Likewise, the decision whether to attract oil palm investments or apply a REDD strategy in the Indonesian landscapes will probably be determined by the best deal for the district government (and its officials) rather than concerns about outcomes for local people. In such a situation there is a risk that the earlier mentioned 'low-cost conservation' provides local leaders with cash making them opt for a conservation scenario which could deprive local people from ameliorating their income situation. On the other side, it could also make local leaders opt for a conservation scenario which 'protects' local people from negative affects associated with the BAU scenario like large scale pollution and forest loss from oil palm plantations. Conservationists should therefore assess different scenarios with their trade-offs to assure they don't provoke an unethical situation where the poor are disadvantaged.

## CONCLUSION

In an attempt to understand the relation between conservation and development, we found that an increase in the well-being of local people in the landscape can either go at the cost of natural resources or be coherent with conservation. However, in all cases, a population remaining in poverty, impacts conservation outcomes negatively in the long term. This suggests lifting people out of poverty ultimately changes unsustainable pressure on natural resources in the long term though it depends on the development pathway chosen whether this pressure is reduced or increased. The choice of pathway can be influenced by PES schemes. Yet, the potential of PES is limited and it is unlikely to lift people out of poverty. It can only incentivize less environmentally destructive options if these come along with substantial non monetary benefits for local people.

The business as usual scenarios for the five landscapes all give worst outcomes for conservation and in some cases for development as well. This urges for a change in current conservation approaches and for each landscape, possible conservation and development pathways should be explored. In landscapes like the Ghanaian, where no conservation alternative is likely to compete with economic drivers, we should accept that a REDD scenario doesn't stand a chance and invest for example in enrichment of the plantation with timber species. In landscapes like the Indonesian one, where forests are being lost at a fast rate and large scale, yet locally there exists interest for alternative options, REDD negotiations should be given an impulse to reach a fast implementation of such strategies. As the CAR landscape shows us, when defining a conservation and development strategy, we have to take into consideration the major impacts of external factors like investments in the local economy and development of the national economy. This means in some cases, conservation and development organizations working on the local scale can have more impact by taking up a negotiating role, influencing policy formulation and local government decisions. Therefore, in landscapes like the Central African examples, conservationists might find themselves charged with tasks like advocating better governance and supporting the government in the negotiation process so they will attract logging companies with a desire to get certified. These tasks might seem far removed from wildlife conservation but in reality they hold a major impact on conservation.

Culas (2007) suggests to effectively reduce pressure on natural forest, environmental policies and institutions should be improved rather than limiting economic or population growth. Our findings concur with this, since limiting economic growth comes with unsustainable pressures on natural resources. We suggest the exploration of conservation and development scenarios to test whether an investment in a conservation strategy means throwing away money in a lost cause, or whether such an investment can guide the conservation-development pathway in a desired direction.

## REFERENCES

- Albrechtsen, L., J. E. Fa, B. Barry, and D. W. MacDonald. 2006. Contrasts in availability and consumption of animal protein in Bioko Island, West Africa: the role of bushmeat. *Environmental Conservation* **32**:340-348
- Apaza, L., D. Wilkie, E. Byron, T. Huanca, W. Leonard, E. Perez, V. Reyes-Garcia, V. Vadez, and R. Godoy. 2002. Meat prices influence the consumption of wildlife by the Tsimane' Amerindians of Bolivia. *Oryx* **36**:1-7
- Brandon, K. 2001. *Moving beyond Integrated Conservation and Development Projects (ICDPs) to achieve biodiversity conservation* (Chapter 22). Pages 417-432 in D. R. Lee, and C. B. Barrett, editors. Trade-offs or synergies? CAB International.
- Costanza, R., R. d'Arge, R. d. Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, and M. v. d. Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* **387**:253-260
- Culas, R. J. 2007. Deforestation and the environmental Kuznets curve: An institutional perspective. *Ecological Economics* **61**:429-437
- Christensen, J. 2004. Win-Win Illusions. Over the past two decades, efforts to heal the rift between poor people and protected areas have foundered. So what next? *Conservation in Practice* **5**:12-19
- Fisher, B., K. Kulindwa, I. Mwanyoka, R. K. Turner, and N. D. Burgess. 2010. Common pool resource management and PES: Lessons and constraints for water PES in Tanzania. *Ecological Economics* **69**:1253-1261
- Frost, P., B. Campbell, M. Luckert, M. Mutamba, A. Mandondo, and W. Kozanayi. 2007. In Search of Improved Rural Livelihoods in Semi-Arid Regions through Local Management of Natural Resources: Lessons from Case Studies in Zimbabwe. *World Development* **35**:1961-1974
- Godoy, R., D. S. Wilkie, V. Reyes-Garcia, W. R. Leonard, T. Huanca, T. McDade, V. Vadez, and S. Tanner. 2006. Human body-mass index (weight in kg/stature in m<sup>2</sup>) as a useful proxy to assess the relation between income and wildlife consumption in poor rural societies. *Biodiversity and Conservation* **15**:4495-4506
- Heath, J., and H. P. Binswanger. 1996. Natural Resource Degradation Effects of Poverty and Population Growth are Largely Policy Induced: The Case of Columbia. *Environment and Development Economics* **1**:65-84
- Ickowitz, A. 2006. Shifting Cultivation and Deforestation in Tropical Africa: Critical Reflections. *Development and Change* **37**:599-626
- Karsenty, A. 2007. Questioning rent for development swaps: new marketbased instruments for biodiversity acquisition and the land-use issue in tropical countries. *International Forestry Review* **9**:503-513
- Kremen, C., A. M. Merenlender, and D. D. Murphy. 1994. Ecological monitoring: a vital need for integrated conservation and development programs in the tropics. *Conservation Biology* **8**:388-397
- Moeliono, M., E. Wollenberg, and G. Limberg 2008. The Decentralization of Forest Governance: Politics, Economics and the Fight for Control of Forests in Indonesian Borneo. Earthscan Publications Ltd.

- Noss, A. J. 1998. The Impact of Cable Snare hunting on wildlife populations in the forest of the Central African Republic. *Conservation Biology* **12**:390-398
- UN. 2006. World Urbanization Prospects: The 2005 Revision. Database. United Nations, Department of Economic and Social Affairs, Population Division, New York, USA.
- WB. 2009. Gross national income per capita 2008, Atlas method and PPP.
- Wells, M., S. Guggenheim, A. Khan, W. Wardojo, and P. Jepson. 1999. *Investing in biodiversity: a review of Indonesia's integrated conservation and development projects*. The World Bank, Washington DC.
- Wilkie, D. S., and J. F. Carpenter. 1999. Bushmeat hunting in the Congo Basin: an assessment of impacts and options for mitigation. *Biodiversity and Conservation* **8**:927-955
- Wilkie, D. S., M. Starkey, K. Abernethy, E. N. Effa, P. Telfer, and R. Godoy. 2005. Role of Prices and Wealth in Consumer Demand for Bushmeat in Gabon, Central Africa. *Conservation Biology* **19**:268-274
- Wunder, S. 2001. Poverty Alleviation and Tropical Forests - What scope for synergies? *World Development* **29**:1817-1833
- Wunder, S., B. Campbell, P. G. H. Frost, J. A. Sayer, R. Iwan, and L. Wollenberg. 2008. When Donors Get Cold Feet: the Community Conservation Concession in Setulang (Kalimantan, Indonesia) that Never Happened. *Ecology and Society* **13**:12 URL [<http://www.ecologyandsociety.org/vol13/iss1/art12/>]