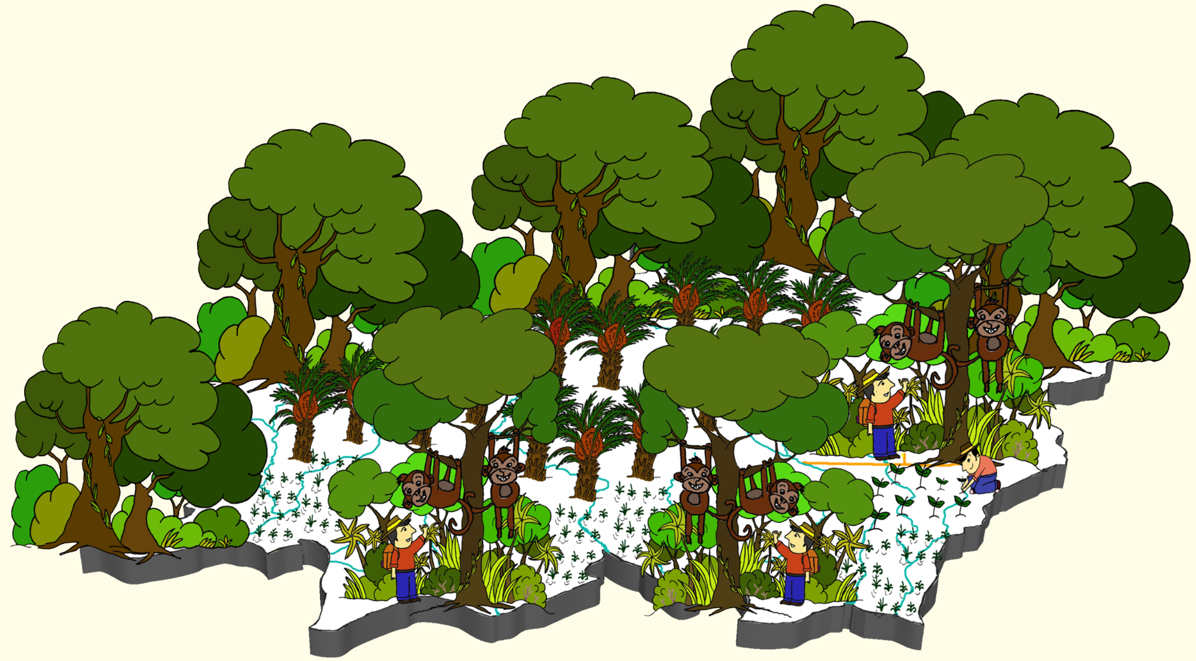
Optimising land use
in Central Kalimantan Province, Indonesia:
Modelling ecosystem benefits and land-use dynamics



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This research was conducted under the auspices of the Graduate School for Socio-Economic and Natural Sciences of the Environment (SENSE)

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Modelling ecosystem benefits and land use dynamics

Aritta Suwarno

Thesis
submitted in fulfilment of the requirement for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. Dr A.P.J. Mol,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Friday 2 September 2016
at 11 a.m. in the Aula

Aritta Suwarno
Optimising land use in Central Kalimantan Province, Indonesia: Modelling ecosystem benefits and land-use dynamics
170 pages

PhD thesis, Wageningen University, Wageningen, NL (2016)
With references, with summaries in English, Dutch and Bahasa Indonesia

ISBN 978-94-6257-873-9
DOI 10.18174/387054

To my dearest family and friends
especially for you Mom..

Acknowledgements

Doing my PhD research and writing my PhD thesis are like a journey to a place that I never visited before. This journey involves many people that encouraged and inspired me to start and support me to finish it. Accordingly, I'm really blessed to have Lars Hein, Rik Leemans (both the Environmental Systems Analysis Group (ESA)) and Hans-Peter Weikard (Environmental Economic and Natural Resource Management Group (ENR)) as supervisors. Lars first invited me to start this PhD journey in the carriage of the Ecospace project (coordinated by ESA).

Lars, thanks for inviting me to join this innovative project and for providing me with all your support to improve my research, my scientific papers and, finally, my PhD thesis. I enjoyed working with you and truly appreciated your effort in finding financial support for the studies in the Mawas' area. I hope than we can continue our collaboration work to sustain local livelihoods and conserve forest ecosystems. Rik, thanks for all of your support on my PhD research, especially in the final stage, and on my personal life, especially when I lost my mother in 2013. I surely appreciate your hospitality in ESA group and do really enjoyed the culinary session in your home when we arranged an international New Year's dinner. Hans, thanks a lot for all of your encouragements , not only for this thesis but also all your personal support, especially when I started my new life in Wageningen. You wrote a recommendation letter for the school of my son and solved several other settlement problems in Wageningen. Having you around made me worry much less. You also kept providing valuable input and suggestions to improve my research quality.

During my PhD journey, I also received help and support from people in my home country. Mr. Yusurum Jagau (Palangkaraya University) provided me with adequate support to get my research permit and introduced me to key persons in this province. These persons gave me much useful information. Mr. Bayu Nugroho (Head of Kapuas Protected FMU) and Mr. Reza Pahlevi (Head of Kotawaringin Barat Production FMU) strongly collaborated on my PhD research in Central Kalimantan. Further, Mr. Jamartin Sihite (BOSF), Mr. Baba Sarbana (BOSF) and Mr. Kresno Dwi Santosa (TBI Indonesia) kindly provided me with valuable data and information for all the analyses in my thesis. I strongly appreciate all the efforts and inspiration by all these persons.

I would also like to thanks to my former colleague and modelling teacher, Pak Meine van Noordwijk, who is now become my PhD advisor on modelling. Pak Meine, thanks a lot for all of your support. I really bless to have you and Ibu Cho not only in this journey but also in the previous and the next one.

I started my journey in the WUR-Aqua building with my room mates Eugenie and Serge. Eugenie, thanks for your kind assistance with all domestic issues to start my new Dutch life (call phone providers, housing company, insurance etc.) and all your warm discussions and encouragements. Serge, you supported me a great deal when I missed my home country. Next, this journey moved me to the 'Ecospace' room. This started a fabulous time with my lovely roommates, Roy and Matthias. Roy and Matthias, thanks for accompanying me in spending working hours together for almost four years and for colouring this journey with valuable discussions, laughter, friendship and happiness. I surely enjoyed sharing the office with you, surrounded by duplicated plants, bottles of beer and wine, and tons of chippies. The annoying noise from the outer blinds was always a funny twitch to talk about but it didn't really bothering us though. Roy, I do really enjoy our enjoyable talks and discussions, even though sometimes you humorously teased me. But, I accepted this because we like each other a lot, even though sometime we had to fight because of the sunshine. Your capacity to deal with spicy food is amazing to me and I hope to treat you when you put your feet in Jakarta sometime, someday. Matthias, thanks for teaching me to analyse data and write research papers efficiently. I am amazed how well you organize your life and I hope that someday I follow your (German) example. One more important thing, you taught me how to eat vegetables, which was a nightmare in my earlier life.

The amazing part of this journey was to meet the old generation of ESA PhDs who all give me a very nice time by sharing their good lives. To my yellow pages, Alexander, thanks for all useful tips to deal with the Dutch boys' lifestyle. Even though sometime you came up with crazy ideas, they unbelievably worked. Most of that, thanks for the ice coffee time, cold coffee is always more delicious for me. To Sander, thanks for the afternoon tea-time and for being there when I got uninterested in my research. To Maryna, many thanks for all talks and discussions, not only academically but also socially and personally. Also to Linda, Ingeborg, Sara, Yafei, Halima, Cheng, Morgan, Elham, Slava, Alexey and Claudia, thanks for all good time that we've shared.

When most of the old generation of ESA graduated, a new generations emerged and coloured ESA differently. I would like to thanks to all members of the new ESA generation (Lucie, Lena, Confidence, Shahid, Leonardo, Mengru, Sarahi, Momo, Saritha, Eka, Dian, Kanokwaan, Jilllian) for all good times that we shared. Lucie, thanks for your hospitality to later accept us (me and Roy) in your room. I really enjoyed the new arrangement in our room, felling the positive energy from the surrounding plants and inner garden, and, of course, to share all coffee beans and the 'koffie apparaat' make coffee sharing easier. Lena, your thoughts, spirits and commitments in saving nature is inspiring. Not only that, you also have magic ideas for everything. I am surely amazed how you advance unique and innovative ideas.

I would also like to thank all ESA staff (Arnold, Mathilde, Carolein, Wichertje, Andre, Sophie, Karen, Nynke, Dolf, Bas, Nicholas, Wim et al.) for their hospitality and caring. The coffee morning and afternoon always become more and more interesting, even tough I did not really show up except when anniversaries were celebrated with cake.

As I also did this journey with ENR group, I also experienced a very nice time with all ENP colleagues. I would like to thanks to my PhD colleagues in ENR (Irene, Pini, Maria, Shinta, Maria, Adam et al.) and staff (Rolf, Ekko, Gre et al.) for all of their support. Especially Irene, we use to cry and laugh together for the same reason. I realised that I did not really spent much time in this group, but their acknowledgement and inspiration means much to me tough.

In my journey, I also met with many wonderful people and appreciate their support and assistance. Peter van der Meer collaborated with me and I hope that we can continue this in the future. Rob and Lex shared data, information and, most importantly, their youth happiness. I enjoyed having amusing talks with you both and hope that we will keep in touch. Rasmus supported me, in different ways, from the northern part of Europe and I do really hope that we can continue our precious collaboration and even strengthen it. My entire group of Indonesian friends in Wageningen, especially to Tini (and family) and Audrie (and Melly), shared their social life in this town. Further, Glen, my old best friend, kept my spirit up and made this journey complete. Jolande, my friend and the best piano teacher for my son, provided tips and hints to start an easy life in this new country. I shared precious and gorgeous time with Dede, Alex and Sean. Their presence is more than special for me and my small family and we are truly happy to have them around.

The most difficult part of my journey started when I had to leave my parents in my home country. I do remember that my mom was crying before I departed. Mom, thanks for being the first one who showed up to protect me and teach me about life and most other important issues. This thesis is your birthday gift, no matter where you are. I love you more and more every day. Dad, millions thanks for giving me a wonderful childhood and believing that I can make it happen. I know it is difficult for you to understand the way my life is evolving and how I am becoming an academic and independent scholar. With this thesis in your hands, I hope now you do. I love you and hope that you can stay with us someday somewhere. Thanks to my big sisters (Mbak Ditta and Kak Ikka) for your unconditional love. Mbak Ditta, thanks for being a loyal supporter and unlimited chef, not only for me but also for Radipa. I will always remember your funny tales and delicious food. Kak Ikka, thanks for your passion in taking care of our father and understanding my position. I know it is not easy to deal with him and wish I could somehow pay your efforts back.

Finally, I would like to give unlimited thanks to the boys at home, for bringing the joy and happiness in this journey. Agung, thanks for all of your efforts to be my husband, my friend, my partner, my supporter, my opponent and the father of our son. I knew

that to start your new life in this town was not easy, but surprisingly you were the one, who actually taught me how to start here. I never thought that you can cook or even do the dishes, but actually you managed very well. You incredibly take care of our son. You become his teacher, music partner, football trainer and partner in crime. Many thanks also to my "sunshine stampot penguin", Radipa, for his presence in this hemisphere. Thanks for teaching me how to observe this wonderful world from a different perspective. I was bit worried about you when you started your first day in this country, but you showed your best efforts. With your amazing language skills, you spoke very well Dutch in three months and immediately moved from Group 1 to Group 3. Not only that, you managed to put yourself in the Plusklas, something that we (me and your papa) never though could be achieved by non-Dutch children. Your soccer talent is also amazing! Even your coaches impress about that. I do really enjoy my time at the soccer field's side during your training and competition. These events teach me (and of course you) much about fairness and sportsmanship and this might be difficult to get from others. Beyond that, thanks for pushing my self-confidence with your love and care.

So, I have found the 'Tarzan' that I looked for (that is what you (Radipa) said about my PhD research: to discover where Tarzan lives) and now it is time to find the alien that you are looking for. This new journey has now started for both of us. It will travel across the Moon, the Sun and the Milky Way to find your alien, to see all the lights and shooting stars and find a place to play soccer and jazz on Jupiter. Thanks boys, I love you from earth to the EGS ZS8-1 and back.

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Chapter 1

General Introduction

1.1 Background

There is a major challenge in balancing economic growth and sustainable natural resource management world-wide. Currently, a broad range of ecosystems including tropical forests are still being converted or suffer from unsustainable management practices. This degradation must be slowed or stopped by new strategies that focus on restoring and sustaining ecosystems. These strategies rest on improving knowledge and information on Ecosystem Services (ES) and ecosystem management in different governance systems and on integrating them into decision-making processes. Meanwhile, understanding the influence of governance systems on ecosystems is required to support the improvement of ecosystem management locally, regionally and globally. In this thesis, I focus on improving ecosystem management in Indonesian decentralized forest governance systems, in particular through land-use optimisation.

1.1.1 Ecosystem services and ecosystem management in decentralised natural resource governance

In the last few decades, the understanding of ES and how they can be modelled and quantified has been growing rapidly. Early work included for example (Daily, 1997; Ehrlich and Mooney, 1983), followed by the first global study of ES (Millenium Ecosystem Assessment (MA), 2005). Recent years have shown detailed work on definitions, metrics and assessments (Boyd and Banzhaf, 2007; Bennett et al., 2009; Bateman et al., 2011; Seppelt et al., 2011; Hein et al., 2015).

The concept of ES is nowadays widely used to understand the contribution of ecosystems to human wellbeing. This concept reframes the relationship between humans and the rest of nature (MA, 2005; Balmford et al., 2010; Turner et al., 2003) and broadly refers to benefits that people obtain from well-functioning ecosystems (MA, 2005; TEEB, 2010; UN et al., 2015) . The ES concept provides not only a framework to anticipate a wide range of social and ecological consequences resulting from different decisions but also several tools for identifying, negotiating, avoiding and managing potential trade-offs (DeClerck et al., 2006; Ingram et al., 2014). This framework and such tools are very important to lead and support ecosystem management.

The ES concept as ecosystems' contributions to peoples' benefits has been utilized in ecosystem management over the last decade. According to this concept, ecosystem management should include the participation of different groups of stakeholders in developing the future conditions of ecosystems, including where pristine ecosystems have undergone radical degradation and change. The changes are a consequences of constant societal and political change (Stringer et al., 2006; Reed, 2008; Seppelt et al., 2011; Luyet et al., 2012). However, implementing the ES concept in effective decision making of ecosystem management practices is still challenging and not yet fully achieved. It is clear that ecosystem management is strongly influenced by the interests of the beneficiaries and other stakeholders who optimise their expected benefits with the support of the current natural resource governance system.

The discussion on using the ES concept in ecosystem management is now entering a wider set of social political processes to address all complex social-environment interactions in ecosystems (Cardinale et al., 2012; Haines-Young and Potschin, 2014; Turnpenny et al., 2014). The ES link between the ecosystem's biophysical structure and processes to the benefits they supply (Potschin and Haines-Young, 2011) assumes that the knowledge of ecosystem benefits is necessary to govern these benefits. The monetary valuation of ES provides information for the economic arguments of decision-making (Bateman et al., 2011; Potschin and Haines-Young, 2011). In practice, however the value of ES benefits does not translate arguments directly into decisions (Vatn, 2009, Spangenberg & Settele, 2010; Spangenberg et al., 2014;). Monetary valuation, for example, has had a poor record in influencing actual policy in several contexts (Laurans et al., 2013). Hence, recent work points to information on economic values of ES under different types of management not being sufficient as a driver for more sustainable ecosystem management. Other crucial aspects are how the different ecosystem services present incentives for different stakeholders to engage in ecosystem management, and the governance system guiding ecosystem use. Improving ecosystem management within an ES framework should therefore start from a governance analysis (Primmer et al., 2015).

1.1.2 Deforestation, forest management and forest moratorium in Indonesia

In my thesis, I will focus on Indonesian forests, which account for 2.3% of the global forest cover (FAO, 2010) and represent 39% of the Southeast Asian forest area (Achard et al., 2002). According to the Indonesian Ministry of Forestry (MoF, 2011), the total designated forest and marine conservation area in Indonesia in 2010 was about 134 million ha. However, Landsat satellite images show that approximately only 98 million ha of this designated forest area was forested around 2010 (MoF, 2011) – with deforestation continuing in the period 2010-2015. Indonesia is currently experiencing the world's second highest rates of deforestation due to pressures associated with socio-economic and political changes (Broich et al., 2011; FAO, 2001, 2010; Margono et al., 2014). This rapid deforestation has contributed to an increase in carbon emissions, loss of biodiversity and a reduction in ecosystem services supply (Pagiola et al., 2002; Sunderlin et al., 2005). Given the key role of forests in providing benefits to people globally, nationally and locally, the Indonesian government has taken initiatives to decelerate deforestation and restore forest ecosystems through the improvement of sustainable forest management and the establishment of forest moratorium policies. I will use the ES framework to assess the effectiveness of these initiatives.

Sustainable forest management practices have been established in Indonesia over the last few decades. This improvement in forest management practices and policies has been established through Forest Management Units - FMUs (Bae et al., 2014; FORCLIME, 2011). FMUs are permanent, manageable and controllable forest areas. These forest areas should provide sustainable livelihoods to forest dependent people (FORCLIME, 2011; Setyarso et al., 2014). Accordingly, these units should apply the ES concept in developing their management plan (Deal et al., 2012; Quine et al., 2013). However, the lack of capacity and the absence of guidelines incorporating the ES concept in management plans have to be addressed.

The forest moratorium policy was established based on the Presidential Instruction (i.e. No. 10/2001 in May 2011). This policy was established as part of the government's reforms and a larger bilateral 'REDD+ Readiness' forest conservation programme (Sloan et al., 2012). This policy primarily aims to restore forest ecosystems and to improve transparency in forest governance. It also entails ceasing the issuance of concession licences for primary and peat forests and producing integrated forestry map. However, it neglects livelihood options for forest dependent people. This exclusion currently limits its implementation and success (Sloan, 2014; Sloan et al., 2012).

1.2 Problem statement

The potential contribution to reduce Indonesian deforestation rates and to restore the ES from Indonesian forests was frequently studied and debated in the last few decades (Achard et al., 2002; Bae et al., 2014; Broich et al., 2011a). These studies and debates include the ES concept to support biodiversity and conservation programmes. However, how the ES concept could be applied to improved forest management practices in decentralised governance systems has been poorly captured in these studies and debates.

Considerable challenges to improve forest management practices remain. Forest is a common pool resources that receives a high interest from various stakeholders (Gamfeldt et al., 2013; Meijaard et al., 2013; Pagiola et al., 2002). In the Indonesian context, improving forest management practices is challenging due to the complexities of governance and land-use systems, economic development, poverty and unemployment. The big question is always what should be the starting point. My research was designed to address this issue. The 'improvement of current sustainable forest management practices' was used as the critical starting point.

Central Kalimantan was selected as the study area based on the importance of its forest ecosystems in providing the services for not only local people but also for national and international markets. It is one of 34 provinces in Indonesia and covers approximately 15.4 million ha, of which 12.7 million ha are designated as forests areas (MoF, 2011). Central Kalimantan's total population in 2010 was 2.15 million, with a population density of 14 people per km^2 (BPS, 2013). In terms of local income, forestry and agriculture (particularly oil palm) are the most important sectors.

Central Kalimantan's forest and peatlands are part of Borneo's biodiversity hotspots which are believed to be among the most species-rich environments in the world (Whitten et al., 2004). They provide vital ES locally, regionally and globally. These include provisioning services, such as timber and non-timber products (Meijaard et al., 2013); cultural services, such as nature recreation (Hernández-Morcillo et al., 2013; Plieninger et al., 2013); and regulating services, such as carbon sequestration and water (Paoli et al., 2010; Leh et al.,2013). However, rapid deforestation to enhance agricultural and silvicultural developments particularly oil palm has been a salient issue over the last decade. The province has suffered the second highest rate of deforestation in Indonesia and lost approximately 0.9 million ha of forest in the period 2000-2008 (Broich et al., 2011a). Moreover, it has also suffered annual smoke and haze problems resulted from forest and land fires. For example, during September and October 2015, the forest and land fires caused a dramatic reduction in air quality, particularly in Palangkaraya City, where the air quality index rose to the highest level pm10 concentration ever measured (on average about 1,600 µgram per m^3; Environmental Agency, 2015).

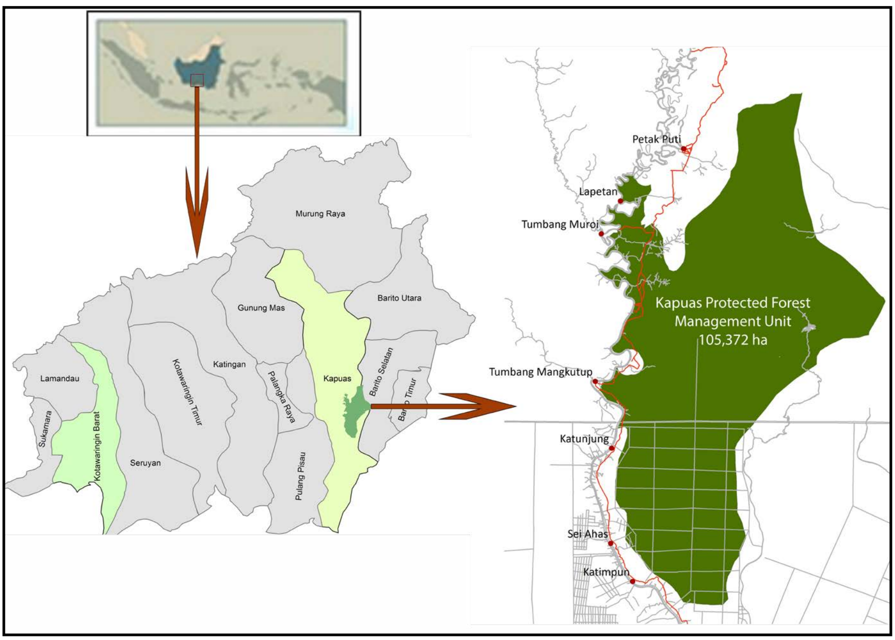


Figure 1-1 Case study area

Considering the importance of Central Kalimantan's forest ecosystems in providing benefits locally, regionally and globally, ecosystem management for this province should be redesigned through the application of the ES approach. A comprehensive study that integrates forest governance, ecosystem benefits and beneficiaries, land-use change modelling, forest zonation, and that analyse the trade-offs in ESs supply and benefits as a function of the management options is thus required to cope with the challenges and complexity in managing forest ecosystems in this province.

1.3 Objectives and research questions

Considering the complex dynamic problems of the on-going Indonesian deforestation and forest degradation and the current research gaps, this study aims to examine how ESs concept and a land-use change model can be applied to support current forest management through land-use optimisation in Central Kalimantan. To achieve this objective, four research questions (RQ) are formulated.

RQ1: How does decentralised forest governance influence deforestation rates?

Recent tensions in the international debate have highlighted the importance of forest governance in developing countries in response to growing concerns over declining ES provided by degraded forest ecosystems. In the Indonesian context, the performance of decentralised forest governance has been indicated in many studies as the main underlying cause of deforestation and forest degradation (Béné & Neiland, 2006; Casson, 2001; Colfer & Capistrano, 2005; Larson & Soto, 2008; Ribot, Agrawal, & Larson, 2006). Decentralised forest policies have provided more authority to district governments to manage their forest areas. The poor performance of district forest governance is probably very important to explain local deforestation rates. This study therefore assesses the performance of eleven district forest governments in Central Kalimantan, with deforestation rate as the main outcome indicator. The assessment was conducted for the periods 2000-2005 and 2005-2010, following the local election period for the head of districts (Bupati). It incorporates the four principles of good forest governance (i.e. accountability, equality, transparency and participation) developed by PROFOR-FAO (Kishor and Rosenbaum, 2012) and the World Bank (Huther and Shah, 1998).

RQ2: Who benefits more from ES?

ES benefits are not just a function of ecosystem dynamics but also a function of the socio-economic system (e.g. governance system, market system and informal land use system; Fisher et al., 2008). Understanding how the current socio-economic system influence benefits received by different beneficiaries is very important when improving management practices. Benefits associated with localised ES and their related beneficiaries must be identified to determine alternative and sustainable ways of managing ecosystems (Kettunen et al., 2009). The retrieved monetary values of selected ES are subsequently used to analyse the trade-offs associated with land use conversion. This study assesses the monetary benefits from seven ES and their distribution to three different types of beneficiaries. The ES benefits and beneficiaries groups were identified base on an ecosystem accounting approach that is inline with the System of National Account (SNA) (UN et al., 2015). The assessment on benefits received by different groups of beneficiaries was conducted based on current forest and agriculture governance systems. It includes government policies related with tax, provisioning and fees in forest utilisation and agriculture production.

RQ3: How do stakeholders' perspectives and expectations lead to their management decisions on land use and how these this influence the dynamics of ES supply?

Understanding what influences stakeholders' decisions on land-use change is important when providing direction for ecosystem management. Kettunen et al., (2009), Smajgl et al., (2011) and Villamor et al., (2014) suggest that economic perspectives and stakeholders' expectations are the most important factors that drive stakeholders' decisions to change land-use in response to certain government policies. To understand the stakeholders' decision making process in land-use change, agent-based models are the most suited because this approach is primarily used for simulating socio-ecological processes and incorporates the decision making processes of all heterogeneous stakeholders (Heppenstall and Crooks, 2012; Kelly et al., 2013).

For this thesis, I developed an agent-based model, the Land-Use Change and Ecosystem Services model (LUCES) for the Kapuas and Kotawaringin Barat districts. This LUCES model captures planned and unplanned land-use change that is driven by the decision of communities and private companies respectively. The potential dynamics of land-use change and the supply of seven ES are predicted by LUCES based on the three different scenarios for the implementation of forest moratorium policy. This part of the thesis builds upon the research conducted to address RQ1 and RQ2 by using detailed information on forest governance and ES benefits obtained from different beneficiaries to build the basic assumptions.

RQ4: How can the ES and land-use modelling concept be applied to optimise sustainable forest management under conditions where data and information is missing?

The integration of the ES concept in forest management is important to sustain the deliverable ES, reduce potential disservices (Deal et al., 2012a; Quine et al., 2013) and address substantial uncertainties of (1) the scale of the valuations and decisions, and (2) the availability of evidence and/or data on ES (Deal et al., 2012a; Williams, 2011). This part of the thesis tests the application of the ES and land-use modelling concept in optimising land use in current forest management practices in the Kapuas Protected Forest Management Unit, through the development of adaptive forest zonation. The Kapuas Protected Management Unit is one of five forest management units established in Central Kalimantan. The adaptive forest zonation captures the balance between conservation and economic development areas. Delineation of the zones combine the ES concept that emphasizes the biophysical and socio-economic aspects of ecosystem in providing sustainable benefits, with a participatory concept that emphasizes the participation of local communities and experts from the forest management unit. In order to understand the long-term economic consequences, this study also included analysis on potential ES benefits received by local people from the two options of forest zonation. This integrative analysis is important to inform decision making on the possibility of applying the ES concept to optimise forest management.

1.4 Thesis outline

To address these research questions, four independent studies were conducted on the socio-economic and biophysical aspects of ES in Central Kalimantan. The first three independent studies were used to understand ecosystem management under decentralised forest governance in Indonesia and its influence on ecosystems, ES and the benefits that different beneficiaries receive. The fourth study combines the outcomes from the previous three studies to assess and select the most appropriate areas for conservation and community development to optimise the land use.

The policy of decentralised forest governance is the key aspect in defining deforestation and forest degradation in Indonesia. To build a better understanding on decentralised forest governance and its influence on deforestation rates, the assessment good decentralised forest governance is then present in Chapter 2 of this thesis to provide a broader understanding on decentralisation in Indonesian forest governance and its influence on deforestation rates. This chapter explains the assessment on decentralised forest governance's performance for eleven districts, from a total of thirteen in Central Kalimantan, with the deforestation rates as the outcome indicator. This chapter highlights the importance of transparency, which is one of the four principles of good forest governance, as the most important factor in explaining districts' deforestation rates. Transparency in good forest governance include the inclusiveness in decision-making process for new policies and evaluating existing policies base on its influence on local livelihood, ecosystems and national economic.

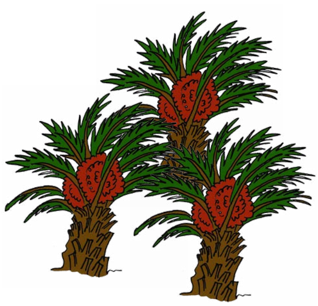
Following this assessment, the influence of decentralised governance on ES benefits receive by different beneficiaries is then assessed in this research and presented in Chapter 3. This chapter examines, describes and analyses how different groups of beneficiaries receive different ES benefits based on the current natural resource governance system. The potential loss and gain from different ES are also analysed and discussed to understand the influence of the current setting of natural resource governance on local livelihoods. This chapter highlighted the importance of policies governing forests and agriculture as the main aspect in defining different benefits receive by different beneficiaries. Considering the policies influence in changing the perspective of beneficiaries in maximising their expected benefits, information resulted from Chapter 2 and 3 are then used in this thesis to develop an agent-based model on land-use change, as presented in Chapter 4. The development of an agent-based model on land-use change is discussed to examine the influence that different scenarios of forest moratorium policy have on communities' and private companies' decision making on land use and the impact of these decisions on ES supply. This chapter highlights the importance in including livelihood programme that secure local livelihood to make forest moratorium policy work. This chapter also shows that the option in providing livelihood programme through economic incentive and market support for non-timber forest products collection has influenced the awareness of local people in conserving forests rather than change it to other uses. This information is very important for decision makers to develop such of livelihood programmes to make forest moratorium policy work in sustaining and restoring forest ecosystems.

The applicability of ES concept and agent-based land-use model in supporting ecosystem management is then presented in Chapter 5. In Chapter 5, I applied the information on forest governance performance (from Chapter 2), benefits received by different groups of beneficiaries (from Chapter 3) and the influence of forest moratorium policy on land-use change and ES supply (from Chapter 4) to optimise the land use in recent forest management practise in forest management units. Chapter 5 thus describes the development of adapted forest zonation for one forest management unit. The adapted forest zonation was developed to meet the main aim of forest management units in restoring and conserving the capacity of forest ecosystems in providing benefits for local people and the global community. Finally, I provide in Chapter 6 my answers to the four research questions, reflections on my findings and the conclusion that integrated ES concept and land-use modelling could practically used to optimise sustainable forest management.

Chapter 2

Government, decentralisation and deforestation:

The case of Central Kalimantan Province, Indonesia



Published as:

A. Suwarno, L Hein and E. Sumarga (2015). Governance, decentralisation, and deforestation: the case of Central Kalimantan Province, Indonesia. Quarterly Journal of International Agriculture 54 (1): 77-100

Abstract

The implementation of the decentralisation policies in Indonesia, which started in 2000, has fundamentally changed the country's forest governance framework. This study investigates how decentralisation has influenced forest governance, and links the forest governance to deforestation rates at the district level. We measure and compare the quality of forest governance in 11 districts in Central Kalimantan province in the periods 2000-2005 and 2005-2010, and relate forest governance to deforestation rate. This study shows that decentralisation has led to marked differences in forest governance between districts and that deforestation rates are strongly related to the change of forest governance. We recommend revisiting the Indonesian forest governance framework to ensure more checks and balances in decision making, better monitoring and increased transparency, with particular support for Forest Management Units as a new tool for forest management, and government support to facilitate the design and implementation of $REDD^+$ projects.

Keywords: Indonesia, decentralisation, deforestation, forest governance

2.1 Introduction

Indonesian forests account for around 2.3% of global forest cover (FAO, 2010) and represent 44% of the Southeast Asian forested area (Koh et al., 2013). According to the Indonesian Ministry of Forestry, the total designated forest area in Indonesia was about 131 million ha (MoF, 2011). In 2009/2010, approximately 98 million ha of the designated forest area was still forested (MoF, 2011). Indonesia is experiencing the world's second highest rates of deforestation, due to pressure associated with socio-economic and political changes (FAO, 2010, 2001; Hansen et al., 2009, 2008; Margono et al., 2012). Indonesian deforestation is of global concern, because of the resulting carbon emissions, the associated loss of biodiversity as well as the impacts on local ecosystem services (Pagiola et al., 2002; Sunderlin et al., 2005).

Central Kalimantan has suffered the second highest rate of deforestation in Indonesia in recent years. From 2000-2008 the province lost approximately 0.9 million ha of forest (Broich et al., 2011a). Deforestation in this province is driven by a range of economic, institutional, social, ecological, and infrastructural factors. One of the key issues in this context is the effect of the decentralisation policy implemented in Indonesia since 2000. This policy has substantially changed the authority of different levels of government over natural and forest resource management and has been identified as one of the underlying causes of deforestation (Casson, 2001; Colfer and Capistrano, 2005; Béné and Neiland, 2006; Ribot et al., 2006; Larson and Soto, 2008).

Several studies describe how inclusive decision making in decentralised governance can increase the quality of public services (Goldfrank, 2002; Ackerman, 2004), improved responsiveness and accountability of local government (Blair, 2000; Goldfrank, 2002), and enhanced equitable access to services and productive assets (Hardee et al., 2000). However, it has also been shown that a lack of institutional capacities, a lack of transparency and limited citizen participation can act as major constraints for effective decentralised decision making (Crook and Manor, 1998; Gibson et al., 1998; De Mello, 2000). The studies note significant regional, national and sub-national variation in the effects of decentralisation (Larson, 2002; Andersson, 2003), and many of the aforementioned studies do not use sub-national data to examine the specific, local effects of decentralisation.

Given the far-reaching consequences of deforestation in Indonesia, both in terms of local impacts on livelihoods and global impacts on biodiversity and carbon emissions, there is a need to come to a better understanding of the relationship between decentralisation and deforestation in this country. This study analyses how deforestation rate can be linked to the recent decentralisation policy in Indonesia. The study covers 11 districts in Central Kalimantan province. The main innovation of this paper is to provide both a descriptive analysis of the institutional changes that have taken place in Indonesia and an empirical analysis of the relationship between institutional change and deforestation at the district level. To enhance and address the problem of decentralisation, we employed a three-pronged approach. First, we framed the description of the decentralisation process from a new institutionalised perspective, as presented in section 2.2. Second, in section 2.3, we utilised comparable and time-series observations on deforestation as the environmental outcome. We used land cover maps from the Indonesian Ministry of Forestry, for three different years (2000, 2005 and 2010). In this section, we also explore the variation of ten indicators of the quality of forest governance, capturing four principles of good forest governance (accountability, equity, transparency and participation), for the periods 2000-2005 and 2005-2010. Third, we employed comparative analysis to examine the relationship between the quality of decentralised forest governance and deforestation rates at the district level. The key results from the comparative analysis are provided in Section 2.4, followed by the discussion and conclusions in Sections 2.5 and 2.6, respectively.

2.2 Decentralisation Reform and Forest Governance

The East Asian economic crisis in 1997/1998 was the impetus for decentralisation in Indonesia. The crisis put the Indonesian financial and administrative system into disarray. As part of the package offered by the International Monetary Fund (IMF), Indonesia was required to implement various reforms aimed at deregulating markets, privatising state sectors and imposing fiscal austerity. In addition to market reforms, a fundamental transformation in the governance system was a key condition of the package (Robinson et al., 2002). The conditional bail out of the country's economy by the IMF, the World Bank and other donors bankrolled market reforms along with a governance programme that included decentralisation reforms (McCarthy, 2004). The World Bank (2001) argued that under appropriate conditions decentralisation would help alleviate the administrative bottlenecks in the decision making process, increase government efficiency and its responsiveness to local needs, enhance accountability of public institutions, improve service delivery, and allow greater political representation and participation of diverse groups in decision making at different levels.

The decentralisation reforms in Indonesia were guided by a range of specific laws. The initial legal frameworks were Law No. 22/1999 on Regional Governance and Law No. 25/1999 on the Balance of Funds. According to Law No. 25/1999, all districts now receive approximately 25 % of the national budget in the form of block grants. The authority of the districts, in almost all sectors of government, also increased due to the implementation of Law No. 22/1999 (Burgess et al., 2012). Decentralisation in the forestry sector in Indonesia was implemented based on Law No. 22/1999 and No. 25/1999. Law No. 22/1999 grants the authority over forest areas to the Ministry of Forestry and Law No. 25/1999 gives authority to the Bupati (head of the district) or Walikota (head of the

Table 2.1. Proportion of income from the forestry sector among national, province and district before and after decentralisation

Source	Propostion before decentralisation (%)			Proportion after decentralisation (%)		
	National	Province	District	National	Province	District
Levy on forest concession rights	55[1]	30[1]	15[1]	20[3]	16[3]	64[3]
Resource royalty provision	55[1]	30[1]	15[1]	20[3]	16[3]	32[3]
Reforestation fund	100[1]	0[1]	0[1]	60[2,3]	0[2,3]	40[2,3]

Source: [1]President Decree No. 30 per 1999, [2]Law 25 per 1999, [3]Law No. 33 per 2004.

municipality) to utilize forest resources in generating income for local development. To give effect to Law No. 22/1999, the Ministry of Forestry issued ministerial decrees No. 05.01/Kpts-II/2000 and No. 21/Kpts-II/2001 granting Bupati and Walikota the authority to issue small-scale timber concession licences to co-operatives, individuals, or corporations owned by Indonesian citizens for areas of up to 100 hectares within conversion forests and production forests slated for reclassification to other uses. Decentralisation also changed the distribution of public benefit from the forestry sector in favour of district, province and national government (Table 2.1).

Considering the environmental effect on deforestation and forest degradation, central government refined Law No. 22/1999 in Law No. 34/2002 to recall the authority of the district governments in issuing small-scale timber licences. Corresponding to this law, the Ministry of Forestry issued Ministerial decree No P.03/Menhut-II/2005. This regulation basically cancels the authority for issuing timber licences at the district and provincial levels, and provides new guidelines for verifying the licences that had been granted by districts or provinces during the initial decentralisation period.

The outcome of decentralisation reform in Indonesia was determined by the convergence of several national and local forces (Manor, 1999; Ribot, 2003). The economic crisis of 1997 indicated a crisis of legitimacy for state institutions. The inability of the centralised governance system to respond to the economic and political crisis raised serious questions regarding their effectiveness (Rasyid, 2002). Increased autonomy in decision-making and distribution of resources in decentralisation was perceived as a crucial alternative to prevent national disintegration (Van Zorge, 1999).

Decentralised forest governance was expected to influence the social and environmental outcomes in six ways: (i) participation and efficiency for local priorities, (ii) empowerment

Table 2.2. Intentions and outcomes of decentralised natural resource management

Intention	Outcome
Participatory development and greater efficiency for local priorities[1,2,3,4,5]	Local jurisdiction did not receive sufficient power or resources[1,2,3,4,5]
Increased voice for local communities, empowerment and democratisation[1,2,5]	The elite captured resources, as the powerful locals took advantage of uncertainties[1,2,5]
Poverty reduction through equitable access to resources[1,2,3,4,5]	Extreme poor and disadvantaged groups were marginalised[1,2,3,4,5]
Greater accountability in local governments[1,2,5]	Lack of representativeness of decentralised body[1,2,5]
Tailor resource management objectives to local contexts[1,5]	Fragmented management responsibility for ecosystems[1,5]
Local conflict resolution and more sustainable resource management outcomes[1,2,3,4,5]	Created more local conflicts and social tensions, some leading to resource overuse[1,2,3,4,5]

Source: [1]Ribot et al., (2006), [2]Béné and Neiland (2006), [3]Larson and Soto (2008), [4]Colfer and Capistrano (2005), [5]Berkes (2010).

and democratisation, (iii) equitable access to resources, (iv) greater accountability in local government, (v) tailoring resource management to the local context, and (vi) conflict resolutions (Béné and Neiland, 2006; Ribot, 2006; Berkes, 2010). Decentralised natural resource governance requires sufficient and adequate internal institutional capacity. In Indonesia, decentralised forest governance has shifted an important part of the forestry mandate from the central to the district government level. District forest officials received a mandate to enforce forest policies and to control deforestation at the district level (Burgess et al., 2012). In order to carry out the mandated functions, the district government needs to have a certain level of financial resources, qualified personnel and the ability to organize their internal affairs. The actual outcomes of the decentralised policies adopted in Indonesia, have been very mixed and do not conform to these six principles (Table 2.2), as examined in detail for Central Kalimantan in the following sections.

2.3. Methodology

2.3.1 Study Area

Central Kalimantan is located in the southern part of Kalimantan, Indonesia between latitudes 0°45'North and 3°30' South, and longitudes 110°45'-115°50' East (Figure 2-1). The province covers an area of approximately 15.4 million ha (BPS, 2010) of which 82% (12.7 million ha) is designated as forest area (MoF, 2011). Based on the land cover map of 2010, about 57% of the province is covered by forest, including plantation forests, in 2010. Substantial land use and land cover change has taken place in this province; about 1.3 million ha of forest cover has been deforested during the period 2000-2009 (MoF, 2011). The total population in this province in 2010 was 2.2 million, while agriculture and forestry (including timber and non-timber forest products) are the main sources of local gross domestic products (BPS, 2010). Following decentralisation and decentralisation laws No. 22/1999 and No. 25/1999, the number of districts in Central Kalimantan increased from 5 to 13. All of these new districts were founded in 2002 based on Law No. 5/2002. This study covers 11 districts out of the 14 districts in this province. The districts included in the study are presented in Figure 2-1.

2.3.2 Dynamics of deforestation at the district level

To analyse the dynamics of deforestation, we assessed land cover change and analysed various policies and legal aspects of deforestation in designated forest areas. We also compared the designated forest allocated for forest conversion by central government with the proposals from the provincial government. In this context, a "designated forest area" is any particular area designated and per or enacted by the government as permanent forest.

2.3.2.1 Biophysical analysis of deforestation

The analysis of deforestation in this paper was conducted for two different periods: 2000-2005, and 2005-2010. In this process, land cover maps of 2000, 2005 and 2010 (provided by Tropenbos International Indonesia Programme – TBI Indonesia) and the administrative map of Central Kalimantan were overlaid and analysed.

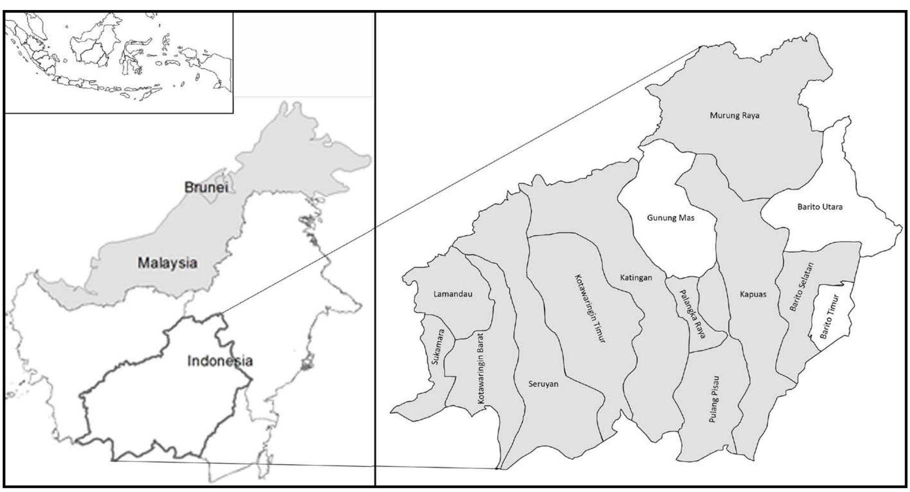


Figure 2-1 Map of Indonesia (inset) showing the zoom out of the study area in Central Kalimantan Province; the districts covered in this study are in grey

Table 2.3. Districts in Central Kalimantan, before and after decentralisation

District before decentralisation	District after decentralisation
Kotawaringin Barat	Kotawaringin Barat, Lamandau, Sukamara
Kotawringin Timur	Kotawaringin Timur, Seruyan, Katingan
Barito Selatan	Barito Selatan, Barito Timur, Barito Utara
Kapuas	Kapuas, Murung Raya, Pulang Pisau, Gunung Mas
Kota Palangkaraya	Kota Palangkaraya

In the first step, the land cover maps were reclassified into two classes (forests and non-forests). Originally, the maps had 19 land-cover classes. These maps were then reclassified by grouping primary dryland forest, secondary dryland forest, primary peat swamp forest, secondary peat swamp forest, primary mangrove forest, secondary mangrove forest, and plantation forest into forests, and the rests as non-forests.

In the second step, deforestation maps were generated for each period by overlying the land cover (forest and non-forest) maps of two different years. For example, we overlaid the land cover maps of 2000 and 2005 to identify the areas that were forested in 2000 but were not forested in 2005; these areas were then classified as deforested areas. The same procedure was applied for the period 2005-2010.

2.3.2.2 Policy and legal analysis

In order to improve our understanding of the legal aspects of the dynamics of the designated forest areas, we examined the policy and legal documents released by the central and provincial government. This analysis was conducted by comparing the percentage of designated forest areas allocated for forest conversion by the national government, based on the Ministry of Agriculture decree No. 759/KPTS/Um/10/1982, with the provincial government proposal which refers to provincial policies and legislation, as presented in Table 2.4.

2.3.3 Assessment of forest governance at the district level

In order to understand decentralisation in forest governance, this study applied the basic theory of decentralised resource governance. This theory assumes and expects that local actors are willing to govern their natural resource effectively, and focus on the characteristics and performance of local institutions (Andersson and Ostrom, 2008; Ribot, 2003). Taking this theory into consideration, this study assessed forest governance, as the forest institution at the district level, in 11 districts in Central Kalimantan, for the period 2000-2005 and 2005-2010. Key variables used in this study cover the four principles of good forest governance (accountability, equity, transparency and participation) as

Table 2.4. Changing dynamics in designated forest areas in Central Kalimantan based on various legal documents released by national and provincial government

Regulation	Designated Forest Area (ha)	Area allocated for conversion* (%)	National (N) or Province (P)
Forest land use by consensus (Ministry of Agriculture decree no. 759/ KPTS/Um/10/1982)	15,320,100	28	N
Provincial legislation no. 5/1993 supported by Letter of Ministry of Home Affairs No. 68/1994	15,356,400	27	P
Integrated and harmonised forest land use and consensus based on Governor decree no. 008/965/IV/BAPP in 1999	15,798,359	34	P
Provincial legislation no. 08/2003 on Spatial Planning of Central Kalimantan	15,356,700	31	P
Proposal for Spatial Planning of Central Kalimantan in 2007	15,410,482	44	P
Update of forest land use and consensus (2009 per 2010)	15,465,543	9	N
Ministry of Forestry Decree No. 529 per Menhut-II per 2012	15,263,242	17	N

Note: * proportion of the designated forest area

explained under the framework of "good forest governance" developed by PROFOR-FAO (Kishor and Rosenbaum, 2012) and the framework of "governance quality" developed by the World Bank (Huther and Shah, 1998), as presented in Table 2.5.

In this study, we conducted field surveys and focus group discussions (FGD) for 11 districts in Central Kalimantan from July – October 2012. In each district we interviewed five different groups at the district level: (1) three forestry officers (head of the forest agency; head of planning, production, and conservation section; and head of forest management unit) from the forest institution which worked from 2000-2010; (2) community representatives; (3) NGOs which ran their activities during the period 2000-2010; (4) representatives of small to medium enterprises and companies; and (5) universities or higher education. Each face-to face interview took approximately 2 – 3 hours. The survey instrument (30 questions) was designed to elicit information regarding the four principles of good forest governance through 10 indicators of quality of the

Table 2.5. Indicators of forest governance quality (Adopted from PROFOR-FAO, 2012 and World Bank, 1998)

Pillars	Principle	Indicators
1. Policy, legal institutions, and regulatory frameworks 2. Planning and decision-making processes 3. Implementation, enforcement and compliance	1. Accountability	1. Existence of district policies on forest management. 2. Consistency and link between district and national policies on forest management. 3. Extension and implementation of a forestry mandate. 4. The independency of the forest district agency from political interference. 5. Capacity of forest agency staff.
	2. Equity	6. Equity in access to forest resources. 7. Law enforcement.
	3. Transparency	8. Access to public data and information. 9. Public hearing and consultation during policy making.
	4. Participation	10. Stakeholder inputs and participation in land management policies.

district forest governance. In addition, to strengthen and improve this survey data, we also conducted focus group discussions at the district level. The focus group discussions involved the representatives of the five groups.

The 10 indicators of forest governance quality were elicited, agreed and scored based on the results of the interviews. These scores were on the scale of 1 to 4 (where 1 represents the worst condition and 4 represents the best). Further, we used the scores of these 10 indicators as independent variables for the empirical analysis.

2.3.4 Analysis of how decentralisation relates to deforestation

Previous studies on decentralisation described how inclusive decision making in decentralised governance may increase the quality of public services (Goldfrank, 2002; Ackerman, 2004), improves responsiveness and accountability of local government (Blair, 2000; Goldfrank, 2002; Wheeler et al., 2013), and enhance equitable access to services and productive assets (Hardee et al., 2000). Considering the basic theory of decentralisation and findings from the previous studies above, this study examined the 10 indicators of the quality of forest governance in the period 2000-2005 and 2005-2010 and linked to the deforestation rates for the same time periods (2000-2005 and 2005-2010). We specify deforestation as the percentage of forest cover lost in the forested areas of each district.

The main hypothesis formulated in this paper is that deforestation will be inversely related to the score of each indicator as well as each principle of forest governance. High scores for the quality of forest governance would equate to a better accountability, equitability, transparency and participation in forest governance and lower deforestation. (c.f. Blair, 2000; Hardee et al., 2000; Goldfrank, 2002; Ackerman, 2004; Wheeler et al., 2013).

2.4 Results

2.4.1 Dynamics of deforestation at district level

The analysis of land cover maps for the years 2000-2005 and 2005-2010 shows negative changes in forest cover in almost all districts. In the period 2000-2005, some districts such as Murung Raya and Kota Palangkaraya managed to maintain their forests and experienced no annual change in their forest cover. However, in the period 2005-2010, negative changes in forest cover were experienced in all districts. Table 2.6 shows that deforestation has accelerated in all districts, except for Seruyan, in the period 2005-2010.

2.4.2 Quality of forest governance at the district level

In the first period of decentralisation (2000-2005), the forest governance quality of most of districts remained relatively stable. In this period, the new districts had just been established and they received additional support from the central government and per or from the old districts. Changes in quality of forest governance in the districts began in the period 2005-2010, when most districts experienced negative trends. However, some districts managed to improve their quality as measured with some of the indicators. These improvements were mostly related to their commitment to sustainable forest management practises through the planning and establishment of the Forest Management Unit (FMU), in Kapuas and Barito Selatan, and the provision of an area to release orangutan in Murung Raya (BOSF, 2012). This condition supports the findings of previous studies that decentralisation efforts do not uniformly lead to better or worse local governance (Gibson and Lehoucq, 2003; Smoke, 2003; Wheeler et al., 2013). Forest governance quality in 11 sample districts in the period of 2000-2005 and 2005-2010 is presented in Figure 2-2.

2.4.3 The impacts of decentralisation on deforestation

The dynamics of the institutional arrangements under decentralised forest governance has changed the interest of the district heads, as well as the dominant political party, and changed the quality of forest governance. The results of our comparative analysis show that most districts experienced a decrease in the total score for forest governance in 2005 – 2010 compared with those in 2000 – 2005 (except for Kapuas district). In addition, the deforestation rate for most districts in 2005-2010 had increased compared with those in 2000-2005 (except for Seruyan district that witnessed a reduction in the pace of deforestation). The scores for forest governance and changes therein, and the deforestation rates are shown in Table 2.7.

Table 2.6. Annual changes in forest cover at the district level (expressed as a percentage of the total forest cover in the district)

District	Annual change of forest cover (% of deforested area)	
	2000-2005	2005-2010
Kotawaringin Barat	-0.8	-2.3
Lamandau	-0.4	-3.0
Sukamara	-4.9	-6.6
Kotawaringin Timur	-4.4	-5.1
Seruyan	-1.9	-1.1
Katingan	-0.1	-1.3
Barito Selatan	-1.6	-1.9
Barito Timur*	-2.3	-5.3
Kapuas	-0.7	-1.3
Murung Raya	-0.0	-0.3
Pulang Pisau	-0.3	-2.6
Gunung Mas*	-0.1	-0.9
Kota Palangkaraya	-0.0	-1.5
Barito Utara*	-1.2	-1.9
Provincial average	-0.9	-1.7

Source: land cover map 2000, 2005 and 2010

* not capture in the study

Our analysis shows that the change in score for accountability (indicators 1, 2, 3, 4 and 5) has a weak relationship with the change of deforestation rate (see Table 2.7 and Appendix 1.1 and 1.2). There is no obvious correlation between (changes in) the forest governance score and (changes in) the deforestation rate. These results support the findings of previous studies that indicate that accountability is not necessarily a main aspect in explaining deforestation (Casson, 2001; McCarthy, 2004; Andersson and Ostrom, 2008).

We also found that the change in score for equity (indicator 6 and 7) has a weak correlation with the change of deforestation rates (Appendix 1.1 and 1.2). Districts with a higher score for indicator 6 and 7 still experience fast deforestation, while some districts with a lower score have a low deforestation rate. In terms of indicator 6, which measures the equitable access to forest resources, our interviews with communities who live around the forest area show that even in the case of a degraded forest they generally still have sufficient access to the forest to collect NTFPs for their livelihoods. As for law enforcement (indicator 7) our interviews with staff of forestry agencies and NGOs shows that the police often gives low priority to arresting illegal logging, which may be related

Table 2.7. Scores for forest governance and the deforestation rates in two periods

District	Deforestation per year (% of forest area in the district)		Governance (total score of 10 indicators)		Change (2010-2005) – (2000-2005)	
	2000-2005	2005-2010	2000-2005	2005-2010	Deforestation	Governance
Kotawaringin Barat	-0.8	-2.3	23	20	1.5	-3
Lamandau	-0.4	-3	23	18	2.6	-5
Sukamara	-4.9	-6.6	20	16	1.7	-4
Kotawaringin Timur	-4.4	-5.1	21	18	0.7	-3
Seruyan	-1.9	-1.1	20	19	-0.8	-1
Katingan	-0.1	-1.3	24	21	1.2	-3
Barito Selatan	-1.6	-1.9	20	19	0.3	-1
Kapuas	-0.7	-1.3	23	23	0.6	0
Murung Raya	0	-0.3	23	22	0.3	-1
Pulang Pisau	-0.3	-2.6	23	20	2.3	-3
Kota Palangkaraya	0	-1.5	23	21	1.5	-2

to the involvement of well-connected people in illegal logging (c.f. Palmer, 2000; McCarthy, 2001a; McCarthy, 2001b). Since the decentralisation did not manage to significantly improve law enforcement, indicator 7 also has a weak correlation with deforestation.

The principle of transparency is captured in indicators 8 and 9, while the principle of participation is captured in indicator 10. Our analysis shows that districts with an increase in transparency and participation tend to have a lower increase of the deforestation rate (Appendix 1.1 and 1.2). Access to public data and information is captured in Law No. 14/2008 and Provincial regulation No. 59/2008 concerning the procedures for research and data collection involving government institutions. This regulation requires all agencies at the district and provincial levels to share data and information with researchers, including students, university staff and scientists, conditional on them having a research permit. In return, this regulation also requires the researcher to report and share their research results with the district(s) and province(s). Our study shows that the districts with a lower increase in deforestation rates were more supportive to research, although it is not clear if the research led to the improvement in managing forest conditions or if better-governed districts were more open to work with researchers. Our analysis also shows a significant correlation between the change in score for indicator

9 and deforestation rates (see Appendix 1.1 and 1.2). Districts in which public hearings and consultations were conducted in higher numbers tend to have a low deforestation rate. This suggests that public hearings and consultations are important in the policy-

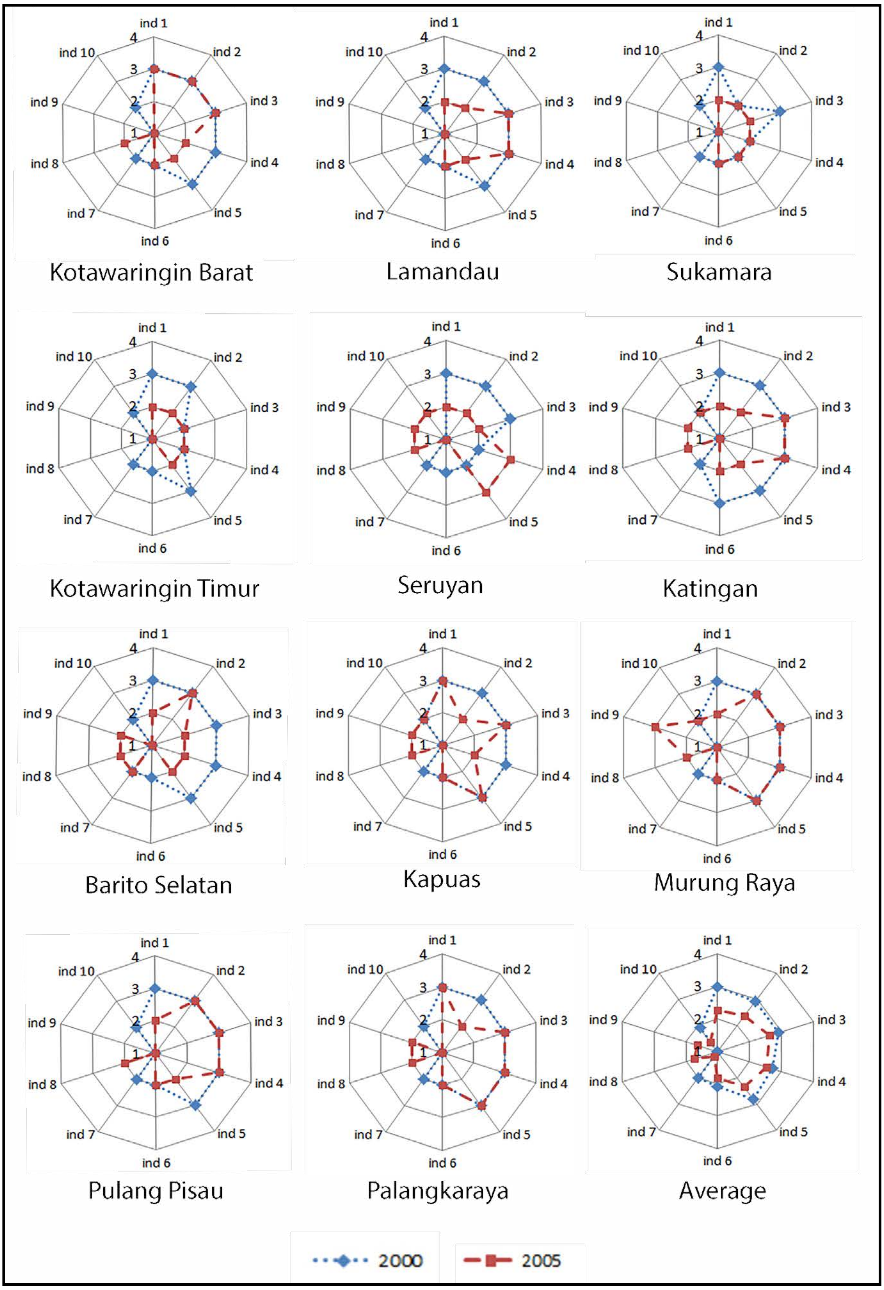


Figure 2-2 Trends in forest governance quality in 11 sample districts in Central Kalimantan Province

making process in order to capture public interest and opinions, as was confirmed by our interviews of stakeholders in NGOs and the forest sector. Our correlation analysis also indicates that the participation of stakeholders (indicator 10) is important in promoting better forest governance, confirming the work of (Bae et al., 2014) in West Nusa Tenggara Province. A Pearson test shows that the correlation between deforestation and indicator 8, 9 and 10 was significant at $\alpha = 0.01$, $\alpha = 0.05$, and $\alpha = 0.01$ respectively (Appendix 1.2). Even though our sample size was too small for a comprehensive correlation analysis, the combination of interview results and our limited statistical test indicates the importance of transparency as a main factor driving deforestation rates at the local level.

2.5 Discussion

2.5.1 Key variables determining deforestation in Central Kalimantan

The results of our study show that the implementation of the decentralisation policy has changed the institutional arrangement of forest governance at the district level, both in the old and new districts. Most districts experienced lower scores for forest governance in 2005-2010 compared to the score in 2000-2005 (only Kapuas district could maintain the score at the same level). Hence, contrary to the objective of the decentralisation policies, our study shows that an improvement in forest governance at the district level in the period after the decentralisation could not be observed.

Law enforcement and consistency between the district and national forest policy have been identified as a significant driver for illegal deforestation in Indonesia (Palmer, 2000; Colfer and Capistrano, 2005). However, our analysis did not show a strong correlation between law enforcement and deforestation in the districts we sampled. This can either point to the lack of importance of law enforcement or, perhaps more probable given persistent reports of illegal logging in Central Kalimantan (Casson and Obidzinski, 2002) to the option that illegal logging takes place in all districts and is not strongly influenced by the differences in governance that are observable between districts in this province. Our interviews showed that there may be a general lack of transparency across the province in terms of the process followed by district forest officers to issue logging permits or stop illegal logging, even though differences between sites occur for example due to NGO or local citizens' activities (Casson and Obidzinski, 2002).

The notion that the dynamics of institutional arrangements for forest governance is a key underlying cause of deforestation is also captured in changes of forest policy and regulations in designated forest areas. Based on policy analysis of various legal documents released by the national government, we found changes in the designated forest areas, as well as designated areas for conversion forest in Central Kalimantan. An important finding from our policy analysis is that the provincial government is keen to promote the conversion of forest area to other land uses to support their development programme. The provincial government started with allocating approximately 27% of forests for conversion in 1993 (Provincial legislation No 5/1993 supported by the Letter of Ministry of Home Affairs No. 68/1994) and increased this to approximately 44% in the spatial planning proposal of 2007 (Table 2.3).

Our study has only analysed the quality of decentralised forest governance as an underlying cause of deforestation, and does not include other drivers of deforestation. Several studies show that the expansion of oil palm plantation is a major driver of deforestation in Indonesia (Butler et al., 2009; Boer et al., 2012). Oil palm expansion and governance are of course related, since the local government is one of the actors that issues permits for new plantations (Casson, 2001; McCarthy, 2004).

2.5.2 Deforestation impact and policy implications

Forests provide a range of valuable commodities (timber and non-timber) and other ecosystem services such as watershed protection, recreation, landscape beauty, climate stabilizer, carbon sequestration and genetic information storage (TEEB, 2010). Deforestation will lead to a reduction in the capacity of forest ecosystems to provide such services with associated impacts at local to global scales (Pagiola et al., 2002; Sunderlin et al., 2005; Lamb, 2011).

Deforestation in Central Kalimantan induces an additional environmental concern due to the wide occurrence of peatland forest. Peatland forest has a high capacity for storing carbon and maintaining hydrological functions. A very deep peat layer is able to store carbon up to 7,700 ton C per ha while converting peatland forest followed by drainage leads to high carbon emission up to 23 ton C per ha per year (Hooijer et al., 2010). In addition, the drainage of peatland will lead to soil subsidence of about 3 to 5 cm per year depending on drainage level and contributes to high risk of fires and flooding (Hooijer et al., 2010).

Considering the social and environmental consequences of deforestation, there is a need to examine how policies can be strengthened to enhance the quality of forest governance at the district level and ensure the implementation of better forest management practices. In order to meet these needs, we propose the following policy recommendations:

1. Revisit the decentralisation policy framework

The decentralisation policy plays a crucial role in forest and land management in Indonesia. The disconnection between theory and practice of decentralised forest governance is exemplified when dealing with land use management, based on Law No. 22/1999. The practical lack of congruence between this procedure and actual practice of granting permits has, in many districts, led to a lack of local participation and transparency in forest resource utilization. Hence, as also illustrated by our regression analysis, there is a need to enhance and enforce the requirements for stakeholder consultation and public hearings in forest management planning, with due consideration for the limitations of public hearings as an environmental management tool (Soma and Vatn, 2014). In addition, there is a need for establishing better procedures for public litigation. Litigation is an important tool in combating environmental degradation, particularly where state monitoring is suboptimal (Arnold, 2008). In particular, procedures for litigation should be established in forestry law as well as decentralisation laws. Finally, there is a need to carefully consider and streamline the responsibilities of the different government agencies in managing forests, in order to ensure that sufficient checks and balances are in place and that there are no overlapping mandates.

2. Support for Forest Management Units – FMUs (Kesatuan Pengelolaan Hutan – KPH).

The FMUs were initiated by the national government based on Ministry of Forestry regulations No. 6/2007 and No. 3/2008 on the establishment of forest systems, and the preparation of the forest management plan and forest utilisation (Kartodihardjo et al., 2011). The development of FMUs is meant to ensure that economic, environmental and social functions are sustainably implemented in forest management, as stipulated in Law No. 41/1999 on forestry and government regulation No. 44/2004 on forest planning. Hence, the FMU is a promising instrument that could help to improve forest governance. However, central government needs to facilitate and improve the integration and coordination between existing forest agencies at the district and provincial level and FMU (Bae et al., 2014). The budget and technical capacity of the FMUs also need to be improved. Our interviews, supported by the survey conducted by Bae et al., (2014), show that currently most FMUs operate under severe budget constraints (e.g. a lack of funds for transport, monitoring and enforcement). The technical staff also require training, for instance in community engagement. Sustainable funding from the district, province and national government needs to be safeguarded to ensure the continuity of the FMUs, and the cost of developing participatory management plans and their implementation should be covered by the district or province (in line with Government Regulation No. 6/2007 and Head of Forestry Planning Decree No. SK. 80/VII-PW/2006).

3. Facilitation of the development of new REDD$^+$ projects

The implementation of REDD+ provides economic incentives based on forest carbon credits that could make a significant contribution to reduce deforestation and forest degradation. REDD$^+$ could also provide innovative and stable forms of finance for local development programs, assist benefit distribution for community development through national and local government policies, and support the monitoring of forest cover and condition (Danielsen et al., 2011; Hoang et al., 2013). In order to make REDD$^+$ work, the enabling conditions need to be improved by establishing and implementing regulations for the Environmental Management and Protection Law, which are not yet in place. These laws include transparent permit procedures and regulations to avoid uncertainty for REDD$^+$ projects or programmes. Further, these laws could be used as the guideline to define the roles and mandates of local and central government, particularly in terms of clarifying the rights and responsibilities related to $REDD^+$. For investors, a key element will be to ensure that multi-stakeholder processes play a central role in $REDD^+$ design and implementation, and that sufficient time is allocated to stakeholders' involvement.

4. Better monitoring and sharing information on forest condition at the district level

Monitoring is a key aspect of sustainable forest management. Transparency in forest governance requires a long-term national forest monitoring system to achieve sustainable forest management, and reduction of deforestation and forest degradation (Fuller, 2006). The national forest monitoring system in Indonesia is being developed based on monitoring, reporting and verification requirements of the $REDD^+$ scheme. The system would provide real time data and information on forest cover, generated from high resolution satellite images in combination with field measurements. The information in this monitoring system should be made available not only to technical officers in the district and provincial government but also to other stakeholders (community organisation, NGOs, companies) in order to enhance transparency which we believe is a key factor in improving forest governance in Indonesia.

2.5 Conclusion

Deforestation is a function of complex interactions between natural, socio-economic and institutional processes. We examined the relationship between ten indicators of forest governance and district-level deforestation in Central Kalimantan, Indonesia. Our study in 11 districts indicates that local governance quality influences deforestation rates. A key factor appears to transparency of local procedures, as expressed by the number of public hearings and consultations the district organises in support of forest policy formulation and implementation. Furthermore, our study shows that decentralisation of Indonesian forest policies has, in the case of Central Kalimantan, led to a decrease in local governance quality and an increase in deforestation, over the period 2000-2010. In 10 out of 11 examined districts (the exception being Seruyan district), deforestation rates increased in the period 2005-2010 compared to the period 2000-2005. We recommend revisiting the Indonesian forest governance framework in order to ensure more checks and balances in decision making, better monitoring and increased transparency, with particular support for Forest Management Units as a new tool for forest management as well as for existing and new $REDD^+$ projects.

Acknowledgements

We would like to thank Hans-Peter Weikard, Roy Remme, Matthias Schröter, Alexey Pristupa and Morgan Mutoko for their constructive comments on the manuscript. We are grateful to Vu Vo Duc Hoang for assistance with the empirical data analysis, and to all of district's staff in 11 districts for their cooperation. This research has been made possible through ERC grant 263027 (Ecospace).

Chapter 3

Who benefits from ecosystem services?
A case study for Central Kalimantan, Indonesia

Published as:
A. Suwarno, L. Hein and E. Sumarga (2016). Who benefits from ecosystem services? A case study for Central Kalimantan, Indonesia. Environmental Management (57): 331-344

Abstract

There is increasing experience with the valuation of ecosystem services. However, to date, less attention has been devoted to who is actually benefiting from ecosystem services. This nevertheless is a key issue, in particular if ecosystem services analysis and valuation is used to support environmental management. This study assesses and analyses how the monetary benefits of seven ecosystem services generated in Central Kalimantan Province, Indonesia, are distributed to different types of beneficiaries. We analyse the following ecosystem services (1) timber production; (2) rattan collection; (3) jelutong resin collection; (4) rubber production (based on permanent agroforestry systems); (5) oil palm production on three management scales (company, plasma farmer and independent smallholder); (6) paddy production; and (7) carbon sequestration. Our study shows that the benefits generated from these services differ markedly between the stakeholders, which we grouped into private, public and households entities. The distribution of these benefits is strongly influenced by government policies and in particular benefit sharing mechanisms. Hence, land use change, and policies influencing land use change can be expected to have different impacts on different stakeholders. Our study also shows that the benefits generated by oil palm conversion, a main driver for land use change in the province, are almost exclusively accrued by companies and at this point in time are shared unequally with local stakeholders.

Keywords:

Ecosystem services, beneficiaries, benefits, ecosystem accounting, ecosystem management

3.1 Introduction

Ecosystem Services (ES) are increasingly recognised as a concept that can be used to assess the benefits humans derive from ecosystems in support of ecosystem management (Millenium Ecosystem Assessment (MA), 2005). The concept of ES is broadly defined as the contributions of ecosystems to economic and other human activity (TEEB, 2010; UN et al., 2013; Haines-young & Potschin, 2013). Benefits from ES are not just a function of ecosystem dynamics, but also a function of the socio-economic system (i.e. governance system, markets and informal land use) (Fisher et al., 2008). Identification of benefits and beneficiaries from ES is paramount to identify enhanced ecosystem management options (Kettunen et al., 2009).

Several studies have described the concept of beneficiaries and stakeholders of ES for spatial range and specific ecological and economic processes (Hein et al., 2006; TEEB, 2010; Bagstad et al., 2014). Studies on how ES benefits received by beneficiaries are altered due to land use change in several countries have also been conducted from a regional (Tomich et al., 2004; Law et al., 2014) to global scale (Lambin et al., 2003; Howe et al., 2014). However, there is still insufficient insight in how different stakeholders benefits from different types of ES, and what this means for ecosystem management (Daily et al., 2009)

The objective of our study is to analyse the benefits of seven ES in Central Kalimantan Province, Indonesia, and to examine how these benefits are distributed to different types of beneficiaries. Our study was conducted in three steps: First, we defined the beneficiaries based on the spatial range of ES, related to specific ecological and economic processes (Hein et al., 2006; Bagstad et al., 2014). Second, we calculated the monetary benefits of ES based on ecosystem accounting (UN et al., 2014). Third, we analysed the benefits received by different types of beneficiaries among others based on existing government regulations in the forestry and agricultural sectors. Further, we analysed the potential gains and losses of land use changes through the calculation of total benefits of ES and the estimation of damage costs of CO_2 emissions (Interagency Working Group on Social Cost of Carbon, 2013).

We use the ecosystem accounting framework as the methodological framework for our study. Ecosystem accounting is a new area of environmental economic accounting that aims to measure ecosystem capital in a way that is consistent with national accounts (Boyd & Banzhaf, 2007; UN et al., 2014, 2013; Edens & Hein, 2013). Ecosystem accounting provides a framework for analysing ecosystem condition, ecosystem service flow and ecosystem assets, using a set of physical and monetary indicators. This approach analyses the monetary value of production and consumption based on exchange values at 'arm's length'. Contrary to welfare-based valuation approach, it does not include consumer surplus.

The innovative aspects of our study are: (1) the implementation of an ecosystem accounting approach to determine the monetary benefits of ES received by the different groups of beneficiaries and (2) linking this information to support ecosystem management. Given the importance of ES benefits in supporting ecosystem management, from the results of this study we aim to provide valuable input to establish ecosystem management in Central Kalimantan Province.

3.2 Methodology

3.2.1 Study area

This study was conducted in Central Kalimantan Province, Indonesia (Fig 3.1). The province covers an area of approximately 15.4 million ha, of which 12.7 million ha are designated forest (Ministry of Forestry, 2011). The total population in 2010 was 2.15 million, with a population density of 14 people per km^2. In terms of local GDP, forest and agriculture (particularly oil palm) are the most important sectors. The forests and peatlands of Central Kalimantan are part of the biodiversity hotspot of Borneo's forest and believed to be among the most species-rich environments in the world (Whitten et al., 2004). They provide vital ecosystem benefits on a local, regional and global scale including livelihood products (e.g. timber and non-timber products) (Meijaard et al., 2013); cultural services (e.g., nature recreation) (Hernández-Morcillo et al., 2013; Plieninger et al., 2013); and regulating services (e.g., storage of vast amounts of carbon stock) (Paoli et al., 2010; Leh et al.,2013). However, rapid deforestation to further agricultural and silvicultural development, particularly oil palm, in Central Kalimantan has been a salient issue over the last decade. From 2000-2008 the province lost approximately 0.9 million ha of forest (Koh et al., 2011; Broich et al., 2011b). Some studies indicated the expansion of oil palm plantation as the main driving factor of deforestation in this province (Koh et al., 2011; Boer, et al., 2012). The oil palm expansion in Central Kalimantan Province has been one of the fastest in Indonesia in the period 2000-2010 (Broich et al., 2011; Koh et al., 2011; Gunarso et al., 2013).

3.2.2 Identification of beneficiaries and stakeholders

ES stakeholders can be defined as any group of individuals who can affect or are affected by the ecosystem's service (Hein et al., 2006). ES beneficiaries benefit from ecosystem goods or services either through active or passive consumption, or through simple appreciation resulting from the awareness of these services (Harrington et al., 2010; Nahlik et al., 2012). The distinction between stakeholder and beneficiary is related to the ability to influence ES provision and the dependency on the ES. Each beneficiary should be considered a stakeholder (Hein et al., 2006; Rastogi et al., 2010), but not all stakeholders are necessarily beneficiaries.

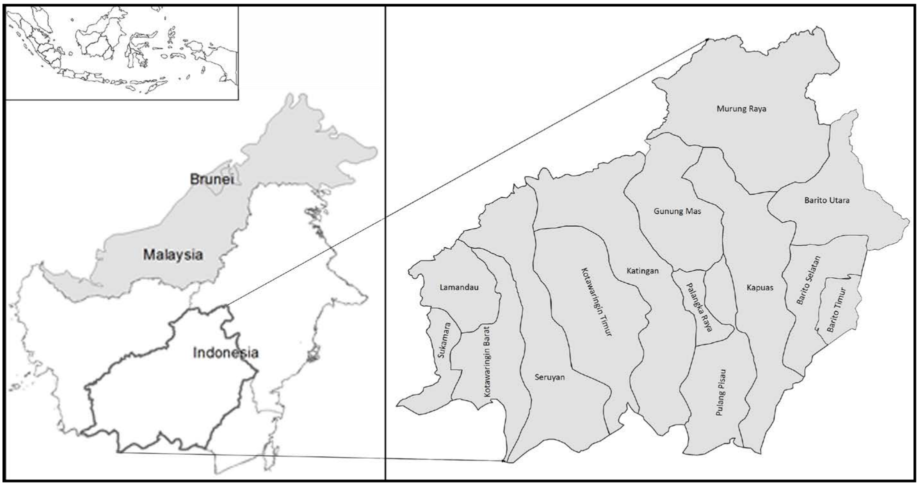


Figure 3-1 Case study area

The ES benefits vary depending on the type of their individual characteristics, spatial scale and distance between production area and the location of beneficiaries (Fisher et al., 2008; Bagstad et al., 2014). In this study, we grouped beneficiaries based on spatial extent and bio-economic-process to be consistent with the beneficiaries' concept in the System of National Accounts (SNA). The beneficiaries of ES are then grouped into: (1) private (large companies, small medium enterprises and smallholder with hired labour); (2) public (governmental agencies at various levels); and (3) household entities as presented in Table 3.1.

In this study, we selected six provisioning and one regulating services which are important for the livelihood of local people and the economic development in the district and the province. These seven ES include: (1) timber production; (2) rattan collection; (3) jelutong resin (*Dyera costulata*) collection; (4) rubber (*Hevea brasiliensis*) production (based on permanent agroforestry system); (5) oil palm production on three management scales (company, plasma farmer and independent smallholder); (6) upland paddy production; and (7) carbon sequestration. In this study, we also include the analysis of nature recreation in Tanjung Puting National Park due to its importance for the livelihood of local people living around this national park. Further, we also include the analysis on orangutan habitat as a global concern.

3.2.3 Valuation of ecosystem services

The benefits of the provisioning services in this study are assessed in monetary terms. We applied the valuation approach of ecosystem accounting (UN et al., 2014). Ecosystem accounting is the approach used to measure ecosystem capital in a way that is consistent with the national accounts (Edens and Hein, 2013; UN et al., 2014). Ecosystem accounting

Table 3.1. Ecosystem Services and their key beneficiaries analysed in this study (Adopted from Haines & Young (2013))

ES Category	ES Sub-Category	ES Benefit Domain	Beneficiaries		
			Private (large companies, SMEs, smallholders with hired labour)	Public (Government agencies at various levels; global communi-ties)	Household
Provisioning	Traditional agriculture	Upland paddy production			Paddy farmer
		Rubber production under permanent agro-forestry system			Rubber farmer
	Intensive agriculture	Oil palm production	Oil palm companies Independent smallholders		Plasma farmer Local community
	Forest harvesting	Timber production	Logging company	Government at district, provincial and national level	Local community
		Non Timber Forest Products (NTFP) (Rattan collection)		Government at district level	Rattan collector
		NTFP - Jelutong resin collection		Government at district level	Jelutong resin collector
Regulating	Climate regulation	CO_2 sequestration		Government at district, provincial and national level; Global community	Local community at the village

involves an extension of the production boundary of the system of national accounts (SNA) to assess the capital of ecosystems based on their flow into economic and other human activities (UN et al., 2014; Hein et al. 2015). This approach allows for the inclusion of a broader set of ecosystem service types (i.e. regulating services) and the natural growth of biological assets in the accounts (UN et al., 2014).

In this study, we analysed the net benefits of ES that are traded in the market (timber, rattan, jelutong resin, agroforestry rubber, oil palm and paddy) expressed as an annual resource rent (RR). The annual RR has been valued by analysing the market price and deducting the total costs (intermediate, employment and user production cost) (Edens and Hein, 2013). Considering the different time dimensions of the investment in ecosystem capital, we applied an ordinary annuity approach to calculate the annual RR of oil palm and agroforestry rubber production to make these services comparable. The annual RR was calculated from the net present value (*NPV*), which is the sum of the discounted revenues *R* minus cost *C*.

$$NPV = \sum_{t=1}^{T} (R_t - C_t)(1 + i)^{-t} \qquad \text{...}(1)$$

The *NPV* can be transformed into an annual payment A

$$A = NPV \cdot \frac{i(1 + i)^T}{(1 + i)^T - 1} \qquad \text{...}(2)$$

where A is annual RR, *T* is the life time of the investment, and *i* is the discount rate, which is set at 10% in our study (Based on Sumarga et al., (2015)).

In this study we also analysed the benefits of carbon sequestration (as the regulating service) based on the marginal social damage costs (Tol, 2005) expressed as the social cost of carbon (SCC). The SCC is "an estimate of the monetized damages associated with the increment increase in carbon emissions in a given year" (Interagency Working Group on Social Cost of Carbon, 2013). Since these marginal damage costs give a present value of future damage cost estimates, the discount rate plays an important role in determining the marginal damage costs. The SNA (UN et al., 2014) indicates that discounting should take place with market discount rates. In order to capture the public goods character of carbon damages we apply a social discount rate of 3% (Interagency Working Group on Social Cost of Carbon, 2013). Consequently, we used an SCC value for 2010 at USD 32 per ton CO_2 that is equivalent to € 24 per ton CO_2 (€ 88 per ton C) with an exchange rate of USD $ 1.33 for € 1 (average in 2010).

The main data and information used in this study were mostly obtained from previous studies (2008-2010) and field work in 2012, as presented in Table 3.2. These secondary data include the information for economic analysis, the potential production of each service per year (yields) and macroeconomic parameters in 2010.

Table 3.2. Details of the data used in this study

Ecosystem service	Remark	Sources
Timber production	Financial report Performance of logging activities	Two logging companies; Setiawan et al. (2011)
Rattan collection	Economic analysis Potential yield per ha	Iwan (2008); Martoniady (2009)
Jelutong resin collection	Economic analysis Potential yield per ha	Sapiudin (2009); Budiningsih and Effendi (2013)
Agroforestry rubber production	Economic analysis Potential yield per ha	Herman et al., (2009); Suyanto et al., (2009)
Upland paddy production	Economic analysis Potential yield per ha	Nugroho (2008); Yandi (2008)
Oil palm production	Economic analysis Potential yield per ha	Two oil palm companies; Iksan and Abdussamad (2010); Ismail (2010); Boer et al., (2012)
Carbon sequestration	Potential CO_2 emission Social Cost of Carbon	Sanchez (2000); Agus et al., (2009); Hooijer et al., (2010); Lim et al., (2012); Carlson et al., (2012b); Carlson et al,.(2012c); Interagency working group on social cost of carbon (2013); Agus et al,. (2013); Gunarso et al., (2013)

3.2.4 Allocation of benefits to different types of beneficiaries

Beneficiaries receive benefits from ES through different mechanisms. The allocation of benefits from ES received by beneficiaries was analysed to explore the way benefits are shared between private, public and household beneficiaries based on the framework presented in Figure 3-2. The allocation of benefits to private entities was based on the annual net benefits. The allocation of benefits to household entities was based on annual benefits plus wages. The shares of the benefits public entities received from ES were calculated based on relevant public finance regulations applied at different levels of government. For instance, the share of benefits from timber production that public entities received at the district level was based on Government Regulation (PP) No.55/2005 concerning the procedure for governing timber and non-timber forest products and Law No.33/2004 concerning financial aspects of decentralisation. These regulations determine taxes, including tax on timber and a land tax, and fees for extracting timber and non-timber forest products both from natural forests and plantation forests. Public finance regulations covered in this study are presented in Table 3.3.

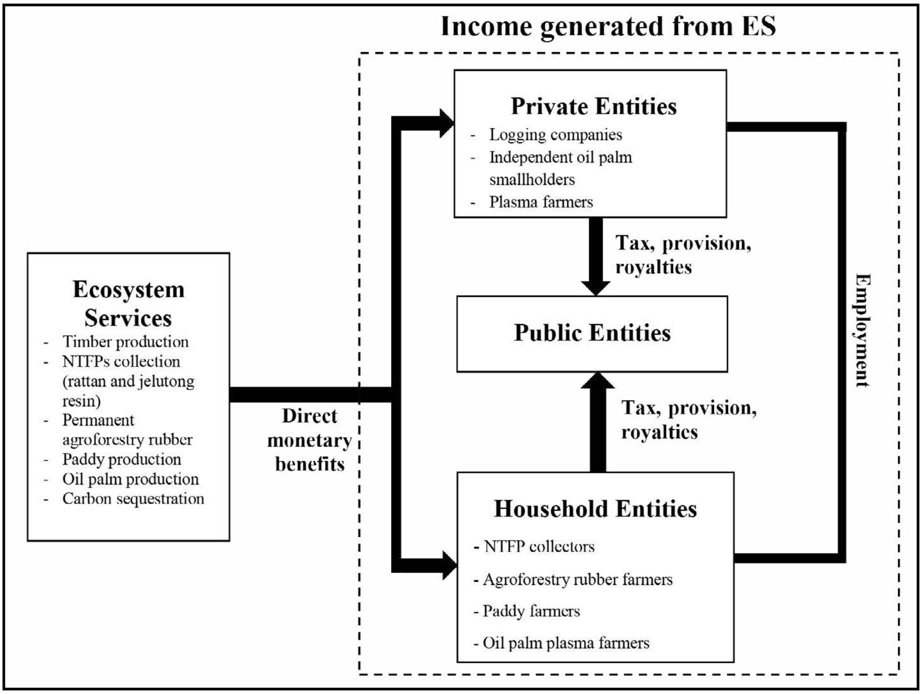


Figure 3-2 Income generated from ES by different groups of ES beneficiaries

3.2.5 Potential benefits in different land uses

We explored the total monetary benefits private, public and household beneficiaries received from different land uses. The total monetary benefits for each land use type were derived from the sum of the monetary benefits beneficiaries received. The calculation of potential loss from carbon emissions was conducted based on marginal damage costs, capturing the cost of emitting a ton of carbon (CO_2). We applied the social cost of carbon (SCC) value for 2010 at € 24 per ton CO_2, based on an assumed discount rate of 3% (Interagency Working Group on Social Cost of Carbon, 2013).

3.3 Results

3.3.1 Monetary benefits generated by ecosystem services

Provisioning services

Compared to the other provisioning services that we analysed, oil palm production provides the highest net benefit per ha, however it also leads to significant societal costs related to CO_2 emissions, in particular when oil palm is cultivated on peatland.

Table 3.3. Legal framework in relation to taxes, provisioning, royalties and benefit distribution

Services	Legally binding on public policies
Timber	Law (UU) No. 33/2004 Government Regulation (PP) No. 55/2005
Rattan	Government Regulation (PP) No. 55/2005
Jelutong resin	Government Regulation (PP) No. 55/2005
Permanent agroforestry rubber	Government Regulation No. 7/2007
Paddy	Government Regulation No. 7/2007
Oil Palm	Government Regulation (PP) No. 7/2007

Oil palm production on peatland generates an annualised resource rent for company, smallholder and plasma farmer of € 683 per ha per year, € 395 per ha per year and € 451 per ha per year, while on mineral soil this is € 902 per ha per year, € 537 per ha per year and € 765 per ha per year respectively. This difference reflects that the production costs, in particular for plantation establishment, are higher for peatland.

Timber production, both on peatland and mineral soil, generates a resource rent of, on average, € 30 per ha per year. This relatively low value indicates that most of the forests in Central Kalimantan have been heavily logged in the past, and that many of the commercial timber species (e.g. *Gonystylus bancanus* and *Eusideroxylon zwageri*) have already been harvested. The benefits from other forest products, in particular rattan and jelutong resin are considerably higher, on average, for the forest areas in Central Kalimantan, € 82 per ha per year for rattan and € 83 per ha per year for jelutong. However, generation of the resource rent from these products is concentrated in the areas where there is active management and harvest of rattan or jelutong. In these areas, production can be as high as 1.3 ton per ha per year for rattan and 0.5 ton per ha per year for jelutong (in case enrichment planting of rattan or jelutong trees respectively has been carried out) (Sapiudin, 2009). The resulting resource rent generated per ha, in these cases, amounts to € 110 per ha per year for rattan, respectively € 157 per ha per year for jelutong.

Rubber production captured in this study is produced under a permanent agroforestry system with an average yield of about 0.67 ton per ha per year for the mineral soil and 0.54 ton per ha per year for the peatland (Suyanto et al., 2009). Agroforestry rubber production on the mineral soil provides a net benefit of € 112 per ha per year, while production on peatland provides a net benefit € 47 per ha per year.

Paddy is the most important food crop produced in this province. It is mainly grown by transmigrants who originally came from Java or Sumatra, although traditionally the Dayak 'Ngaju' in the provinces of Central and West Kalimantan, have been practicing swidden rice cultivation for many generations (de Jong, 1995). The average production

Table 3.4. Annual resource rent from provisioning services

Soil type	Ecosystem services	Yield (m^3 per ha per yr; ton per ha per yr)	Price (€ per m^3; € per ton)	Gross revenue (€ per ha per yr)	Production cost (€ per ha per yr)		Value added (€ per ha per yr)	Labour cost (€ per ha per yr)	Resource rent (€ per ha per yr)
					Interme-diate cost (€ per ha per yr)	User cost of fixed asset (€ per ha per yr)			
Peat land	Timber	0.86	118	101	62	0	39	9	30
	Jelutong	0.28	342	96	6	0	90	7	83
	Rubber	0.54	500	270	7	0	263	216	47
	Oil Palm (company)	19	123	1,997	778	112	1,107	424	683
	Oil Palm (smallholder)	12	123	1,278	403	164	711	316	395
	Oil Palm (plasma farmer)	16	123	1,697	701	189	807	356	451
	Paddy	1.7	238	405	80	6	319	135	184
Mineral soil	Timber	0.86	118	101	62	0	39	9	30
	Jelutong	0.79	145	115	16	0	99	17	82
	Rubber	0.67	500	335	7	0	328	216	112
	Oil Palm (company)	19	123	1,997	637	84	1,276	374	902
	Oil Palm (smallholder)	12	123	1,278	338	123	817	280	537
	Oil Palm (plasma farmer)	16	123	1,697	471	142	1,084	318	766
	Paddy	2.22	238	528	87	7	434	147	287

of paddy in this area is about 2.2 ton per ha per year on the mineral soil, and 1.7 ton per ha per year on the peatland. Paddy production generates an average resource rent of € 287 per ha per year on mineral soil and € 184 per ha per year on peatland. The large majority of paddy production in Central Kalimantan is used for local consumption.

Details of the results of the analysis on net benefits from provisioning services are presented in Table 3.4.

Regulating services (Carbon sequestration)

The result of our analysis on monetary benefits from carbon sequestration shows that conversion of forest areas on the peatland and mineral soil to oil palm plantation provides the lowest benefits due to high CO_2 emissions. Potential CO_2 emission from

Table 3.5. Potential CO_2 emissions and its Social Cost of Carbon (SCC)

Soil type	Land use	CO_2 emission (ton per ha per yr) (- indicates emission, + is sequestration)	SCC
Peatland	Forest	19.4	465.6
	Agroforest	-14.4	-345.6
	Oil palm plantation	-85	-2040
	Agriculture	-27.3	-655.2
Mineral soil	Forest	13.6	326.4
	Agroforest	7.3	175.2
	Oil palm plantation	-25	-600
	Agriculture	7.3	175.2

converting forest to oil palm in the peatland is about 85 ton per ha per year and on mineral soil is about 25 ton per ha per year. The resulting monetary benefits generated per ha, in these cases, amount to € -2,040 per ha per year for the peatland and € -600 per ha per year for mineral soil respectively. These results show that converting forest area to oil palm plantation will increase the potential CO_2 emission, which have become a global public concern. Detail on potential CO_2 emissions and SCC analysed in this study is presented in Table 3.5.

3.3.2 Benefits from employment

The monetary benefits beneficiaries receive from ES as employees or household entities are defined by the number of person working days per ha and wages per person per working day. In this study, we are concerned with farmers' paddy and oil palm production (under plasma) based on the household system, which mainly 'employs' family members. Ecosystem accounting required deducting actual or implemented cost for labour, also in case the labour is provided by the farmer himself (UN et al., 2014; Obst et al., 2015). In order to keep the calculation in line with the ecosystem accounting methodology, we calculated the employment costs for these services based on the number of person days of family labour used per ha per year and multiplied this by the local average daily wage.

The results of our analysis show that in terms of the number of working days per ha, oil palm plantation under companies provides the highest number of person days (107 person days per ha per year), while timber production provided the lowest (0.7 person days per ha per year). On the other hand, in terms of wages, timber production provides the highest wages (€ 13 per person per day), while the lowest wages are provided by paddy production (€ 3 per person per day). The details of the benefits beneficiaries received for employment are presented in Table 3.6.

Table 3.6. Benefits beneficiaries received for employment

Ecosystem services	Number of person days per ha	Wages (€ per person day)	Wages (€ per ha)
Timber	0.7	13	9
Rattan	3.1	5.4	17
Jelutong resin	1.2	5.8	7
Rubber	54	4	216
Paddy	49	3	147
Oil palm			
Smallholder	80	3.5	280
Plasma	91	3.5	318
Company	107	3.5	374

3.3.3 Potential net benefits and loss of ES received by beneficiaries from different types of land use

The change of forest to other land use will influence the supply of ES. Our analysis shows that the change of forest to other land use, particularly oil palm plantation, can potentially increase income for the sectors households and industry. However, it is important to note that within the household sector there may be important differences between costs and benefits accruing to different groups of people. For example, Dayak groups have in some cases sold (sometimes very cheaply) or lost their land to independent smallholders or oil palm companies. In this case, they have lost the opportunity of gaining benefits from other ES without adequate compensation, even though they may still receive benefits from oil palm production through employment. However, not all local people can be employed on the plantations (McCarthy et al., 2012; Palupi, 2014) and wages for casual labour are relatively low (€ 3.5 per day; see Table 3.6).

The conversion of forest to oil palm plantation, particularly on the peatland, generates high CO_2 emissions. Estimates for the CO_2 emissions resulting from oil palm development on peatland range from 875 to 2,125 ton per ha for the total period of 25 years, equal to 35 – 85 ton per ha per year (Herman et al., 2009; Agus et al., 2010; Hooijer et al., 2010; Lim et al., 2012; Carlson et al., 2012a; Carlson et al., 2012b; Couwenberg and Hooijer, 2013). This results in social costs ranging from € -840 per ha per year to € -2,040 per ha per year. On the other hand, a permanent agroforestry system on peatland may generate lower monetary benefits but also leads to much lower CO_2 emissions. CO_2 emissions from agroforestry systems strongly depend on type of agroforestry and drainage depth (if any drainage is applied). They vary from a small capture of carbon to net CO_2 emissions of 14.4 ton CO_2 per ha (average from Sanchez, 2000; Agus et al., 2013). We do not consider methane emissions from paddy fields in our study since all paddy fields in the study area are upland fields that do not cause methane emissions (Inubushi et al., 2003; Hadi et al., 2012). The results of our analysis on potential annual benefits received by private, public and household entities, as well as potential losses due to the estimated CO_2 emissions, are presented in Table 3.7.

Table 3.7. Potential monetary benefits from ES, its distribution to beneficiaries and environmental loss of land use change

Soil Type	Land use	Ecosystem Services	Household (€ per ha per yr)					Private (€ per ha per yr)					Public (€ per ha per yr)				
			Production cost	Employment	Benefit sharing	RR	Total (RR + Employment + Benefit sharing)	Production cost	Tax	Benefit sharing	Revenue	RR	Tax	Benefit sharing	CO_2 emission (- indicates emission, + is sequestration) (tonCO2 per ha per yr)	SCC	Total
Peatland	Forest	Timber		9	0.2[1]		9.2	-62	-17.8[2]	-0.2	101	30	17.8[2]				
		Jelutung	-6	7		83	90								19.4	466	
		Carbon sequestrattion															492
	Agroforesty	Rubber	-7	216		45	261								-14.4	-346	-346
	Oil palm plantation	FFB (Company)		424			424	-890	-26[5]		1997	683	26[5]				
		FFB (Smallholder)		361			316	-576			1278	395			-85	-2040	-2014
		FFB (Plasma Farmer)		356			356	-890			1697	451					
	Agricultural land	Paddy production	-86	135		184	319								-27.3	-655	-655
Mineral soil	Forest	Timber		9	0.2[1]		9.2	-62	-17.8[2]	-0.2	101	30	17.8[2]				
		Rattan	-16	17		82	99						12[4]		13.6	326	351
		Carbon sequestrattion															
	Agroforesty	Rubber	-7	216		112	328								7.3	175	175
	Oil palm plantation	FFB (Company)		374			374	-721	-2.6[5]		1997	902	26[5]				
		FFB (Smallholder)		280			280	-461			1278	537			-25	-600	-574
		FFB (Plasma Farmer)		318			318	-613			1697	766					
	Agricultural land	Paddy production	-84	289		147	436								7.3	175	175

[1,2,3,4] Based on Government Regulation No. 55 per 2005

[5] Land acquisition, paid once for 25 years (Boer et al., 2012)

3.4 Discussion

3.4.1 Who benefits from ecosystem services?

People obtain benefits from ecosystems in different ways. Our analysis of six provisioning and one regulating service in Central Kalimantan Province shows the monetary benefits received by different stakeholders. This study shows that upland paddy production provides the highest monetary benefits to household entities, while private and public entities receive most from oil palm and timber production. This study also shows how the monetary benefits from timber, NTFPs (rattan and jelutong resin) and agroforestry rubber are distributed to private, households and public entities.

NTFPs and agroforestry rubber are the main source of local livelihoods in Central Kalimantan (Meijaard et al., 2013; Abram et al., 2014). However, the decrease in forest quality and agroforestry rubber areas has consequently decreased the stock of NTFPs and agroforestry rubber, and influences the monetary benefits received by household and public entities.

Oil palm production is a profitable venture in the case study area, in spite of fluctuations in market prices. Stakeholders have increasingly converted forest and agroforestry area to oil palm plantation, and have neglected the NFTPs and agroforestry rubber. The local government has seen oil palm plantation as an opportunity for economic development in their area through the increase in the number of jobs and local people see it as an employment opportunity. In addition, the national target for crude palm oil production has also supported this interest and caused an increase in the expansion of oil palm plantation in Indonesia.

The expansion of oil palm in Indonesia has been criticized locally and internationally. One of the criticisms in economic and social terms is related to the disadvantaged position of local communities when negotiating land transactions and business arrangements (Sirait, 2009; McCarthy & Cramb, 2009; Rist et al., 2010; Larsen et al., 2012; Obidzinski et al., 2012; Budidarsono et al., 2013; Dehen et al., 2013). An assessment of the characteristics of the private entities connected to oil palm production reveals that this activity is dominated by stakeholders with a high capital outlay, due to the high cost of establishing oil palm plantations. The cost of establishing an oil palm plantation in the first 3 years, on an independent smallholder scale, can be between € 428 per ha per year and € 862 per ha per year (Iksan and Abdussamad, 2010; Boer et al., 2012;). The break-even point can only be achieved with a minimum of 3 ha, assuming that smallholder farmers sell the fresh fruit bunches (FFB) at the farm gate (Boer et al., 2012; Budidarsono et al., 2013). Smallholders with the capital to establish oil palm are likely middle or upper class individuals with a close relationship with either an oil palm company or a key person at the district, provincial or national level (Rist et al., 2010; Larsen et al., 2012; Dehen et al., 2013). Hence, the monetary benefits from oil palm production are mostly gained by companies and the elite with only a small share of the benefits going to the local communities and government through public regulations.

At the same time, some of the costs associated with palm oil production (traffic, road maintenance and local externalities of oil palm plantations such as reduced access to the forest) occur at the district level. In addition, the rapid expansion of oil palm plantation in Central Kalimantan has also increased social conflicts associated with labour allocation (Rist et al., 2010; Dehen et al., 2013). Oil palm cultivation requires special skills that are more frequent among migrant smallholders with prior exposure to oil palm rather than for the local community with no prior experience. This has caused exclusion of local people from this kind of work. The change in regulations governing partnerships in oil palm plantations, due to the establishment of Ministry of Agriculture Regulation No. 98/2013 that replaced Regulation No.5/2011, has also created problems related to tenure and arrangements concerning plasma systems (McCarthy et al., 2012; Potter, 2012). According to this new regulation, the plantations can no longer allocate 20% of their concessions for plasma farming; they must find this outside their concession. This regulation is extremely difficult to implement in Central Kalimantan Province, since most of the recent transmigrants have become independent smallholders. Hence, plantations prefer to buy up Dayak land for inadequate levels of compensation to meet this regulation, which eliminates the opportunity for Dayak groups to receive other ES benefits, other than casual day labour (Palupi, 2014). Problems related to environmental degradation have also increased due to the impact of oil palm expansion on deforestation, soil subsidence, hydrology and climate change (Sauerborn, 2008; Kimberly M. Carlson et al., 2012; Germer and Larsen et al., 2012b; Yamamoto and Takeuchi, 2012), see also the related work of Sumarga and Hein (2014) and Sumarga et al., (2015) in the same area.

3.4.2 Potential benefits and losses when changing a forest ecosystem to a monoculture plantation

Ecosystem services trade-offs arise from management choices made by humans, who intentionally change the type, magnitude, and relative mix of services provided by an ecosystem. Trade-offs occur when the provision of one ecosystem service is reduced as a consequence of increased use of another (Rodríguez et al., 2006). A common pattern of provisioning services is that they compete with each other (Tilman et al., 2002; Rodríguez et al., 2006). For example, an increase in oil palm production will reduce the timber and NTFPs production when oil palm is planted and replaces the forest.

Our analysis on potential benefits and losses in different land-uses shows that the conversion of forest to oil palm plantation will increase the monetary benefits received by private and household entities, and decrease the monetary benefits received by public entities due to the absence of a regulation governing the FFB. The conversion of forest to oil palm plantation will also reduce the potential monetary benefits from nature recreation. Our interview with stakeholders in Tanjung Puting National Park shows that this national park has generated the highest number of visitors (since visitors have been recorded) among all the national parks in Central Kalimantan. In 2010, the number of foreign visitors reached 8,422 and domestic visitors 2,343. The report from Tanjung Puting National Park shows that in 2010, this national park has contributed € 612,578 to the local economy and € 51,471 to the national government (BTNTP, 2012). However, the establishment of oil palm plantation around the buffer zone of this national park has become a salient issue that might reduce the environmental quality of Tanjung Puting National Park and consequently influence the number of visitors. Our interviews with 50 boat operators and 150 tourists, during the period July to September 2012, also show the high concern about the water quality of the Sekoyer River. The reduction in water quality is due to the recent establishment an oil palm plantation (in 2011) in the buffer zone of Tanjung Puting National Park. Most of the tourists (125 of 150) stated that they were upset about this environmental condition and most of the boat operators (35 of 50) thought that it would reduce the number of tourists visiting this national park in the future.

In environmental terms, converting forest to oil palm plantation will increase the environmental risk of deforestation, soil subsidence and carbon emissions, as well as decrease of biodiversity and the quality and quantity of river water (Germer and Sauerborn, 2007; Hooijer et al., 2012; Agus et al., 2013; Azhar et al., 2014). As we show, the social costs related to CO_2 emissions from oil palm in peat are higher than the total benefits private and public beneficiaries receive from oil palm production (cf. Sumarga et al., 2015).

The conversion of forest to oil palm plantation will also reduce the habitat of many endangered species such as the orangutan. The orangutan is an endangered species listed in appendix 1 of the Convention on International Trade in Endangered Species (CITES) for flora and fauna. It is Asia's only remaining great ape, living only in Borneo and Sumatera (Nellemann et al., 2007). Moreover, Central Kalimantan is likely to have the world's largest population of orangutan at the provincial level. The total population of wild orangutan in this province is about 33,000 individuals and 61% of them occur in protected areas (Wich et al., 2008). Based on the unique place of Central Kalimantan as home to some 50% of the remaining orangutan in the wild, maintaining the habitat for this species should be of special concern in particular in this province.

3.4.3 Policy implications

The establishment of policy instruments in natural resource management is vital when governing the distribution of ES benefits to private, public and household entities. These instruments may not only ensure the sustainability of local livelihoods but also secure environmental funding that could be used to explore alternative and sustainable sources of financing ES management (Kettunen et al., 2009). For example, a reforestation fund from timber production could be used to cover reforestation costs of degraded forest areas.

Forest degradation and biodiversity loss has increased the awareness of the need to improve sustainable forest and land management in Indonesia. In response to that awareness, the government of Indonesia has released various regulations on sustainable forest management to govern the extraction of timber and NFTPs (including carbon sequestration), as well as nature recreation. The extraction of timber, both from natural forest and/or plantation forest, must be conducted according to certain regulations concerning reforestation funds, taxes on forest resources and fees for concession permits. The national government also released a regulation governing the system for NTFPs collection and tariffs for entering a national park.

Considering the rapid deforestation and expansion of oil palm in Indonesia, it is very important to analyse the contribution of ES to forest ecosystems. Our analysis shows that timber and NTFPs have provided the highest benefits to public entities through Government Regulation No. 55/2005 on sustainable forest management. This regulation governs reforestation funds, taxes on forest resource and fees for timber concession (both from natural forest and per or plantation forest) and NTFP collection. However, the change in the value added tax status of agricultural products in Government Regulation No. 12 per 2001 has eliminated any contribution from oil palm production to the public budget. In this regulation fresh fruit brunches is listed as a non-taxable agricultural products, and the plantations (both companies and households) are only required to pay the cost of obtaining land cultivation rights (Hak Guna Usaha – HGU) of about € 208 to € 333 per ha for 25 years and a land and building tax (PBB) of about € 10 to € 15 per ha per year (Boer et al., 2012).

The public finance regulation applied to the palm oil sector is the tax on exporting crude palm oil, kernel palm oil and their derivative products. The export tax on these products is governed by the Ministry of Finance Regulation No. 67/Pmk.011/2010, based on Annex No II of the Ministry of Finance Regulation No. 223/Pmk.011/2008. The export tax is calculated in a progressive way, based on international prices of these products in Cost, Insurance and Freight (CIF) Rotterdam. The export tax on crude palm oil, kernel palm oil and its derivative products is amended annually by the national government to increase the national revenue from the palm oil sector. However, this revenue is not distributed to the district and provincial governments. Considering the high cost of maintaining the infrastructure in the district, particularly roads (due to heavy loads transporting crude palm oil and kernel palm oil), a request for a proportion of the income, from the import per export tax on crude palm oil and kernel palm oil, to be directed to the producing district, was released by the Association of Indonesian District Government (Asosiasi Pemerintah Kabupaten Seluruh Indonesia – APKASI) at their meeting on 5 July 2014.

In order to support the sustainable production of agricultural products and address the environmental problems caused by the conversion of forest to monoculture plantations, there is a need to set up another policy instrument to govern the benefit distribution from the agricultural sector, particularly oil palm. This policy instrument should capture environmental aspects on sustainable oil palm production and secure the rights of local and poor people who depend heavily on forest ecosystems, in which the forests area are converted to oil palm plantation. It is also important to revisit the financial regulation in this sector, to ensure that the monetary benefits received by public entities.

3.5 Conclusions

This study assesses and analyses the monetary benefits of seven ES in Central Kalimantan, and how these benefits are allocated to different types of beneficiaries. This study shows that oil palm production provides the highest monetary benefits to private entities and lowest to public entities and local indigenous households, particularly Dayak groups. The benefits generated by this service are almost exclusively accrued by companies with at this point in time very little if any benefit sharing with local stakeholders, in particular when the local costs of oil palm expansion are considered. Considering oil palm plantation establishment as one driver of land use change, there is a need to set up additional policy instruments to govern the sustainability of this product and to ensure that the monetary benefits are received by public entities through a tax schedule. This policy instrument should reflect the environmental indicators for sustainable palm oil production and secure the rights of local and poor people who depend heavily on forest ecosystems. In addition, it is also important to link up with the international carbon system in securing the economic incentives under REDD^{++} schemes, particularly if the government and communities decide to conserve forest instead of converting them to oil palm plantation.

Acknowledgements

We would like to thank Hans-Peter Weikard, Matthias Schröter, Roy Remme and Morgan Mutoko for their constructive comments on the manuscript. This research has been made possible through ERC grant 263027 (Ecospace).

Chapter 4

Effectiveness of forest motarorium policies in reorienting land-use change in Indonesia:

A multi-agent model

Based:

A. Suwarno, M. van Noordwijk, H.-P Weikard and D. Suyamto (2016). Effectiveness of forest moratorium policies in reorienting land-use change in Indonesia: A multi-agent model. Mitigation and Adaptation Strategy for Global Climate Change. Accepted.

Abstract

The Indonesian Government recently confirmed its Intended Nationally Determined Contributions (INDCs) to mitigate global climate change. A forest moratorium policy that protects forest and peatland is a significant part of the INDCs, however, its effectiveness is unclear in the face of complex land-use and land-cover change. This study aims to assess land-use change and ecosystem services supply as a function of local decision-making. We developed an agent-based model "Land-Use Change and Ecosystem Services (LUCES)" and we explore the possible effects of the forest moratorium policy on private companies' and communities' land-use decisions. Results from our simulations for two districts in Central Kalimantan Province show that the current implementation of the forest moratorium policy is not effective in reducing forest conversion and carbon emissions, in these two districts. This is because companies continue to invest in converting secondary forest on mineral soil, and because the moratorium does not affect community decision-making. A policy that combines a forest moratorium with livelihood support that increases farm-gate prices of forest and agroforestry products could increase local communities' benefits from conservation. Forest and agroforestry areas that are profitable and competitive are more likely to be conserved and reduce potential carbon emission for about 35% for Kapuas District and 23% for Kotawaringin Barat District. Results for two districts, with different pressures on local resources, suggest that appropriate additional measures require local fine-tuning. The LUCES model could be an *ex ant*e tool to facilitate such fine-tuning and help the Indonesian government to achieve its INDC goals as part of a wider sustainable development policy.

Keywords: Agent-based model, households decision-making, private companies decision-making, land-use change, emission reduction, Central Kalimantan

4.1 Introduction

A landmark agreement in combating climate change was made at the conference of parties (COP) 21 of the UN Framework Convention on Climate Change (UNFCCC) in Paris (2015). This agreement charted a new course in the global effort to enhance support and assistance for developing countries to combat climate change and to adapt to its effects. The Paris Agreement's central aim is to strengthen the global response to the climate change threats and the ability of countries to deal with the impacts of climate change. In preparation of the agreement, countries have agreed to publicly outline what post-2020 climate actions they intend to take under a new international agreement, known as their Intended Nationally Determined Contributions (INDCs). The INDCs will largely determine whether a path toward a low-carbon, climate-resilient future seems feasible. INDCs link national climate policy targets with a global framework that drives collective climate action. INDCs should also articulate how a country is integrating climate change into other national priorities, such as sustainable development and poverty reduction, and encourages the private sector to contribute to these efforts (UNFCCC, 2015a).

Indonesia, as one of the countries that has already submitted its INDCs, has outlined its transition to a low carbon emission future, describing the enhanced actions and necessary efforts to prevent a 2^0C increase in global temperature (UNFCCC, 2015b). Initiatives to reduce carbon emissions started in 2009 when Indonesia voluntarily pledged to unconditionally reduce 26% of its projected greenhouse gases under a business-as-usual scenario by 2020. Conditional on international support, a 41% emission reduction was deemed possible (Howson and Kindon, 2015; Yamamoto and Takeuchi, 2016). In the INDCs the estimates were revised to a 29% reduction by 2030 compared with the business as usual scenario, with 41% feasible with international support. Since 2009, Indonesia has stepwise progressed to formulate legal and policy instruments to support this commitment. One significant step was a moratorium on primary forest clearance and peatland conversion from 2010-2016 to reduce emissions from Land-use, Land-use Change and Forestry (LULUCF), and to restore the benefits from forest ecosystems (McNeish et al., 2011; Astuti and McGregor, 2015). This policy also aims at improved transparency in forest governance that could be seen as the means to establish enabling conditions to reduce the emissions from LULUCF (Murdiyarso et al., 2011). This policy entails that new concessions for primary and peat forest conversion would not be issued. Moreover, an integrated forestry map would be produced. Actions and investments in a sustainable low carbon emission future under the forest moratorium are important to protect high terrestrial carbon stocks (Minang et al., 2012). However, the moratorium as such does not address livelihood options for forest-dependent people. This exclusion has caused difficulties in implementing the policy (Sloan, 2014) together with unresolved contests over land tenure (Galudra et al., 2011; Sloan et al., 2012; van Noordwijk et al., 2014).

Several studies have been conducted to explore the effectiveness of the forest moratorium in decelerating land-use change and forest conversion (Sloan et al., 2012; Sloan, 2014; Margono et al., 2014; Astuti and McGregor, 2015; Busch et al., 2015). In these studies, the effectiveness of the forest moratorium is analysed by comparing the rate of land-use change and forest conversion before and after the implementation of the policy. These studies highlighted the options to improve the capacity of local and national governments (Sloan et al., 2012; Sloan, 2014) by monitoring systems (Margono et al., 2014; Astuti and McGregor, 2015) or carbon pricing (Busch et al., 2015) to make a forest moratorium work towards decelerating land-use change. However, the option of improving the effectiveness of a forest moratorium through sustainable ecosystems benefits and local livelihoods support has not been considered.

The aim of this study is to model land-use change and ecosystem services supply including carbon storage in two Indonesian districts, and to explore the influence of the forest moratorium policies on changing the land-use decisions of companies and communities. As a tool for this analysis, we developed an agent-based 'Land-use Change and Ecosystem Services (LUCES)' model to capture the human-environment system in tropical forest margins. The LUCES model is a hybrid model that provides a comprehensive representation of the coupled socio-ecological system. It was developed and calibrated for two districts in Central Kalimantan Province to address the integration of local community (household) and private company decision-making in response to the forest moratorium policies and the impact of these decisions on the capacity of ecosystems to provide provisioning and regulating services. The two districts were selected based on the differences in local community composition, migration history, population density and history of natural resource extraction (Suwarno et al., 2015). These differences are assumed to have influenced communities' and private companies' decisions in changing land-use that impacts forest ecosystems and carbon emissions. In the context of Indonesia's INDCs the results of this study will support the design of additional programmes for effective forest moratorium policies that reduce emissions from LULUCF and sustain local livelihoods. Results of this study can also contribute to integrating climate change in national priorities, particularly in sustaining and restoring ecosystem services to support sustainable development and poverty reduction.

4.2 Method

4.2.1 Site description

This study was conducted for Kotawaringin Barat and Kapuas districts in Central Kalimantan Province. These two districts experienced different histories in natural resource management that still influence the perceptions and expectations of local people and districts' governments.

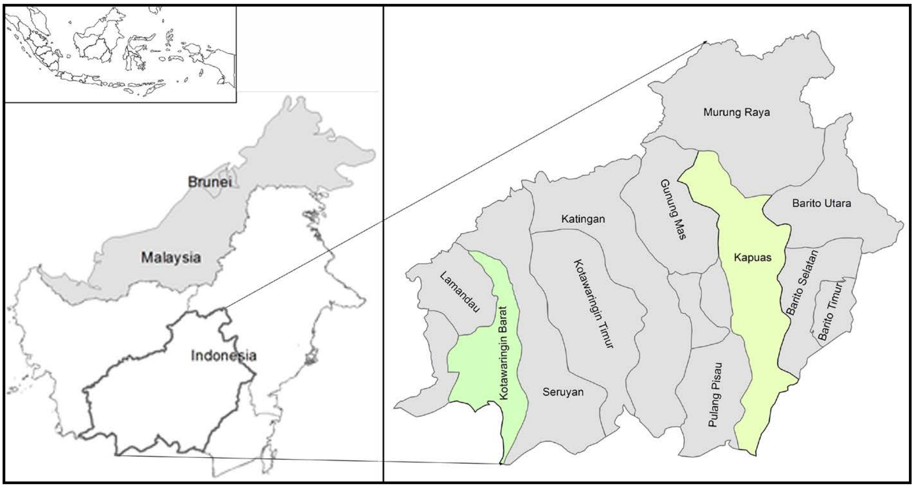


Figure 4-1 LUCES model case study area in the districts of Kotawaringin Barat and Kapuas

Kotawaringin Barat District is situated in the west part of Central Kalimantan Province with a total area for about 8,381 km^2. The district has a population density of about 28 people/km^2 with an annual population growth rate of 4.2% (see Table 4.1). Logging and timber plantation have been the main livelihood of the local people for almost two decades, starting from 1980ies. The boom of logging and timber plantation not only provided sufficient income for local people but also for the district government. In the two following decades Kotawaringin Barat had become one of the richest districts in Central Kalimantan Province (BPS, 2005). The collapse of the logging business in the mid 2000s and the increase of international palm oil prices have driven logging companies to shift their business to oil palm plantation. In addition, also local people (illegally) converted their forest and agroforest area to oil palm plantation (Rist et al., 2010; Budidarsono et al., 2013).

Kapuas District is located in the south east of Central Kalimantan Province with a total area of 17,339 km^2. Major land-use change in this district started from the establishment of a mega rice project in 1994/1995 that converted most of the peat forest to agricultural area. This project was integrated with a transmigration programme that relocated many people from Java, Sumatra and Bali islands. The mega rice project was declared to have failed in 2000/2001 and resulted in degraded peat forest and poverty in the area. Most trans-migrant people have been leaving the area causing low annual population growth and low population density (Suyanto et al., 2009; Galudra et al., 2011). The annual population growth rate in this district is 0.7% per year and the population density is about 19 people per km2 (National Statistic Bureau (BPS), 2013). Forest is the dominant land-use with timber production and Non-Timber Forest Products (NTFPs) as the main benefits.

Table 4.1. Basic characteristics of Kotawaringin Barat and Kapuas districts

	Kotawaringin Barat District	Kapuas District	Source
Area (km^2)	8,381	17,339	BPS, 2013
Population density (people/ km^2)	28	19	BPS, 2013
Annual population growth rate (%)	4.2	0.7	BPS, 2013
Per capita income (USD/ year)	1,860	1,510	BPS, 2013
2010 Forest cover (%)	52	74	MoF, 2010
Dominant Forest Use	Timber	Timber, NTFP	Land cover map 2010 (TBI Indonesia)
(Potential) land-use and land cover change	Oil palm plantation (community and/or company scale)	Permanent agroforestry rubber, timber plantation	FGD in March 2014

4.2.2 LUCES model

4.2.2.1 Model description

The LUCES model was designed to understand communities' and private companies' decisions responding to forest moratorium policies and their effect on land-use and ecosystem services supply in the two study districts (Kotawaringin Barat and Kapuas). The LUCES model adopts the FALLOW model framework and the LUDAS model. The FALLOW model includes 5 main annual dynamic processes of biophysical and socioeconomic conditions of farmers and their decisions on land-use (Mulia et al., 2013; Suyamto et al., 2009), while the LUDAS model includes spatio-temporal interactions in a human-landscape system (Le et al., 2008). The LUCES model was constructed for the simulation of 100 x 100 cells with input from land cover maps provided by Tropenbos Indonesia. The current version of the LUCES model was developed with a default plot size of 0.5 ha. This plot size is adjustable depending on the objective of the study and adjustments to input parameters. The LUCES model is coded in NetLogo 5.0.5 and the impacts of land-use strategies are presented as ecosystem services supplies. The ecosystem services in the LUCES model include six provisioning services (rattan and jelutong collection and production of timber, agroforestry rubber, oil palm and paddy) and one regulating service (above and below ground peat carbon stocks). The decisions households make about land-use change are influenced by (1) the expectations of market prices based on past dynamics; (2) knowledge of the market and modes of production; and (3) preferences for and perceptions of income. The land-use decisions of private companies are mainly influenced by market prices and land zoning policies. The intended use of the LUCES model is the *ex ante* evaluation of proposed land-use policies, e.g. the improvement and extension of the current forest moratorium. Details of the LUCES model are described in Appendix 4.1 using an Overview-Design concept-Details protocol (Grimm et al., 2006; Grimm et al., 2010).

4.2.2.2 Input maps and parameter values

The LUCES model requires inputs of spatial data and parameter values. The spatial data includes: (1) land cover maps; (2) maps of existing timber concessions and timber plantations; (3) maps of existing oil palm plantations and (4) maps of soil and plantation suitability. The parameter values used in the LUCES are related to economic, biophysical and demographic aspects. These include market prices, returns on land and labour, production, employment, demographics and ecosystem services supply. The maps and parameter values used in the LUCES model were obtained from different sources as explained in Table 4.2. Details are presented in Appendix 4.2.

Table 4.2. List of data and parameters used in the LUCES model

Data	Year	Source
Land cover map	1990, 2000, 2005, 2010	MoF, TBI Indonesia, ICRAF
Map of oil palm plantations (based on permit status)	2013	FNPF; OVI
Map of logging and forest plantation concessions	2010	MoF
Map of soil and plantation suitability	2012	Balittanah and ICRAF
Provincial spatial planning map	2003	Provincial government
Baseline map	2000	National government
Data on demography, production, prices, markets and employment at the sub district level	1990, 2000,2005, 2010	National Statistic Bureau
Ecosystem supply per land-use type	2010	Sumarga et al., 2014; 2015
Returns on land and labour	2010	Suwarno et al., 2016
Perceptions, learning, knowledge and selected agents for land change and ecosystem services	2012, 2013, 2014	Survey, personal communications, FGDs, scientific assumption

4.2.2.3 Scenarios and model simulations

In the forest moratorium scenario, we simulated the Forest Conversion Moratorium and two alternatives as follows:

Table 4.3. Key features of the three Forest Conversion Moratorium scenarios using the LUCES model to determine current and future landscapes as well as ecosystem services supply

No	Scenario	Description	Remarks
1.	Business-As-Usual (BAU)	• Protection for peat forest from conversion activities on a company scale (2011-2014) • Illegal conversion of peat forest on a community scale	• No change in road network and market prices is assumed during the 15 years simulation • Settlement distribution change based on the change in land demand and centre of economic activities
2.	Extended Moratorium (EM)	• Similar to BAU, plus: • Extension of the period for protection of peat forest from companies' conversion activities (2011-2036) • New oil palm and timber plantations on a company scale can only be established in mineral-soil areas	• Same as BAU
3.	Moratorium-plus-Livelihoods (MPL)	• Similar to Conventional Moratorium plus: • Increasing the market prices for NTFP, agroforestry products and community timber by about 15 % • Local demand for timber can only be supplied from community timber plantations	• Support the NTFP market chain, agroforestry products and community timber products • Increase of illegal logging litigation • Other conditions are the same as BAU

1. 'Business-As-Usual' (BAU) reflects the current trend, including the Forest Conversion Moratorium, which initially ran from 2011 to 2014. The Moratorium applies only to new or extended permits for companies converting peat forest to other land-use; it does not apply to local communities.
2. The 'Extended Moratorium' (EM) scenario extends the period of the Forest Conversion Moratorium to 25 years starting from 2011. The Forest Conversion Moratorium applies to new or extended permits for companies converting peat forest to other land-use; it does not apply to local communities.
3. The 'Moratorium-plus-Livelihoods' (MPL) scenario adds to the Conventional Moratorium an improved livelihood programme with enhanced markets for NTFPs,

agroforestry products and community timber as well as an improved monitoring programme to avoid community logging.

4.2.2.4 Model validation

A validation test was used as an indication of the type of deviation that can be expected for the baseline predictions. Since LUCES models a complex human-environmental system model, the validity of this model could not be achieved by a single test on point to point history matching. Hence, the model testing (Nguyen et al., 2007) was implemented to test (1) empirical verification and validation of the sub models, and (2) rationality evaluation of the model structure. Further, we also applied backcasting and social validation approaches. The backcasting validation approach was applied to check similarities in patterns of simulated maps resulting from the model using reference maps (Pontius et al., 2008; Ray and Pijanowski, 2010). Meanwhile, social validation was achieved through simulation results with key stakeholders in the two districts. In this simulation, we asked stakeholders to play the part of human agents (households and private companies) and the government as the legislator. Each group of agents (households and private companies) was allowed to make direct and indirect changes to land use based on their negotiations with other agents to meet their economic and conservation expectations. This simulation also included government regulations on forest and land-use management as the restrictive boundaries for agent groups in defining their land-use decisions.

4.3 Results

4.3.1 Land cover output maps

Our simulations under the three different moratorium scenarios in Kotawaringin Barat and Kapuas districts show different patterns of land-use in the last year of the simulation (2025) (Figure 4-2). In Kotawaringin Barat, where the forests were under threat from the local communities and companies, the implementation of the Business-As-Usual scenario from 2010 to 2025 would potentially reduce the area of peat forest and forest on mineral soil by about 11% and 5%, respectively. Meanwhile, the implementation of this scenario will potentially increase the area of agroforests, timber plantation and oil palm plantation by about 2%, 6% and 5%, respectively (see Figure 4-3). These increments are due to high un-planned land-use changes communities would have to make to meet their expected income. The Extended Moratorium scenario in this district does not provide any significant effort to reduce land-use change. The implementation of this scenario would also potentially decrease the area of peat forest and forest on mineral soil by about 7% and 3% respectively, and increase the area of agroforests, oil palm plantation and paddy fields by about 2%, 4% and 6%, respectively. However, our simulation under the Moratorium-plus-Livelihoods scenario shows significant effort in decelerating land-use change. The area of forest on mineral soil decreased by about 4% while the area of peat forest remained constant. This result shows that the implementation of this scenario would potentially decelerate conversion of forest in meral soil and peat forest for about 6% and 5% respectively (compared with Business-As-Usual scenario (see Figure 4-3).

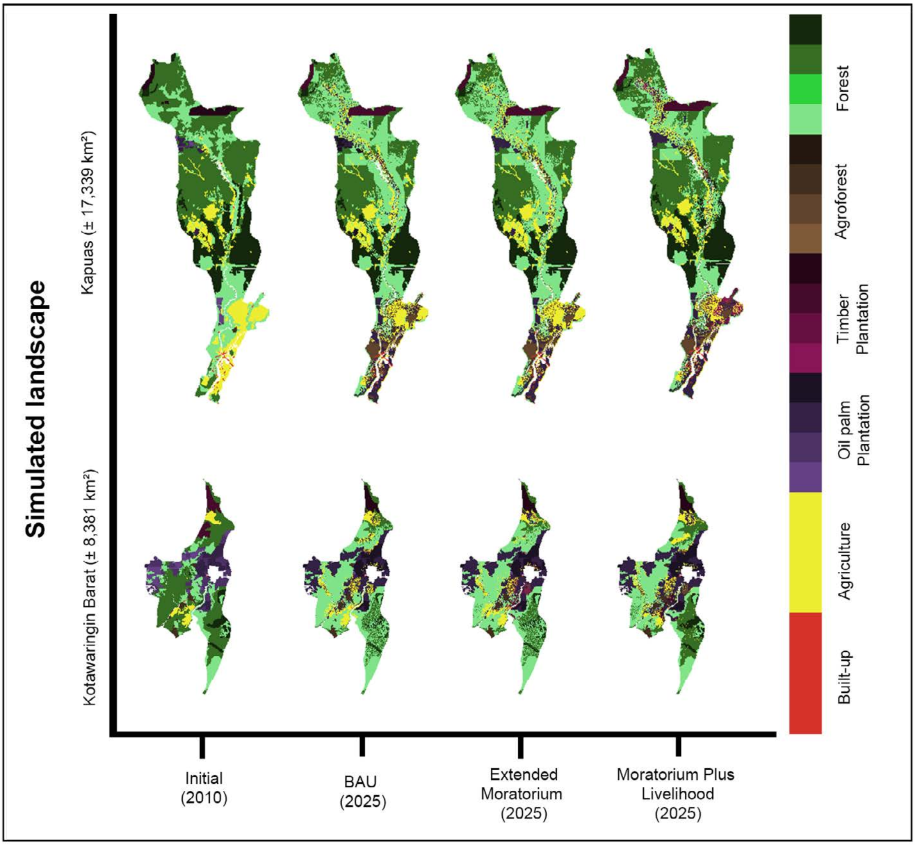


Figure 4-2 The dynamics of land cover output resulting from the simulations of the LUCES model under three different scenarios

Our simulations also show the reduction of forest on mineral soil and peat forest areas resulting from the implementation of the Business-As-Usual scenario in Kapuas District by about 11% and 5% respectively for the period 2010 to 2025. The implementation of the Extended Moratorium scenario in this district would significantly increase the loss of mineral soil forest and slightly decrease the loss of peat forest. Our simulation shows that the area of forest on mineral soil, peat forest and agroforest are decreased by about 13% and 4% and 1%, respectively, while the area of oil palm plantation and paddy increased by about 15% and 4%, respectively. Contrary to the results for Kotawaringin Barat District, the implementation of the Moratorium-plus-Livelihoods scenario in

Kapuas District only provides small differences in the dynamics of the forest on mineral soil and the peat forest, which decreased by about 8% and 2%, respectively. We find a significant increase in agroforests and a decrease in oil palm by about 7% and 9% respectively, compared with the Business-As-Usual scenario. These land-use changes can be attributed to the availability of economic incentives for NTFPs and agroforestry that increased local income. These competitive incomes, comparable to the income from oil palm, have potentially influenced communities' conservation of agroforest and forest areas and slowed down the conversion to oil palm plantations.

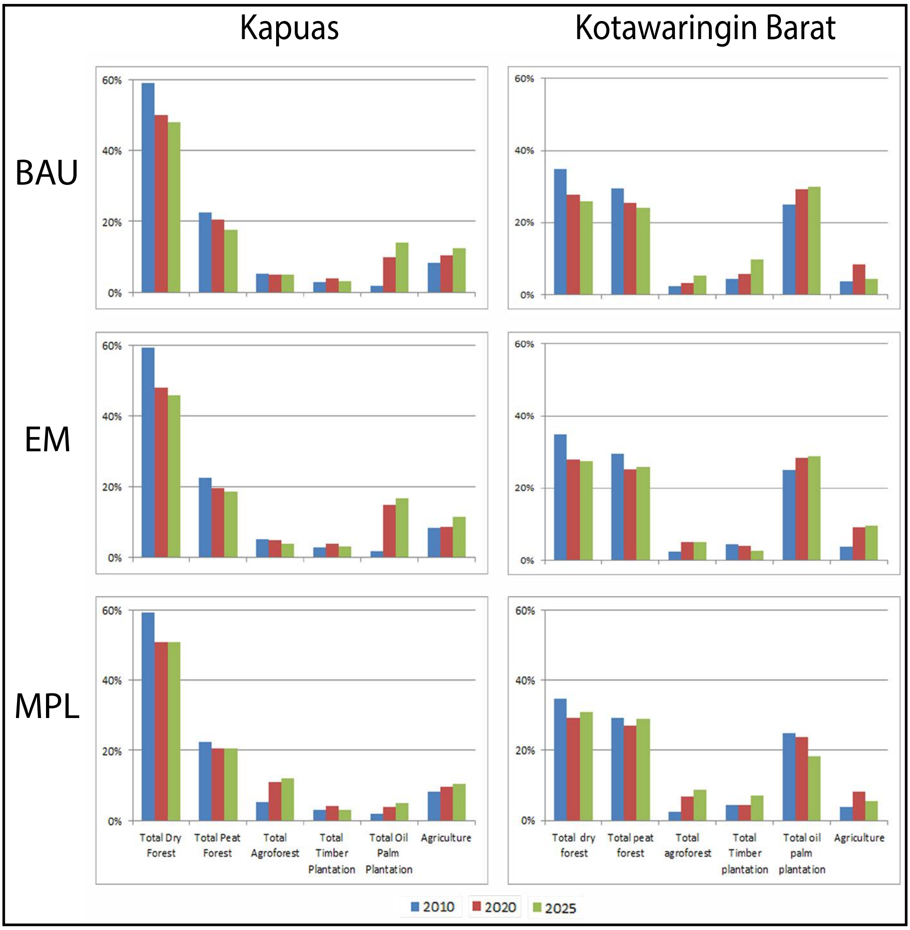


Figure 4-3 Simulated trends in land use as a percentage of the total area under three different scenarios

4.3.2 Ecosystem services supply

The results of the LUCES model show that, in general, the implementation of the Moratorium-plus-Livelihoods scenario provides better ecosystem services supply in

Table 4.4. The dynamics of ecosystem services supply under three different scenarios using the LUCES model

Scenario	Ecosystem services supply (x 1000,000)								
	Timber (m3)	Rattan (ton)	Jelutong (ton)	Agroforest rubber (ton)	Rice (ton)	Oil palm (ton)	Above ground carbon (ton CO_2e)	Peat Carbon (ton CO_2e)	Total carbon (ton CO_2e)
Kapuas District									
Initial 2010	43	0.8	0.4	0.01	0.5	0.08	759	2,781	3,541
BAU 2025	40	0.8	0.3	0.3	0.4	1.7	721	2,752	3,446
EM 2025	41	0.8	0.4	0.4	0.3	1.6	730	2,730	3,460
MPL 2025	41	0.8	0.4	0.4	0.3	1.6	736	2,726	3,467
Kotawaringin Barat District									
Initial 2010	14	0.3	0.1	0.09	0.07	2	276	439	716
BAU 2025	9	0.2	0.06	0.1	0.1	3.5	213	416	629
EM 2025	10	0.3	0.07	0.2	0.2	3.6	215	422	637
MPL 2025	15	0.6	0.09	0.4	0.1	2.7	234	457	691

Kapuas and Kotawaringin Barat. However, the results differ between the two districts due to the differences in land-use change patterns (see Table 4.4).

Our simulations for Kotawaringin Barat show that the implementation of the Bussines-As-Usual scenario could potentially decrease the ecosystem services supply from forests on mineral soil, peat forests and agroforestry ecosystems (rattan, jelutong, timber and carbon sequestration) and agroforests (rubber). The Extended Moratorium only provides insignificant improvements of the ecosystem services supply and the rate of land-use change remains high. However, the implementation of the Moratorium-plus-Livelihoods scenario could potentially increase forest and agroforestry areas and subsequently increase the supply of timber, rattan, jelutong, rubber and carbon stock. The increase of total CO_2 stock (above ground and peat) has significant contribution in reducing potential CO_2 emissions. Result of our simulation show that CO_2 emissions could potentially reduce for about 23 % through the implementation of Moratorium-Plus-Livelihood scenario in this district. These results support the findings of Mulia et al. (2014) and Tata et al. (2015) that indicate the importance of economic incentives for NTFP collection in sustaining forest, increasing the supply of rattan and jelutong and reducing potential CO_2 emissions. Premium prices for NTFPs, agroforestry rubber and community timber could change local perceptions of forest and agroforestry conservation and reduce potential CO_2 emissions from land-use change consequently.

For Kapuas District, the results of our simulations show that the three scenarios for the forest moratorium policies are not significantly different with respect to the dynamics of ecosystem services supply for provisioning services. However, we found significant improvements in total carbon stock under the Moratorium-plus-Livelihoods scenario that consequently reduce potential CO_2 emissions. We found that CO_2 emissions could potentially reduce for about 35% through the implementation of Moratorium-Plus-Livelihood scenario. This result indicates a strong correlation between the low population in this district and low expected income with low interest in land-use change and storing carbon. Another factor that influences this result is associated with the patterns of planned land-use change of private companies (see Table 4.4 for more information concerning this data on Kapuas and Kotawaringin Barat Districts).

4.4 Discussion

4.4.1 Land-use scenarios, land-use change and ecosystem services supply

Land-use policies are a key determinant of stakeholders' land-use decisions. Stakeholders respond differently to land-use policies in an effort to maximise the benefits they receive from certain land-use (Brooks et al., 2014; Nelson et al., 2009; van Noordwijk et al., 2011). Their decision making is mainly influenced by their income expectations that are defined based on their knowledge and social networks (Berkes et al., 2000; Rogers, 2004; Turnpenny et al., 2014). As shown in our simulations, forest moratorium policies in Indonesia influence stakeholders in their land-use decisions. However, we find that extending the period of the forest moratorium in its current form has little effect on land-use change in Kotawaringin Barat District due to the high income-expectations of households and private companies from oil palm. Extending the period of the moratorium only stops private companies from converting peat forests to oil palm but not households, since this regulation only applies to companies. High income-expectations for oil palm profitability have increased the households' interest to expand the oil palm area, including on peatland. Meanwhile, private companies tend to expand their oil palm plantations in degraded forest on mineral soil, since the regulations of the forest moratorium only apply to peat and natural forest. Moreover, it if often unclear if forests can be considered natural or degraded, and government officials may not always have strong incentives to carry out a strict interpretation of the moratorium (Sloan, 2014). Hence, the moratorium in the way it is currently implemented is not sufficiently effective to ensure a strong decline in forest loss (Margono et al., 2014).

In Kapuas District, the lower population density and low expectations for oil palm performance result in more stable land-use conditions. This result supports the empirical findings of Tachibana (2016) that highlight population and expected income as a main driver of land-use and land-cover change.

In our Moratorium-Plus-Livelihoods scenario, we assumed that economic incentives for farmers/households were provided through premium prices for NTFPs, agroforestry rubber and community timber. We also assumed that the local government provides subsidies for producing these provisioning services through tax reductions. Based on these assumptions, our simulations show a greater increase in forest, agroforestry rubber and community timber plantation areas in Kotawaringin Barat and Kapuas districts, compared with the other two scenarios. The premium prices for NTFPs, agroforestry rubber, and community timber have shifted the expectations of the households and changed their land-use decisions. House tent to conserve more forest and agroforest areas and in-directly reduce potential CO_2 from land-use change. This result supports other studies that found positive ecological effects when land-use scenarios that give priority to conservation and livelihoods were implemented (Mulia et al., 2013; Sunderland et al., 2008). However, premium prices did not change the expectations of the private companies concerning oil palm plantations, timber plantations and logging concessions.

4.4.2 Policy implication

Terrestrial ecosystems, such as forests or managed agricultural lands, are subject to multiple natural processes and human interventions that have major effects on the global climate (Carreño et al., 2012; Foley et al., 2005; Le et al., 2010). Reducing GHG emissions and increasing carbon sequestration in terrestrial ecosystems represents an important short-term option for mitigating global climate change. However, an array of policies to govern land-use changes is needed to achieve this. Considering the integration of climate change, sustainable development and poverty reduction, flagged in the Paris agreement, the implementation of such policies at the national level should articulate the integration of local livelihood programmes in a country's strategic approaches (UNFCCC, 2015a).

A wide scope of forest moratorium policies was part of the preparations for Indonesia's INDCs to combat climate change and its impact on humans and ecosystems (Murniningtyas et al., 2015). Forest moratorium policies have recently been extended until 2016 and cover the suspension of permits for converting peat and secondary forests. However, the policy has yet to include a livelihood programme, as required in the Paris agreement. Considering local people as the important stakeholders that may contribute to land-use change and global emissions, sustainable local livelihoods are important drivers of land use (Medrilzam et al., 2014; Sunderland et al., 2008; Tachibana, 2016; van Noordwijk et al., 2008). As shown in our simulations, the option of including livelihood programmes in the Moratorium-plus-Livelihoods scenario could significantly decrease the rate of forest conversion in the two districts that in-directly will reduce CO2 emissions. We also found that the model clearly depicts the multi-faceted nature of economic incentives in decelerating land-use change and restoring ecosystems benefits. The option of providing premium prices and cost subsidies for NTFPs and permanent agroforestry production could increase potential local benefits. Equally, this scenario shows that premium prices (15% higher than local prices) and cost subsidies (covering 5% of production costs) have increased the benefits from NTFPs and permanent agroforestry production to the level of benefits received from oil palm. This reduces local interest in converting forests and agroforests to oil palm and thus reduces local carbon emissions. These results support previous findings that the implementation of a conservation scenario will only work with a supporting programme that can promote ecosystem services as a viable livelihood option (Börner et al., 2011; McShane et al., 2011; Wunder, 2013). The role of economic incentives in supporting the effectiveness of an environmental programme has also been shown by Kemkes et al., 2010; McCann, 2013; van Noordwijk et al., 2014.

The combination of conservation and livelihood programmes under the forest moratorium policy in Kotawaringin Barat and Kapuas districts could be achieved if traditional practices of tapping jelutong and agroforestry rubber were encouraged. These activities will potentially support local livelihoods that have had long experience and tradition in jelutong and agroforestry rubber tapping. From an ecological perspective, this option could potentially conserve and restore peat forest ecosystems and reduce emissions from LULUCF.

Considering Indonesia's commitment to reduce emissions from LULUCF, the results of the LUCES model could provide an essential input for decision makers to develop additional programmes to improve the effectiveness of forest moratorium policies in decelerating land-use change and reducing carbon emissions. The LUCES model, developed at the district level could potentially be up-scaled to assess the implementation of forest moratorium policies nationally. Moreover, it could support governments in evaluating and improving their strategies for achieving their INDCs.

4.5 Conclusion

Our paper has demonstrated how land-use decisions and ecosystem services can be modelled at the scale of Indonesian districts. We show that in Kotawaringin Barat District the high economic value of oil palm has influenced communities' interests to convert forests and agroforest areas to oil palm. However, the lower income expectations of communities in Kapuas District (achievable through NTFPs and agroforest rubber production) have led to more conservation of forests and agroforests and, hence, a lower rate of land-use and land-cover change. Our simulations using the LUCES model show that it is important that the current forest moratorium is complemented with livelihood programmes that facilitate the generation of local income from forests that do not involve forest conversion. A moratorium with livelihood support could significantly reduce potential CO_2 emissions from LULUCF and support Indonesia's strategies for meeting its INDCs.

Acknowledgement

We thank Lars Hein for comments on this manuscript. We also thank staff of Kotawaringin Barat Production Forets Management Unit and Kapuas Protected Forest Management Unit for their contribution to essential information, and the anonymous reviewers for their comments and suggestions. This research has been made possible through ERC grant 263027 (Ecospace). Details of the model can be obtained through the author.

Chapter 5

Optimising land use in Kapuas peat forest ecosystem, Central Kalimantan Province, Indonesia

Based:

A. Suwarno, L. Hein, H. -P Weikard, M. van Noordwijk and B. Nugroho (2016). Optimising land use in Kapuas peat forest ecosystems, Central Kalimantan Province, Indonesia. Regional Environmental Change. Submitted.

Abstract

Forest ecosystems provide valuable benefits for people locally and globally and need to be managed sustainably. However, the complexity of socio-ecological processes in forest ecosystems is a major constraint to optimising forest management. In this study, we developed adaptive forest zonation to optimise forest ecosystem management. We employed the ecosystem service concept and land-use change model to identify potential areas for conservation and economic development programmes for the Kapuas Protected Forest Management Unit, in Indonesia. Local people actively participated in this study to jointly define management zones and the stakeholders' associated rights and responsibilities. Our results show that negotiation is imperative to reduce threats to forest ecosystems. Options that provide additional areas for economic development in combination with a stakeholders' agreement increase local awareness of forest ecosystem conservation. Compared to current forest zonation, we show that the availability of an economic development zone in adaptive forest zonation could potentially increase ecosystem benefits local communities receive by about 40%, through rattan and jelutong collection and agroforestry rubber and jelutong production. Although our results are specifically for Kapuas District, the methodology we developed is general. We recommend our methods be included in guidelines for zonation and management plans to help improve the sustainable forest management practices of all forest management units in Indonesia.

Keywords: Ecosystem services, land-use, ecosystem management, peat forest ecosystems, forest management unit, Central Kalimantan

5.1 Introduction

The importance of using the Ecosystem Services (ES) concept for ecosystem management has been widely recognised over the last few decades. The ES concept frames the relationship between humans and ecosystems and is widely used to understand the contribution of ecosystems to human wellbeing (Turner et al. 2003; Millenium Ecosystem Assessment, 2005; Balmford et al. 2010; UN et al. 2014). Integrating ecosystem services into ecosystem management requires consideration of the broader economic, social and political context. In turn, this requires stakeholder participation in order to understand management and governance regimes and to develop proposals for enhanced ecosystem management (Stringer et al., 2006; Reed 2008; Seppelt et al.,2011; Luyet et al., 2012).

In the context of forest ecosystems, sustainable forest management is important to conserve forest ecosystems and secure local livelihoods, particularly those of forest dependent communities (Pagiola et al., 2002; Kroeger and Casey, 2007; LaRocco and Deal, 2011; Deal et al., 2012). The integration of the ES concept in sustainable forest management can then be used to understand the benefits forest communities and other stakeholders receive under different forest management regimes (Deal et al., 2012; Quine et al., 2013). However, forest ecosystems generally provide a broad range of ES involving multiple stakeholders from local to global. The application of the ES concept for ecosystem management is challenging due to a lack of quantitative information on flows of ES and the value different stakeholders place on them (Hein et al., 2006, Deal et al., 2012; Quine et al., 2013).

The evolution of sustainable forest management practices in Indonesia has seen the introduction of Forest Management Units (FMUs) through Government Regulation No 6/2007. The concept of FMUs has its origins in the Forestry Law of 1967 on sustainable forest management in generating sustainable forest ecosystem benefits through forest utilisation and conservation programmes (FORCLIME, 2011; Setyarso et al., 2014). To date, FMUs have not explicitly considered ES in the formulation of forest management plans, which FMUs are requested to develop as per the Ministry of Forestry Regulation No. 47/Menhut-II/2013.

The objective of this study is the use ES for optimising land use in a specific FMU. In particular, we developed and analysed adaptive forest zonation, as the foundation of the forest management plan for Kapuas Protection FMU, in Kapuas District, Central Kalimantan. Adaptive forest zonation involves the identification of specific zones for different forest uses. In this study, these zones have been identified on the basis of both a quantitative analysis of ES flows under different types of management in combination with extensive stakeholder workshops with local forest users. We employed the LUCES model described in Suwarno et al., (2016b) to identify potential land-use change resulting from the current forest governance system. We also identified potential land grabbing and forest encroachment that might have occurred in the current socio-economic conditions. Next, potential areas to be allocated for conservation and economic development zones were identified and delineated based on a combination of potential land-use change and biophysical criteria in sustainable forest management. Subsequently, the participatory process was conducted to discuss the zonation draft with the local communities and revise it to meet the agreement between the communities and the experts from Kapuas Protected FMU. Finally, we calculated and analysed the potential benefits from ES that the communities and management of Kapuas Protected FMU might receive based on recent and adaptive forest zonation. In this paper, we discuss the option of a financial mechanism to govern the potential benefits received by the Kapuas Protected FMU and the option of applying integrated peat management based on landscape boundaries. Given the importance of peat forest ecosystems in Indonesia in providing benefits to humans, the results of this study will provide valuable input to support and improve the implementation of sustainable forest management practices in FMUs in general and Kapuas Protected FMU specifically.

5.2 Methods

5.2.1 Case study area

5.2.1.1 Biophysics and local livelihoods

The Kapuas Protection FMU covers an area of 105,372 ha of which about 95% is peat and swamp forest. Forests in the Kapuas Protected FMU were logged between 1994 and 1998. These logging activities were conducted under the Mega Rice Project that aimed to develop 1 million ha of agricultural land, especially for paddy fields. The project cut through two peat domes in this area and built a main canal that linked three rivers with the aim of draining the peatland. The draining process damaged the peat's hydrological system and reduced the capacity of the peat ecosystem to control the water balance. As a result, the area south of the main canal has become degraded in terms of both hydrology and vegetation. The area is now very dry during the dry season, with a high risk of forest and land fire, whereas it is regularly flooded in the wet season. In contrast, the secondary peat forest to the north of the main canal is still intact and has a unique diversity of typical flora and fauna. It now has the largest remaining wild orangutan population in the world (Singleton et al., 2004; Suyanto et al., 2009).

The seven neighbouring villages in the Kapuas Protection FMU area have a total population of about 5,500 (BPS, 2013). The livelihoods of these local people are mainly related to agriculture, logging and collecting Non-Timber Forest Products (NTFPs). Prior to 1970, NTFPs, such as rattan (*Calamus spp.*), damar (*Shorea sp.*), jelutong (*Dyera costulata*), eaglewood (*Aquilaria malaccensis*), katiau (*Ganua motleyana*), kalanis (a tree root), ehang, nyatu (*Palaquium javense*) and animal (snakes, birds and deer) collection, swidden upland rice system and fishing were the main sources of local livelihoods (Suyanto et al., 2009). These livelihoods then changed due to the establishment of the Mega Rice Project (Suyanto et al. 2009). During Mega Rice Project (1995-1998), agriculture was the main livelihood for most of the people to the south of the main canal, while to the north it remained NTFP collection and shifting cultivation. In 1999, with the failure of the Mega Rice Project many local people to the south either left or planted oil palm (Suyanto et al., 2009; Galudra et al., 2011). The use of slash and burn to prepare the peatland for oil palm has increased the risk of land and forest fire in this area. Together with encroachment, forest fires are now considered the main threat to the area. Reports from Global Forest Watch show that 155 fire alerts, with a 100% confidence level, occurred in this area between 1 September and 15 October 2015 (http://fires.globalforestwatch.org). Most of the fires (92%) occurred on degraded peat land to the south of the main canal, which has open access for some villages.

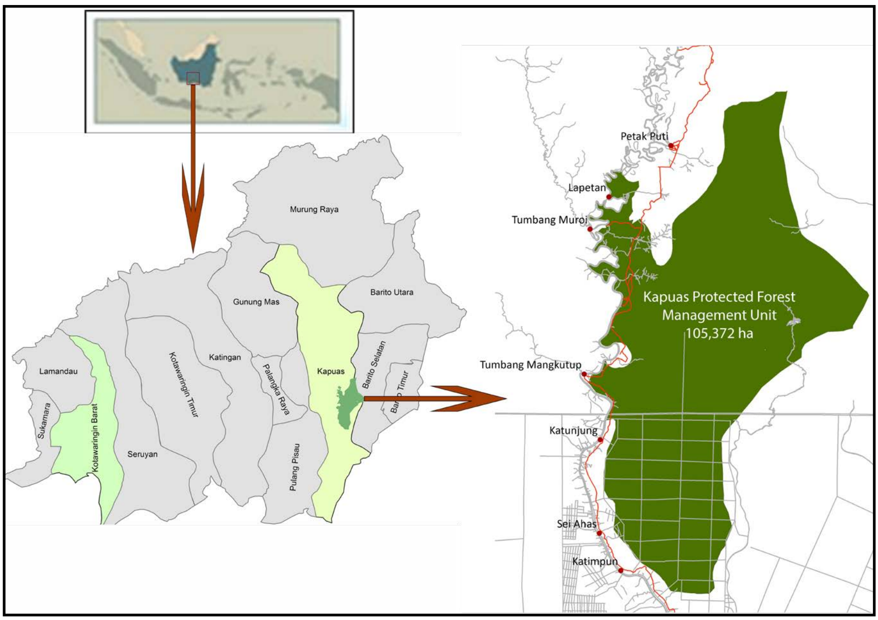


Figure 5-1 The Kapuas Protected FMU area and neighbouring villages

5.2.1.2 Institutional aspects

The Kapuas Protected FMU was established on 2 May 2011, based on the Ministry of Forestry Decree No: SK.247/Menhut-II/2011, covering 105,372 ha. Much of the FMU's area is part of the former Mega Rice Project area. The Kapuas Protected FMU's main task is to address the ecological-economical issues resulting from the ex Mega Rice Project. These issues include reducing carbon emissions and fires from degraded peatland and rehabilitating the degraded peatland area. Moreover, the Kapuas Protected FMU is also required to work with sustainable local livelihoods, which were not fully covered in previous international projects implemented in this area (Olbrei and Howes, 2012; Atmadja et al., 2014; Medrilzam et al., 2014). The Kapuas Protected FMU's long-term vision is to develop a "Protected FMU business for the sustainable use of peat swamp forests, contributing to sustainable livelihoods and prosperous communities through equal sharing of benefits" (Kapuas Protected FMU 2012). The aims of Kapuas Protected FMU are defined as follows: (1) to develop sustainable livelihoods for local communities with minimal greenhouse gas emissions and fires, and (2) to increase the capacity and participation of stakeholders (public, private and local communities) in managing and utilizing peat swamp forests (Kapuas Protected FMU 2012).

5.2.2 Forest zonation development and analysis

In this study, we developed adaptive forest zonation to enhance the effectiveness of the current forest zonation of Kapuas Protected FMU in conserving forest ecosystems and sustaining local livelihoods. The term 'adaptive' is used in this study to refer to adaptive management, which includes structured and iterative processes in decision-making through a learning process to improve long-term management outcomes and reduce uncertainty (Holling, 1978). This decision-making simultaneously meets one or more management objectives and accrues information needed to improve future management. We designed a procedure for the development of adaptive forest zonation in three steps (Figure 5-2). These steps included our learning processes in the outcomes of current management. The details of each step are explained in the section 5.2.2.1 to 5.2.2.4.

5.2.2.1 Land-use change model

The land-use change model was developed in this study to understand land-use patterns and predict the change in land-use based on the stakeholders' interests in changing the land-use. This model was based on the Land-Use Change and Ecosystem Services model (LUCES) . The LUCES model is a hybrid agent-based land-use model that captures the interactions of stakeholders in the decision-making process. The LUCES model was designed to consider the interests of local people and private companies in shaping their opportunities for further socio-economic change and the impact of this interest on land-use decisions (Suwarno et al. 2016b). The LUCES model can produce a spatially explicit representation of a land area (represented as a raster) with the potential for land cover change in each pixel governed by a combination of formally planned and unplanned change, with the latter decided by local agents. Planned land-use change is driven by private companies, which have obtained government permits to maximise their profits. Meanwhile, local community members drive unplanned land-use change with existing labour as the main consideration. One assumption built into the LUCES model is that a community will only expand their area if they have more internal labour. Accordingly, the recent version of the LUCES model only includes internal labour and has yet to include potential migrant labour. Simulation of the potential unplanned land-use change in the LUCES model is based on Unified Modelling Language (UML) and implemented using ABM software, NetLogo 5.0.5.

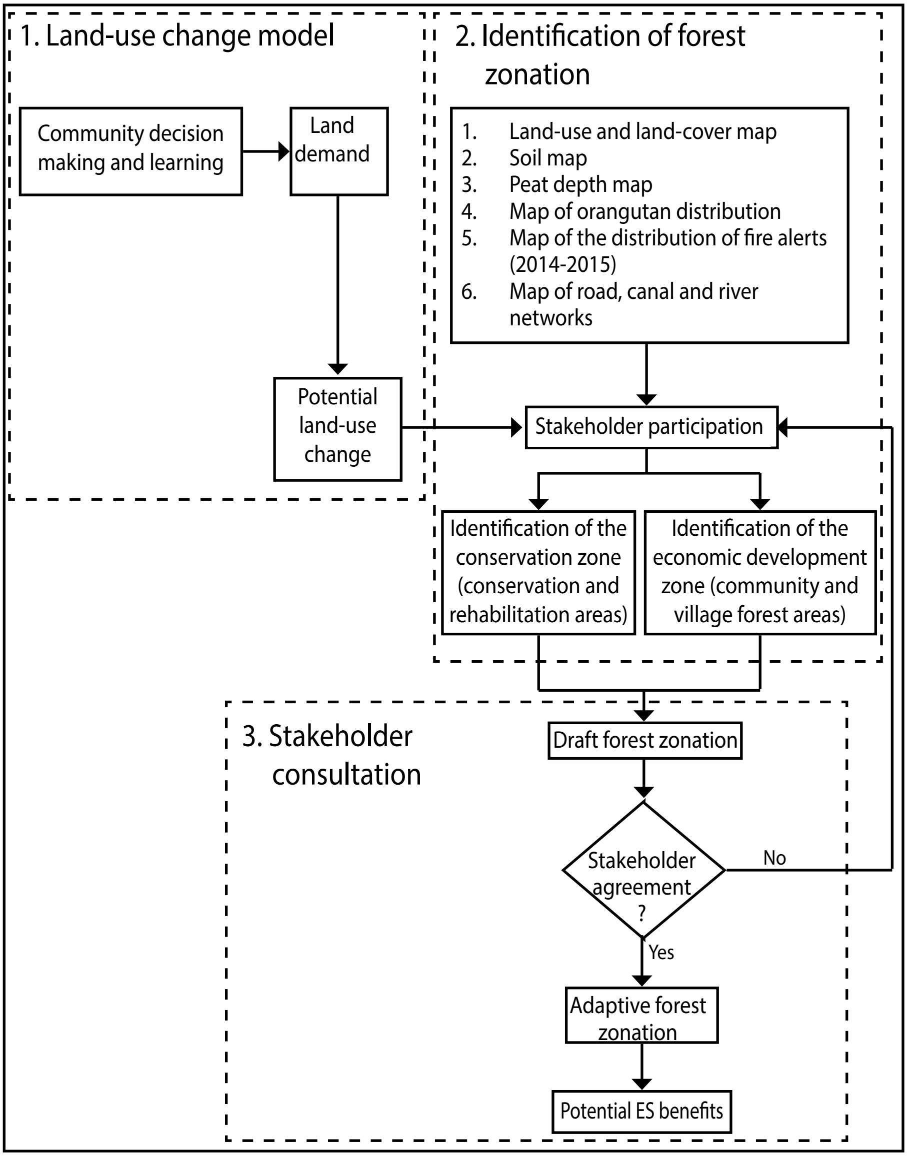


Figure 5-2 Three steps in developing adaptive forest zonation

In this study, we improved the LUCES model by using SARVision land cover maps of 2010. These maps were derived from FBS and FBD ALOS PALSAR strip data provided by JAXA

EORC, with a resolution of 50 m (Hoekman et al. 2010). We also increased the resolution of the model from 0.5 km^2 to 0.2 km^2 per pixel by maximising the number of cells in the NetLogo 5.0.5 to provide more detail. Considering the position of the villages and hydrological units as important factors in sustainable forest management, we first used the ecological boundaries (rivers in the west and east) of the Kapuas Protected FMU area and present the results only for this area.

5.2.2.2 Identification of areas for adaptive forest zonation

The adaptive forest zonation includes conservation and economic development zones to balance conservation and economic interests. Based on the adaptive management concept, we divided the area of Kapuas Protected FMU into (1) conservation and (2) economic development zones to meet the main aim of Kapuas Protected FMU in conserving forest ecosystems and sustaining local livelihoods. The conservation zone includes conservation and rehabilitation areas, while the economic development zone includes community and village forests. The Potential area allocated for conservation and economic zones was identified using biophysical criteria in sustainable forest management that include hydrological units (rivers) as the ecological instead of administrative boundaries (as presented in Table 5.1). It was important to consider hydrological units in this study as Kapuas Protected FMU is located in a peat forest ecosystem influenced by hydrological systems. Hence, we first used the ecological boundaries (rivers in the west and east) of the Kapuas Protected FMU area and present the results only for this area. Moreover, we also considered the position of the villages as important factors in defining the potential area to be allocated for economic development zones. We conducted a series of focus group discussions with communities and representatives from Kapuas Protected FMU, District Forest Agency and District Planning Agency to discuss the possible areas to be allocated for community and village forests. The results were then used as additional criteria.

5.2.2.3 Stakeholder participation and consultation

Stakeholder participation and consultation are crucial aspects of forest zonation development. In this study, we conducted a series of focus group discussions in the period 2014 to 2015 to capture the local communities' preferences for defining the area to be allocated for economic development and conservation zones (see section 5.2.2.2). We also used these focus group discussions to develop stakeholder agreements in terms of rights and responsibilities pertaining to the two zones (see Figure 5-2). Further, several other focus group discussions were conducted in the period June to September 2015 to assess the first draft of the forest zonation with the stakeholders in the villages, sub districts and districts. We also discussed and finalised the agreement on rights and responsibilities relating to the economic development zones in these focus group discussions.

Table 5.1. Biophysical criteria used to delineate conservation and community development zones

Zone	Area	Criteria
Conservation zone	Conservation	• Peat land with a minimum depth of 2m • Good forest cover (old and young secondary peat forest) • Area for orangutan habitat
	Rehabilitation	• Peat land with a minimum depth of 2m • Degraded forest cover (pioneer secondary peat forest) • Area(s) prone to forest fire (based on history of fire alerts
Economic development zone	Community forest	• Mineral soil or peat land with a maximum depth of 1m • Exclude the orangutan habitat • Exclude areas of good forest cover (old secondary peat forest) • A maximum distance of 6km from the centre of the village, river or road (community preference)
	Village forest	• Mineral soil and/or peat land with a maximum depth of 2m • Exclude the orangutan habitat • A maximum distance of 10km from the centre of the village, river or road (community preference)

5.2.2.4 Calculating potential benefits for local communities

The calculation of potential benefits for local communities was conducted in this study to understand potential gains and losses in implementing adaptive forest zonation. The calculation of potential ecosystem benefits for local communities was based on information from the monetary benefits of seven ES (rattan and jelutong resin collection and the production of timber, agroforestry rubber, oil palm, and paddy and carbon emissions) provided by Sumarga et al., (2015) and Suwarno et al., (2016a). These studies employed ecosystem accounting to assess the contribution of ecosystems to economic and other human activities in a way that is consistent with national accounts (UN et al., 2014; Edens and Hein, 2013). The net benefits in ecosystem accounting are expressed as an annual resource rent (RR) and valued by analysing the market price and deducting the total costs (intermediate, employment and user production costs) (Edens and Hein, 2013). Suwarno et al., (2016a) also include Government Regulation No. 55/ 2005, concerning the procedure for governing timber and NTFPs, to support this calculation. These regulations determine taxes, including tax on timber and land, and fees for extracting timber and NTFPs from both natural and plantation forests. Further, we included the potential cost of carbon emissions resulting from forest conversion to

Table 5.2. Potential land-use change in Kapuas Protected FMU area based on the result of the LUCES model

Class	Area (ha)			
	Initial 2010	2020	2030	2040
Old secondary peat forest	67,390	67,301	67,199	67,177
Young secondary peat forest	2,831	2,619	2,611	2,169
Pioneer peat forest	24,912	24,619	24,212	23,996
Agroforestry	7,021	6,922	6,832	6,912
Oil palm	1,946	2,602	3,075	3,598
Agriculture	1,272	1,309	1,443	1,520
Total	105,372	105,372	105,372	105,372

other land use and vice versa. We describe the potential CO_2 emissions resulting from forest fire, frequent in this area, and its negative impact on local communities. The results of this analysis were then discussed with the stakeholders in the district, particularly the District Forest Agency and District Planning Agency, during a focus group discussion that was organised by the management of Kapuas Protected FMU in September 2015.

5.3 Results

5.3.1 Potential land-use change

Our analysis shows the potential land-use and land cover change in this area in the period 2010 to 2040, based on the business as usual scenario (current management). These changes are mostly related to the conversion of forest to oil palm and agriculture (paddy fields). Simulations of the LUCES model show that the area of oil palm and paddy field could potentially increase from about 2% to 3% and 0.2% to 1% per year respectively, while the area of old secondary peat forest, young secondary peat forest, pioneer peat forest and permanent agroforestry could potentially decrease from about 0% to 0.1%, 0.03% to 1.69%, 0.09% to 1.17% and 0.02% to 0.14% per year respectively (Table 5.2).

In addition to land-use and land-cover changes in this area, there is also a high risk of forest encroachment. This risk is related to local interest to meet economic expectations by converting the forest area to other uses. Our interviews with local communities and experts in Kapuas Protected FMU show that local communities have already occupied large areas of forest, particularly close to their villages.

5.3.2 Adaptive forest zonation for Kapuas Protected FMU

Adaptive forest zonation for Kapuas Protection FMU includes conservation and rehabilitation areas in the conservation zones, and village and community forests in the community development zone (Figure 5-4).

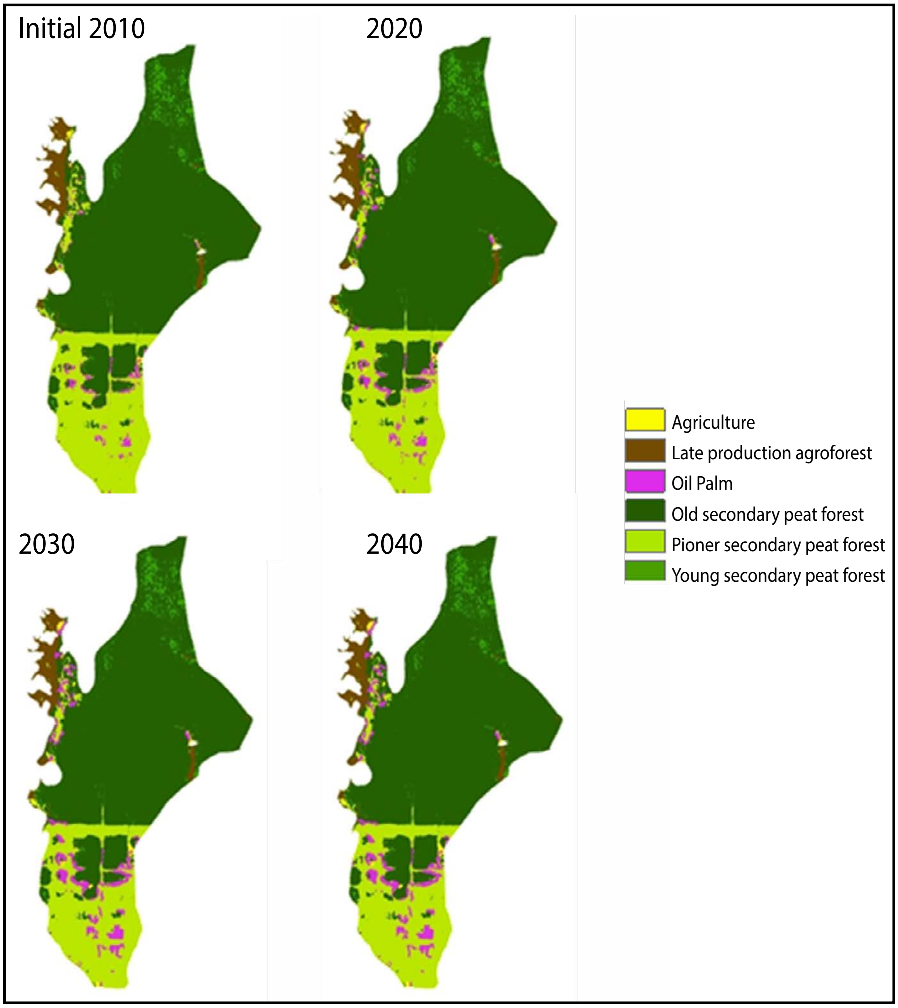


Figure 5-3 Potential land-use change using the LUCES model

5.3.2 Adaptive forest zonation for Kapuas Protected FMU

Adaptive forest zonation for Kapuas Protection FMU includes conservation and rehabilitation areas in the conservation zones, and village and community forests in the community development zone (Figure 5-4). The conservation area in the adaptive forest zonation includes old secondary forest to the north and south of the main canal, delineated based on the condition of the forest cover, peat depth and its importance for orangutan habitat. The rehabilitation area was delineated at the edge of the degraded peat forest (pioneer peat forest) to the south of the main canal. This rehabilitation area is the main aspect for adaptive conservation due to potential problems of forest fire,

Table 5.3. Details of the areas in the current and adaptive forest zonation

Forest zonation	Zone	Programmes	Area (ha)
Current forest zonation	Conservation	Not defined	65,785
	Rehabilitation	Not defined	25,198
	Management	Not defined	14,389
Adaptive forest zonation	Conservation	Conservation	70,296
		Rehabilitation	19,379
	Community development	Community forest	3,711
		Village forest	11,986

encroachment and flooding. The community development zone was divided into community forest and village forest with stakeholder participation in order to secure sustainable local livelihoods in the area of the Kapuas Protected FMU (Table 5.3). Further, the rights and responsibilities of local communities and the management of Kapuas Protected FMU were defined in the stakeholders'agreement as explained in Table 5.4.

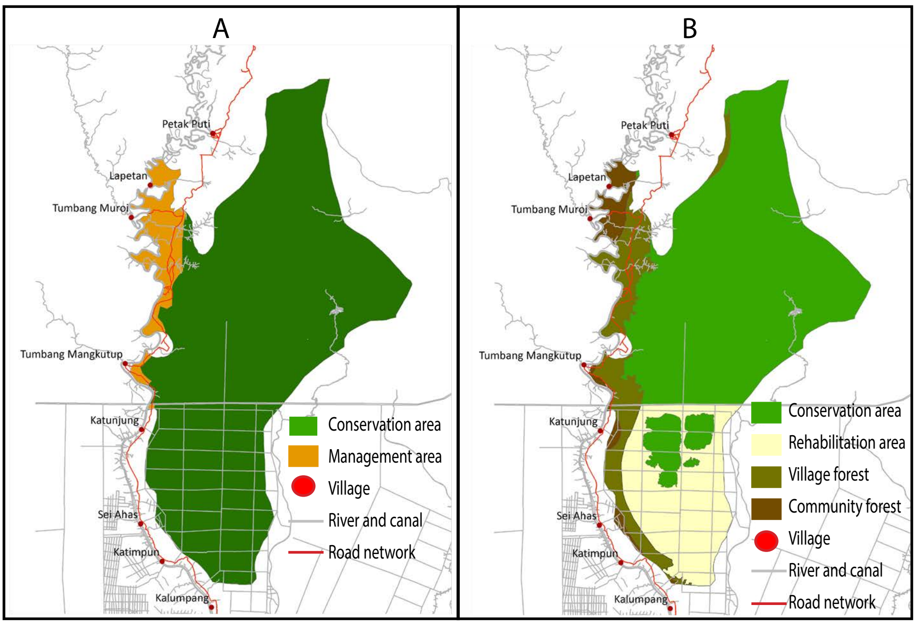


Figure 5-4 Forest zonation for Kapuas Protected FMU current (A) and adaptive (B) and neighbouring villages

5.3.3 Potential benefits from ecosystem services for local people

Our results show that adaptive forest zonation can provide more sustainable options for local livelihoods through the availability of community and village forests under an economic development zone. Communities may increase the annual benefits they receive from NTFP collection by about 12% (from € 1.9 million to € 2.2 million).

Table 5.4. Rights and responsibilities granted to local communities and the management of Kapuas Protected FMU based on the negotiated stakeholder agreement

Zone	Area	Local communities		The management of Kapuas Protected FMU	
		Responsibilities	Rights	Responsibilities	Rights
Coservation zone	Conservation	Prevent: 1. Illegal logging 2. Forest encroachment 3. Forest fire	Communities may collect NTFPs with tax reduction	Monitor and prevent illegal logging Forest fire prevention and suppression	Tax from NTFP collection and limited timber production
	Rehabilitation	Participate in rehabilitation programme under coordination of Kapuas Protected FMU	Communities share in benefits from carbon trading	Conduct and monitor rehabilitation programme	Possibility to enter carbon market

The NTFPs could be collected in the conservation and village forests (assuming the communities only collect NTFPs at a rate of 10% of the conservation forest and 25% of the village forest area due to limited access). The communities could also potentially receive annual benefits from timber production of about € 534 from the village forest. This is due to government regulations that only allow limited timber production under village forest that has protected status (maximum 50 m3 per year per forest) (Ministry of Forestry Regulation No. P.89/Menhut-II/2014 concerning village forests). The availability of community forest would also increase the potential benefits communities receive from rubber and jelutong agroforestry. Our results show that the communities could potentially receive € 190,997 per year from agroforestry rubber or € 483,714 per year from agroforestry jelutong. Moreover, they could also potentially receive € 3.8 million per year from jelutong agroforestry in rehabilitation areas (see Table 5.5). Since the rehabilitation may require a long process, the calculation of potential benefits from this area are not included in the total potential benefits that communities may receive from adaptive forest zonation. In general, adaptive forest zonation could potentially increase ES benefits local communities receive by about 40% compare to the current forest zonation (see Table 5.5).

5.3.4 Inclusiveness and uncertainty

Inclusiveness is an important issue in developing a conservation programme. In order to address this issue, a participatory approach was applied in the development process of adaptive forest zonation. The delineation process included the active participation of

Table 5.5. Comparison of the potential ecosystem service benefits local people and the management of Kapuas Protected FMU receive under the current and adaptive forest zonation

Forest zonation		Current forest zonation			Adaptive forest zonation			
Zones		Conser-vation	Rehabil-itation	Manage-ment	Conservation		Community development	
Programmes		Not defined	Not defined	Not defined	Conser-vation	Rehabilita-tion	Community forest	Village forest
Potential area (ha) for:	Timber production	0		0	0	0	0	58[5]
	Agroforest	0		0	0	6,7833	732[4]	0
	NTFPs collection	6,579[1]		5,247	7,030[2]	0	2,439	2,996[2]
	Paddy production	0		1,272	0	0	1,272	0
Benefits per ha per yr6 (€)	Timber production	0		0	0	0	0	9
	Rubber agroforest	0		0	0	0	261	0
	Jelutung agroforest	0		74	0	560	661	0
	Rattan collection	99		68	99	0	99	95
	Jelutung collection	90		316	90	0	90	90
	Paddy production	0			0	0	316	0
Benefit per yr (€)	Timber production	0		0	0	0	0	534
	Rubber agroforest	0		0	0	0	190,997	0
	Jelutung agroforest	0		0	0	3,798,263	483,714	0
	Rattan collection	651,272		389,575	695,933	0	241,491	284,657
	Jelutung collection	592,065		354,159	632,666	0	114,480	269,675
	Paddy production	0		401,952		0	401,952	0
Total benefits				2,389,022				3,316,0997

[1] We assumed that NTFPs were collected at a maximum distance of 10 km from villages, rivers or road (assuming it would take about 10% of the conservation zone in the current forest zonation)

[2] We assumed that NTFPs were collected at a maximum distance of 10 km from villages, rivers or road (assuming it would take about 10% of the conservation area in the conservation zone and 25% of the village forest and 100% of the community forest area in adapted forest zonation)

[3] We assumed that rehabilitation covers about 35% of the total rehabilitation area

[4] We assumed that agroforestry would be initiated in about 30% of the total community forest area

[5] According to Ministry of Forestry Regulation No. P.89/Menhut-II/2014 concerning village forests, timber production is allowed for domestic consumption with a maximum of 50 m^3 from the whole village forest per year (with the assumption that potential timber production is 0.86 m^3 per ha per year, 50m^3 per year is then equal to 58 ha per year -- Sumarga et al., 2015 and Suwarno et al., 2016a)

[6] Calculations of benefits per ha are based on Sumarga et al., 2015 and Suwarno et al., 2016a

[7] Potential benefits from rehabilitation is excluded due to high uncertainty

local communities in defining the area to be allocated for conservation, rehabilitation, community forest and village forest. This process was conducted in a series of focus group discussions during the period 2014 – 2015.

Adaptive forest zonation does, however, involve uncertainty in terms of the exact benefits people receive from agroforestry systems in community forests and rehabilitation areas. Local people could potentially receive substantial benefits per hectare from jelutong and rubber agroforestry 10 years after planting: € 770 per year for agroforestry jelutong and rubber (Budiningsih and Effendi, 2013), € 261 per year for agroforest rubber (Suwarno et al., 2016a) and € 820 per year for agroforestry jelutong (monoculture) (Budiningsih and Effendi 2013). Thus, the options for alternative livelihoods should be provided in the first 10 years. From this study, we propose that NTFP collection (i.e. rattan, jelutong, germor (*Alseodaphne sp*), illipe nut (*Shorea sp*), fruits and fish), from reachable areas in the conservation and village forests, be included in livelihood options.

5.4 Discussion

5.4.1 Can consideration of the Ecosystem Services (ES) concept support the implementation of sustainable forest management in the Forest Management Units (FMUs)

The ES concept provides a framework to anticipate a wide range of social and ecological consequences that may result from different decisions and tools to identify, negotiate, avoid and manage negative trade-offs (DeClerck et al., 2006; Ingram et al., 2012). This holistic concept is important to improve sustainable forest management practices in Indonesia to promote environmentally, socially and economically sustainable conservation management and to maintain the ecosystem benefits for present and future generations. Moreover, the ES concept will ensure that local livelihoods and the conservation programme funds are included in ecosystem management to balance conservation and development programmes and achieve positive outcomes (Sunderland et al., 2008; Kettunen et al. 2009; Mulia et al., 2013; Alvarado-Quesada et al., 2014).

The integration of the ES concept to support a better ecosystem management has been discussed in a number of studies (de Groot et al. 2010; Deal et al. 2012). The valuation of ES benefits and trade-off analysis on how they will change based on various scenarios provide essential information for forest managers to adapt their management programmes. For example, the information on how the monetary value of ES from forest ecosystems will change due to a land-use change scenario, could provide essential information for forest managers to work with stakeholders in conserving a forest area rather than convert it to other uses (Ruckelshaus et al., 2015).

In this study, the information from the ES valuation and trade-off analysis was used as a foundation to develop adaptive forest zonation. Our research shows that, from an economic perspective, the adaptive forest zonation could potentially increase the ecosystem service benefits local beneficiaries receive. Providing more rights and authority over community and village forests can increase the possibility of local beneficiaries meeting their livelihood expectations and reducing their interest in converting their forests to other uses. These benefits would be generated mostly from NTFP collection and limited timber production from agroforestry in the village forest and rubber and jelutong production in the community forest. From a conservation perspective, we show how the rules, rights and responsibilities in the stakeholder agreement can increase local community awareness of the need to conserve and protect the peat forest.

The stakeholder agreement details the shared responsibility for conservation (preventing forest fire, illegal logging and forest encroachment), which could reduce the risk of forest fire, a major problem in this area especially during El Nino events. The agreement discusses how enrichment planting of fruit and jelutong trees, in the buffer zone of the village forest, will improve the quality of the orangutan habitat and reduce potential conflict between the orangutan and humans. It likewise outlines the benefits of the rehabilitation programme using jelutong trees, which could also speed up the improvement of forest ecosystems and potentially generate benefits from jelutong resin collection over the following ten years. These results confirm the advantages of integrating the ES concept in sustainable, efficient and inclusive forest management that not only considers biodiversity conservation but also local livelihoods. These results also support other studies that indicate the positive impacts of the ES concept in sustaining local livelihoods, (Deal et al., 2012; Quine et al., 2013; Spangenberg et al., 2015) biodiversity conservation (Kettunen et al., 2009; Persha, 2011; Corbera & Pascual, 2012), and preventing land-use change and carbon emissions (Lin et al., 2011; Viglizzo et al., 2012; Sumarga et al., 2015).

5.4.2 Ecosystem management and landscape integrity

A tropical peat forest is a unique ecosystem with an accumulation of partially decayed organic matter from plant debris under waterlogged conditions (Andriesse, 1988). The organic matter accumulates at different rates in time and space resulting in different depths of peat with the highest and thickest points, peat dome summits, being close to riverbanks and mineral soil, forming the ecological boundaries of the peat ecosystem. A tropical peat ecosystem, usually located in lowlands between rivers with extensive floodplains, is a unique hydrological unit that can maintain balance, stability and productivity (Page et al., 2009).

The area of Kapuas Protected FMU is part of a peat forest ecosystem in Central Kalimantan Province. The peat ecosystem in this area consists of three domes, distributed along three big rivers. The boundaries of the Kapuas Protected FMU are designated based on the forest function. In order to capture the complexity of forest ecosystems, the management of Kapuas Protected FMU should integrate ecological and socio-economic systems within specific ecological boundaries rather than political or administrative boundaries (Minang et al., 2015; Mitchell et al., 2013). However, the current boundaries of this FMU do not include ecological boundaries.

Considering the importance of the hydrological unit as well as the dynamics of the socio-ecological processes in tropical peat forest ecosystems, the adaptive forest zonation in this study was developed using two rivers as ecological boundaries. The balance between conservation and economic development zones described in this study aims to increase and sustain the livelihoods of local people and their awareness of the need to conserve peat forest ecosystems. The allocated area for community forest along the riverbanks and villages will provide an opportunity for villagers to increase their income and encourage them not to convert the peat forest to oil palm anywhere between peat domes and rives, which covers most of the drainage system. Long-term agreements between local communities and the management of Kapuas Protected FMU (community and village forests) will increase local participation in the rehabilitation of degraded peatlands. In turn, the peat forest ecosystems will gradually regain balance and capacity to provide benefits.

5.4.3 Policy implementation

Forest degradation and deforestation have become the main issue in the Indonesian forestry sector. Forest degradation has reduced the capacity of forest ecosystems to provide and sustain benefits for forest dependent people and other beneficiaries globally (Achard et al., 2002; Sunderland et al., 2008; Suwarno et al., 2016a). In order to restore and sustain forest ecosystems, the government of Indonesia released two Ministry of Forestry Regulations No. 6/2007 and No. 3/2008 on the establishment of forest systems, the preparation of forest management plans and forest utilisation and introduced FMUs as a new form of sustainable forest management (FORCLIME 2011). The FMUs have been tasked with ensuring that economic, environmental and social functions are sustainably implemented in forest management, as stipulated in Law No. 41/1999 on forestry, and Government Regulation No. 44/2004 on forest planning. The regulation governing the establishment of FMU areas was then strengthened through the Ministry of Forestry Regulation No. P.6/Menhut-II/2009. Meanwhile, the norms, criteria, standards and procedures for developing the management plan for FMUs are governed by the Ministry of Forestry Regulation No. P.6/Menhut-II/2010 and strengthened by the Ministry of Forestry Regulations No. P.47/Menhut-II/2013 and No. P.46/Menhut-II/2013. These regulations list the criteria for management plan development including the ES concept. However, the technical guidelines on the use of the ES concept in developing management plans, is not included in these regulations. Technical guidelines on forest zonation development utilising the application of the ES concept is imperative to achieve better forest management practices in FMUs. These guidelines should contain detailed step-by-step instructions on conducting: (1) ES valuation; (2) land-use change simulation; (3) trade-off analysis; (4) delineation of forest zones; and (5) stakeholder consultations. Considering our experience in utilising the ES concept in developing adaptive forest zonation in Kapuas Protected FMU, we recommend that our diagram for forest zonation development be included in the guidelines.

The institution of FMUs is categorised as a public institution under the Ministry of Internal Affairs Regulation No. P.61/2010. Meanwhile, FMUs have also received a mandate from the national government to generate management and business partnerships with other parties (under sustainable forest management) and to act as a private institution (Setyarso et al., 2014). However, the FMUs' current financial arrangement does not support this mandate. The FMU as an institution was established under district or provincial government, and should follow the financial mechanism under decentralised forest government. Efforts to improve the management of FMUs in providing public services have been made by the national government (Ministry of Forestry) through the introduction of quasi-public agencies (Setyarso et al., 2014). A quasi-public agency is an institution formed, controlled and appointed by a specific government body, with the aim of providing public services while generating its own income (Cummings et al., 2010; Kosar, 2011). The establishment of quasi-public agencies in FMUs will provide them with more financial independence, while the government will be able to maintain some form of control over FMUs.

Experience in establishing quasi-public agencies as financial mechanisms under the Public Service Agency (Badan Layanan Umum Daerah) has been achieved in three FMUs (Lakitan Production FMU in South Sumatra, Yogyakarta Production FMU in Yogyakarta and Gularaya Production FMUs in South East Sulawesi). These three Production FMUs initiated the establishment of District Public Service Agency as a quasi-public agency to support the implementation of the economic development and conservation programme (Setyarso et al., 2014). The experiences of these three Production FMUs show that a District Public Service Agency, as a quasi-public agency, can help FMUs to achieve their objectives in sustaining local livelihoods and conservation funding. Considering the importance of District Public Service Agencies and the different characteristics of Production FMUs and Protected FMUs, we recommend that a quasi-public agency be developed and tested in Kapuas Protected FMU.

5.5 Conclusion

The importance of ES in generating sustainable benefits from well-managed forest ecosystems has been recognised in the FMUs as a promising mechanism to balance conservation and economic development programmes. However, how the ES concept could be used in the formulation of management strategies for Indonesian forest management units has, to date, not been explicitly considered. Our study aimed to test the applicability of the ES concept in optimising land use in a specific FMU through the development of adaptive forest zonation. The adaptive forest zonation was developed in this study to accommodate local community interest in sustaining ES benefits they could receive and FMU interest in conserving forest ecosystems. Our results show that adaptive forest management is important to conserve forest ecosystems and secure local livelihoods. The adaptive forest zonation could potentially increase ES benefits received by local communities by about 40%, through rattan and jelutong collection and production of agroforestry rubber and jelutong, compared to the current forest zonation. It could also potentially decrease the risk of forest fire, carbon emissions and forest encroachment resulting from stakeholder agreements as part of the process in developing adaptive forest zonation. Hence, it is recommended that the adaptive forest zonation development steps in this study be included in the national guidelines for forest zonation development for FMUs. More over, we also recommend that Public Service Agency formulation, as an institution of quasi-government, be created to support FMUs in generating direct benefits to finance their conservation and development programmes. One of the FMUs' mandates is to be a private institution that should be able to generate business partnership with other parties. FMUs are registered as a district or provincial agency and are required to follow the financial mechanisms of decentralised governance that does not allow them to receive direct income from a third party. The establishment of a Public Service Agency could then bridge this financial arrangement between FMUs as the institution under district or provincial government and a private institution.

Acknowledgements

We would like to thank Dirk Hoekman for providing the high-resolution 2010 land cover maps derived from Alos Palsar (provided by JAXA EORC) used in the LUCES model. We would also like to thank Robbert Hassen and Lex Karadonk for their contributions to the spatial data analysis. This research has been made possible through ERC grant 263027 (Ecospace). Details of the LUCES model used in this paper can be obtained through the corresponding author. The results of this study have been used to register the Kapuas Protected FMU with the Verified Conservation Area platform.

Chapter 6

Synthesis:
The utility of ecosystem services assessments for decision makers

6.1 Introduction

In the last few decades, Ecosystem Services (ES) research has advanced rapidly through the integration of biophysical and socio-economic aspects, such as those captured in my research. These advances have captured issues in ES assessment and modelling, and integrated the ES concept into ecosystem management. However, the application of these ES research advances in policy and decision-making is lagging behind.

This research was designed to examine and demonstrate how the ES concept and the agent-based land-use model can be applied to support sustainable ecosystem management in areas of limited data and information. For my thesis, I analysed the impact of decentralised forest governance, as part of natural resource governance, on deforestation rates and the ES benefits different groups of beneficiaries in the Indonesian Province of Central Kalimantan receive. Based on the collected information from my assessment of decentralised forest governance and ES benefits, I identified the possible options to optimise a forest moratorium programme and sustainable forest management. My four research questions (RQs) for this research are:

RQ1 How does decentralised forest governance influence deforestation rates?

RQ2 Who benefits more from ES?

RQ3 How do stakeholders' perspectives and expectations lead to their management decisions on land use and how these influence the ES supply?

RQ4 How can the ES concept be applied to optimise sustainable forest management under conditions where data and information is missing?

Sections 6.1 to 6.4 present the main discussion of this thesis with regards to these four research questions, which are addressed separately in Chapters 2 to 5. Each section first summarizes the conclusions for each research question followed by a reflection and a discussion on how I addressed and answered the question and its relevance to ecosystem management. Section 6.5 presents a discussion on the challenges in applying the results of this research to improve decision and policy making for management practices in other areas of Indonesia. The general conclusion and recommendations for further ES research and implementation in supporting ecosystem management are then presented in Section 6.6.

6.2 Assessing decentralised forest governance to improve sustainable forest management practices

Decentralised governance redistributes or disperses functions, powers, people and resources in response to problems associated with centralised governance. It is frequently introduced to develop local potential in development and sustainable resource management (Ribot et al., 2006; Larson & Soto, 2008). Political and administrative aspects of decentralisation are involved when decision-making and power are moved from central to local government, particularly in natural resource management (Colfer and Capistrano, 2005). In the context of the forestry sector, the establishment of decentralised forest governance aims to restore and sustain forest ecosystems and their services. Decision-making in decentralised forest governance should capture public participation in formulating and implementing local laws and policies that sustain local livelihoods. Moreover, these local laws and policies should be in line with national laws and policies on sustainable forest management.

Decentralised forest governance, in Indonesian, has frequently been assessed and studied (Angelsen and Kaimowitz, 1999; Larson, 2004; McCarthy, 2004; Resosudarmo, 2004; Arnold, 2008). These studies mainly link the start of decentralised forest governance with an increase in provincial deforestation rates. They also found that insufficient power and capacity of local authorities strongly constrained effective decision-making on land-use and forest management. However, these studies ignored sub-national data and did not examine the strong local effects of decentralisation (Andersson, 2003; Larson and Soto, 2008). This gap in the literature is addressed by my first research question on how decentralised forest governance influences deforestation rates.

To address RQ1, I provide my answer through examining the relationship between district forest governance performance and district deforestation rates (c.f. Chapter 2). I described the institutional changes that have taken in place, and empirically analysed the relationship between these changes and the corresponding district deforestation rates. Accordingly, I assessed the performance of district forest governance and used the comparable time series district deforestation rates as the environmental outcome (c.f. Chapter 2). I found that the principle of transparency has strong correlation with district deforestation rates compare with another principles. I further demonstrated how the results from this assessment could be used to improve sustainable forest management practice (c.f. Chapter 5).

My assessment of district forest governance was based on a three-pronged approach that frames (1) the decentralisation process, (2) deforestation in the districts and (3) district forest governance performance. This approach includes policy and deforestation analysis and the assessment of district forest government performance.

The decentralisation process should be framed through policy analysis. This is important to understand the link between district policies and political dynamics. District policies are often established to meet the interests of the district head (i.e. Bupati or Walikota) and his or her political parties (Casson, 2001; Arnold, 2008). The composition of political parties in the district legislative is then important to understand the interests of district decision makers in managing natural resources and ecosystems and the negative impact on ecosystems (Casson, 2001; Colfer and Capistrano, 2005), particularly forest ecosystems that is defined as deforestation and forest degradation.

Deforestation is commonly analysed by comparing forest cover for certain periods. The definition of 'forest' is frequently debated and can differ from institution to institution. In this thesis, 'forest' is defined as an ecosystem unit dominated by mature trees and other biological resources, an environment that supports forests, and is designated and/or stipulated by the government to be retained as permanent forest as per Indonesian Law No. 41/1999 on forestry. Hence, deforestation in this thesis is analysed by comparing the forest area from land-cover maps for 1990, 1995, 2000, 2005 and 2010, which were provided by the Indonesian Ministry of Forestry.

The performance of district forest governance is assessed by governance quality frameworks. These powerful frameworks facilitate systematic thinking about forest governance issues but neglect the broader question of how to collect and analyse empirical data. They capture the indicators of forest governance organised into three pillars and four common principles (i.e. accountability, equity, transparency and participation) (Kishor and Rosenbaum, 2012). The advantages of applying good forest governance and governance quality frameworks are related to their ability to measure forest governance and to provide the information on where governance is weak. This information is important to diagnose problems, advance reforms and monitor the impacts on environmental and socio-economic aspects. However, these frameworks require the willingness of local government to undertake self-assessment and discuss the results with various stakeholders. This limitation needs to be considered when these frameworks are used to assess district forest governance in areas with a high potential for political conflict.

The willingness to collaborate in my case study started with a series of discussions with top decision makers in the district forest government. The discussion focused on the current condition of forest ecosystems and benefits local people receive, and gradually helped to inform the decision makers on the importance of assessment of their forest government performance. In this way, it will help decision makers to understand the weakest and strongest current governance settings, and to assist them in improving this. I found that this series of discussions stimulated the top decision makers of eleven out of thirteen districts to conduct such assessments.

Linking the district forest governance performance and deforestation data provides a better insight into the political and economic interests of district governments (particularly Bupati or Walikota as the district's head) in forest ecosystems. This information is likely to be useful for evaluating current forest and land-use policies and to support better ecosystem management in individual districts. The advantages of integrating the results of forest governance assessments into ecosystem management are shown in Chapters 4 and 5. In Chapter 4, I show how the information on the performance of district forest governance could be used to revisit forest moratorium policies. This information was used to develop a land-use change model that simulated the interests of stakeholders, and maximised their economic benefits under three different scenarios to improve forest moratorium policies.

The developed land-use change maps are important when these policies and their implementation are revisited and assessed. This will ultimately improve such policies. Using information on the performance of district forest governance in optimising forest management practices is further presented and discussed in Chapter 5. Considering the establishment and implementation of Law No. 23/2014 that shifts the authority on natural resource management (i.e. forest, fisheries and mineral energy) from district to province, this study should then be enhanced through the assessment of provincial forest government performance with provincial deforestation rates as the outcome indicator. This assessment will provide adequate input to evaluate the effectiveness of Law No. 23/2014 in sustaining natural resource management in Indonesia.

6.3 Monetary benefits of ecosystem services

The number of studies on ES valuation and their beneficiaries has increased rapidly in the last few decades. These studies have included and tested several valuation techniques to calculate the monetary value of provisioning, regulating and cultural services around the world and define the ES beneficiaries based on spatial and temporal distribution (e.g. de Groot et al., 2002; Hein et al., 2006; Fisher and Kerry Turner, 2008; Laurans et al., 2013). However, how different beneficiaries receive different benefits resulting from different policies is poorly captured in these studies.

This section addresses RQ2 on the ES benefits received by different groups of beneficiaries. I provide my answer to RQ2 through assessing and analysing how the monetary benefits of seven ES are generated and distributed to different type of beneficiaries in the Central Kalimantan Province (c.f. Chapter 3). I first defined the beneficiaries based on the spatial extent and bio-economic processes that are consistent with the beneficiaries' concept in the System of National Accounts (SNA). Accordingly, I group the ES beneficiaries into (1) private (large companies, small medium enterprises, and smallholder with hired labor); (2) public (governmental agencies at various levels); and (3) household entities. Second, I calculate ES monetary benefits based on the valuation approach of ecosystem accounting. Third, I analyse the benefits receive by different type of beneficiaries based on existing government regulations in the forestry and agricultural sectors.

Identifying ES beneficiaries is important to assess ES benefits and its distribution. In Chapter 3, I show that the advantages of using the ecosystem accounting approach to identify ES beneficiaries. Ecosystem accounting groups ES beneficiaries into three different groups (i.e. private, public and households) consistent with the SNA. In this chapter, I also show the advantage of using the ecosystem accounting approach in obtaining ES monetary benefits that are also consistent with the SNA. Valuation methods included in ecosystem accounting, such as resource rent, avoided-damage-cost and replacement-cost methods, can be used to value provisioning, regulating and cultural ecosystem services (UN et al., 2012; Obst et al., 2015). I show that the resource rent and avoided-damage-cost methods can be used to obtain a valid monetary value for provisioning services that are traded on the market (including rattan, jelutong resin, timber, agroforestry rubber, oil palm and paddy) and regulating services (including carbon emissions) – in particular in the context of natural capital accounting. Remme et al., (2014) and Sumarga et al., (2015) also confirm the applicability of a range of monetary valuation methods for ecosystem accounting (e.g. resource rent method, avoided-damage-cost method and replacement-cost methods).

Further, I list the advantages of conducting an assessment of the influence policies have on benefits received by different beneficiaries. For example, the establishment of forest-utilization policies secures forest ecosystem benefits received by the three different groups of beneficiaries. However, the absence of a tax regulation in agricultural policies provides more benefits for private individuals, and neglects the benefits received by household and public entities (i.e. district, provincial and national governments). The experiences above show the advantages of integrating policies on natural resource management in ES benefits assessment. Decision makers would be well advised to use the available information on potential gains and losses resulting from potential land-use change when revisiting current policies and defining, developing and implementing new policies.

People obtain benefits from ecosystems in different ways. Benefits from ES are not just a function of ecosystem dynamics, but also a function of socio-economic systems (e.g. governance systems, markets and informal land use) (Fisher et al., 2008). These socio-economic systems are related to potential gains and losses on the benefits received by different beneficiary groups. One group may increase their benefits and inflict costs on others, who may lose access to resources or livelihoods. These issues, however, are not adequately considered in current ecosystem management. As a result, people who depend on a common forest resource, often lose the opportunity to receive more benefits because of privatisation policies in the forestry and agricultural sectors.

Ecosystem management should include activities that help sustain the livelihoods of the local people who depend on ecosystems. These activities include establishing regulations on land use management, benefit sharing mechanisms and payments for ecosystem services (Sunderlin et al., 2005; Balvanera et al., 2006; Wunder, 2013). These policy and economic instruments should be developed considering the results of ES assessment that includes ecosystem benefits, beneficiaries and policy analysis. Considering locally produced, regulating and cultural services and their globally enjoyed benefits, further ES assessment across districts, provinces and even countries is essential to complete this study in providing comprehensive input for decision makers.

6.4 Analysing land use change to evaluate land use policies

6.4.1 The LUCES model

Land-use studies have naturally gravitated from efforts to monitor and model changes in land-use patterns towards estimating the impact of such changes and patterns on ecosystems and ESs. Changes and patterns in land use are mostly influenced by human activities that are driven by changing socio-economic and environmental conditions. People tend to adjust land use to meet their expectations. This is directly and indirectly influenced by local, national and international policies.

Land-use changes include spatio-temporal and ecological processes that are tied to different types of stakeholders and their specific land-use decisions (Verburg et al., 1999; Lambin, et al., 2003). These decisions are mostly related to the economic expectations driven by recent policies and local markets of specific provisioning services. However, understanding the policies' influence on land-use change is not simple. Adequate approaches must capture complex socio-economic interactions that include the cognitive processes of stakeholder decision-making in response to policies (Rounsevell et al., 2010; Valbuena et al., 2010; Villamor et al., 2014). Such an approach that is recognised by the land use modelling community, is Agent-Based Modelling (ABM). The advantages of using ABM in analysing land-use change are related to its ability to model social processes and non-monetary influences and how these affect individual actors' decision-making. In particular ABM allows the inclusion of behavioural motives of agents that go beyond the rationality assumption conventionally applied in micro-economic models (Villamor et al., 2011). ABMs incorporate the influences of human decision-making on land use in mechanistic, formal and spatially explicit ways and consider social interactions, adaption and decision making at different levels (Railsback, et al., 2006; Robinson et al., 2007; Heppenstall & Crooks, 2012). The application of ABMs in land-use change is promising, starting from a theoretical, abstract model to a more realistically applied model to solve problems and support land-use policy formulation and evaluation (Balmann, 1997; Castella et al., 2005; Bithell and Brasington, 2009; van Noordwijk et al., 2011).

I apply the ABM approach to simulate stakeholders' decisions in response to national forest moratorium policies, as explained in Chapter 4. A land-use agent-based model, namely the Land-Use Change and Ecosystem Services (LUCES), was developed to address RQ3 on how do stakeholders' perspectives and expectations influence their land-use decisions and how these decisions alter ES supply. LUCES was designed and developed to consider the interests of households and companies in shaping their opportunities through land-use decisions in responding to the current national forest moratorium policies. LUCES was developed to improve existing agent-based land-use models (e.g. the FALLOW and LUDAS models) that generally only consider household decisions on land-use change. LUCES includes household and company decisions in defining unplanned and planned land-use changes and their influence on ES supply. LUCES combines biophysical and socio-economic data from my earlier studies (Chapters 2 and 3).

In addition, surveys, interviews and focus group discussions were conducted to obtain the necessary socio-economic variables for the LUCES model and develop scenarios. The scenarios were developed based on a participatory approach that included the stakeholders' preferences and expertise. These scenarios include options to extend the duration of the forest moratorium (Extended Moratorium Scenario) and to complement it with a local livelihood programme (Moratorium Plus Livelihood Scenario).

LUCES is a hybrid model developed for the Kotawaringin Barat and Kapuas districts but could also be applied in other case study areas with different variables to indicate other environmental and socio-economic conditions. Despite its advantages of including planned and unplanned land-use changes, LUCES is still limited in how its variables for household and company land-use choices are obtained. Obtaining these variables is data intensive and time consuming. It also requires scientific expertise to weight some of these variables to meet LUCES requirements. To increase the usefulness of the model for wider use, alternative methods for generating and weighting these variables should be further explored.

6.4.2 Integrating the land-use change model to evaluate and revisit land-use and forest policies

Integrated assessment of land-use change is important to obtain information on how stakeholders' land-use decisions may change in response to land-use policies. Compiling and analysing empirical evidence resulting from land-use change models can be valuable in two ways when evaluating recent land-use policies. First, they provide generic evidence on the impacts of current policy settings on the environment and local people. Second, they provide specific scenarios to help decision makers envision future impacts and define and evaluate options to improve these policies.

In Chapter 4, I show how LUCES' results provide insights into biophysical-socio-economic changes resulting from the establishment of forest moratorium policy. LUCES' results clearly show the different influences forest moratorium policies have on household and company decision-making and the subsequent impact on land-use change and ES supply. The implementation of the current forest moratorium policy has decelerated the planned land-use change (by companies). However, the unplanned land-use change (by local communities) is hardly affected, even when the duration of the forest moratorium is extended (in the Extended Moratorium scenario). Meanwhile, including the livelihood programmes under the Moratorium Plus Livelihood scenario provides substantial effects to decelerates planned and unplanned land-use change. Economic incentives for non-timber forest products and agroforestry products under the livelihood programmes secure the ecosystem benefits that local communities receive, and increase their awareness of conserving forest ecosystems. This could also increase the awareness of decision makers and encourage them to release or extend concession permits to improve local livelihoods. Thus, according to LUCES, implementing forest moratorium policies should also include livelihood programmes to meet the broader objectives to decelerate land-use change and support the national programme on poverty reduction, as stated by the Indonesian Intended Nationally Determined Contributions for the Paris Agreement from December 2015.

Studies on land use make the point that agent-based land-use models are a powerful tool for evaluating current policies and analysing policy change. However, little evidence exists that decision makers have actually used the results of agent-based land-use models. This likely lack of attention to these results is mainly related to outreach and communication between scientists and decision makers. Therefore, public decision makers should be involved in the model applications and scenario building process (see, for example, Mauser et al., 2013). The results of these models should be communicated and disseminated to help decision makers understand the impacts of policies and to design additional programmes to make these policies work.

Examples of the practical applications of agent-based land-use models in evaluating policies are provided in this thesis. My participatory approach helped to develop and test LUCES. Further, the LUCES' results were shared with the district decision makers and then expanded and used to develop adaptive forest zonation in one of the case study areas. This will be presented and discussed further in Section 6.5.

6.5 Integrating ES concepts and a land-use change model to optimise land-use management

Optimising land-use is important to address land-use changes and environmental problems, particularly in Indonesia. Indonesian land-use change and degraded ecosystems involve mostly conversion from forest to other land uses and are mainly related to land-use policies for specific governance systems and poverty due to biased economic developments. Local people and decision makers play a pivotal role in managing and improving these land-use changes.

Efforts to optimise land use in Indonesia should start with improving forest and land management. This should not only include the value of forest ecosystem benefits but also the preferences of local people and decision makers in sustaining their livelihoods and local development programmes (Abram et al., 2014; Suwarno et al., 2015). Hence, the combination of ES concepts and land-use change modelling are invaluable. The advantages of simultaneously implementing ES concepts and land-use change modelling to improve ecosystem management have been highlighted in previous studies. The analysis of ecosystem benefits and trade-offs on how these benefits will change in the various scenarios are valuable inputs for ecosystem managers to achieve positive outcomes in balancing conservation and development programmes (Kettunen et al, 2009; de Groot et al., 2010; Deal et al., 2012; Alvarado-Quesada et al., 2014; Ruckelshaus et al., 2015). Meanwhile, information on how people make their land-use decisions is also essential to support ecosystem managers in reconciling the interest of all possible stakeholders (Matthews et al, 2007; Mulia et al., 2014; Villamor et al., 2014; Sumarga et al., 2015). Possible future land-use conditions seen in the scenarios that were quantified by land-use change models, are valuable as a reference point for policy making and/or evaluation/assessment processes (Matthews et al., 2007; Sumarga and Hein, 2014). Still, the availability of required information for appropriate policy and management decision-making is a challenge for the application of ES concepts and land-use modelling in optimising land use in forest ecosystem management, as formulated in RQ4 of this thesis.

To address RQ4, I show how ES concepts and land-use models can be applied to optimise land use in Kapuas Protected Forest Management Unit (FMU; see Chapter 5) through the development of adaptive forest zonation that improves current forest zonation. Adaptive forest zonation was developed for this research by combining the information on ecosystems benefits (generated from Chapters 2 and 3) and potential land-use changes that could occur in this area (as a LUCES result in Chapter 4). This information was then combined with biophysical criteria and indicators under sustainable forest management to identify potential areas to be allocated for conservation and economic zones and the options of potential economic activities that could be undertaken by local people. Public participation was also captured in the process of adaptive forest zonation development. This process included public participation in defining (1) the area to be allocated for economic development, (2) options for local economic activities and (3) an agreement on rights and responsibilities in managing the area allocated for local economic activities. This participatory process was conducted in collaboration with the management of the Kapuas Protected FMU and other national and international institutions and organisations. As a result, a spatial plan for village forests and community forests in three villages (from a total of nine villages) was agreed. The head of the Kapuas Protected FMU used this plan to register the area on the Verified Conservation Area platform. It has become the first protected area in Indonesia registered on this platform.

Land-use is a salient issue in sustaining forest ecosystems in Indonesia. Considering the main aims of FMUs in conserving forest ecosystems and sustaining local livelihoods, land-use optimisation is important and should be included in FMU management plans. Specific allocation for conservation and livelihood purposes and clear responsibilities for managing the land with public participation could help FMUs to achieve their aims. However, the lack of capacity and data availability can constrain FMUs when trying to include participatory forest zonation options in their management plans. Therefore, technical guidelines for participatory forest zonation development must be developed. These guidelines should include step-by-step instructions for (1) conducting ES assessment, (2) developing a land-use model, (3) delineating forest zonation based on sustainable forest management criteria and indicators, and (4) conducting public participation to communicate and revise forest zonation. Based on my experience and lessons learned in developing participatory forest zonation for the Kapuas Protected FMU, I highly recommend that step-by-step instructions in participatory forest zonation development are included in the technical guidelines for all Indonesian FMUs.

6.6 Conclusions

This thesis clarifies, applies and operationalizes the ES concept and agent-based land-use modelling in support of ecosystem management. This thesis explicitly confirms the applicability of this ES concept and these land-use models in optimising land-use in forest ecosystems, even in data-poor environments. The ES concept provides a framework and tools to assess ecosystem benefits under current natural resource governance settings. Meanwhile, land-use modelling provides an appropriate framework to understand the dynamics of people's decisions to change land use to meet their economic expectations.

ES assessment is important to understand current governance settings and their influence on ecosystems and benefits that are received by different beneficiaries. Information on ecosystem benefits under certain natural resource governance settings provides valuable input to understand the preferences and expectations of decision makers and communities in maximising their benefits. In my thesis, I highlight the importance of assessing forest governance systems before conducting an ES assessment. The information generated provides insight into how certain forest governance systems define policies and regulations and indirectly the environmental outcomes and impacts. I also highlight the advantages of using an ecosystem accounting approach, that is consistent with SNA, and agent-based land-use models in ES assessments. Such ecosystem accounting can be used to monitor the dynamics of ecosystem capital and assess the effectiveness of recent and past policies. Meanwhile, agent-based land-use model can be used to predict ecosystems dynamics as a result of policies implementation. The combination of these two steps will generate crucial and detailed information to support decision making in ecosystem management. In this thesis, I show how decision makers in one of my case study area could actively involved in ES assessment, and use the assessment results to improve forest zonation.

Agent-based land-use models are powerful tools that help scientists, researchers, decision makers and other related stakeholders to understand the potential changes in land-use resulting from the actors' decisions to change local and regional land-use. In this thesis, I highlight the advantages of an agent-based land-use model based on its capacity to provide essential information on potential land-use change in response to certain government policies. This information is important to evaluate and revisit current policies and to support decision-making in designing the programmes to make these policies work, as shown in the LUCES model that I developed for this thesis. LUCES includes the land-use decisions of local communities and private companies as a response to the recent implementation of a forest moratorium policy and the influence of these decisions on the dynamics of ES supply. Lessons learnt from LUCES show that forest moratorium policies should also include livelihood programmes to meet broader objectives.

To incorporate the ES concept and land-use modelling in decision-making for land and ecosystems management requires societal discourse on what to sustain, how much and where. Such discourse is important to optimise land-use and sustain ecosystem management. Land-use optimisation must capture the interest of stakeholders in maximising their benefits and conserving ecosystems. In this thesis, I show how land-use optimisation can be achieved through the development of adaptive forest zonation integrating ES and agent-based land-use change modelling concepts. The proposed method for adaptive forest zonation development includes public participation in allocating forest area(s) to sustain local livelihood. Learning from the development process of adaptive forest zonation in this thesis, this method could be applied in other FMUs to support sustainable forest management. This thesis provides a first important step in practical applications to improve forest ecosystem management and local livelihoods.

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Appendixes

Appendix 2.1. Scores from ten indicators of the forest governance quality in the districts

District	Period	Ind 1	Ind 2	Ind 3	Ind 4	Ind 5	Ind 6	Ind 7	Ind 8	Ind 9	Ind 10	Total Score	Deforestation per year (% to forest area in the district)
Kotawaringin Barat	2000-2005	3	3	3	3	3	2	2	1	1	2	23	-0.8
	2005-2010	3	3	3	2	2	2	1	2	1	1	20	-2.3
Lamandau	2000-2005	3	3	3	3	3	2	2	1	1	2	23	-0.4
	2005-2010	2	2	3	3	2	2	1	1	1	1	18	-3
Sukamara	2000-2005	3	2	3	2	2	2	2	1	1	2	20	-4.9
	2005-2010	2	2	2	2	2	2	1	1	1	1	16	-6.6
Kotawaringin Timur	2000-2005	3	3	2	2	3	2	2	1	1	2	21	-4.4
	2005-2010	2	2	2	2	2	2	2	1	1	1	17	-5.1
Seruyan	2000-2005	3	3	3	2	2	2	2	1	1	1	20	-1.9
	2005-2010	2	2	2	3	3	1	1	2	2	2	20	-1.1
Katingan	2000-2005	3	3	3	3	3	3	2	1	1	2	24	-0.1
	2005-2010	2	2	3	3	2	2	1	2	2	2	21	-1.3
Barito Selatan	2000-2005	3	3	3	3	3	2	2	1	1	2	23	-1.6
	2005-2010	2	3	2	2	2	1	2	2	2	1	19	-2.2
Kapuas	2000-2005	3	3	3	3	3	2	2	1	1	2	23	-0.7
	2005-2010	3	2	3	2	3	2	1	2	2	2	22	-1.3
Murung Raya	2000-2005	3	3	3	3	3	2	2	1	1	2	23	0
	2005-2010	2	3	3	3	3	2	1	2	3	2	24	-0.3
Pulang Pisau	2000-2005	3	3	3	3	3	2	2	1	1	2	23	-0.3
	2005-2010	2	3	3	3	2	2	1	2	1	1	20	-2.6
Kota Palangkaraya	2000-2005	3	3	3	3	3	2	2	1	1	2	23	0
	2005-2010	3	2	3	3	3	2	1	2	2	1	22	-1.5

Ind 1 = Existence of district policies on forest management
Ind 2 = Consistency and link between district and national policies on forest management
Ind 3 = Extension and implementation of forestry mandate
Ind 4 = The independency of forest district agency from political interference
Ind 5 = Capacity of forest agency staff
Ind 6 = Equity in access to forest resources
Ind 7 = Law enforcement
Ind 8 = Access to public data and information
Ind 9 = Public hearing and consultation during policy making
Ind 10 = Stakeholder inputs and participation in land management policies

Appendix 2.2. Pearson's correlation coefficients of the change on forest governance quality on the change of deforestation rate at the district level

Variable a , Variable b	Correlation coefficient (r)	P value
Indicator 1, Deforestation rate	0.08	0.82
Indicator 2, Deforestation rate	-0.11	0.76
Indicator 3, Deforestation rate	0.45	0.17
Indicator 4, Deforestation rate	0.33	0.32
Indicator 5, Deforestation rate	-0.59	0.6
Indicator 6, Deforestation rate	0.55	0.08
Indicator 7, Deforestation rate	-0.29	0.38
Indicator 8, Deforestation rate	-0.76	0.007**
Indicator 9, Deforestation rate	-0.68	0.02*
Indicator 10, Deforestation rate	-0.74	0.009**
Total Indicators, Deforestation rate	-0.78	0.004**

* significant at α 0.05 / ** significant at α 0.01

Appendix 4.1. The Overview, Design concepts and Details (ODD) protocol (cf. Grimm et al., 2006, 2010)

1 Overview

1.1 Purpose

The LUCES model was designed to understand the consequences of decisions households and private companies make on land-use in response to forest moratorium policies. Household decisions are influenced by (1) their expectations of market prices based on past experiences; (2) knowledge of the market and modes of production; and (3) preferences for and perceptions of their livelihood options, while market prices and land zoning policies influence the decisions of private companies. The LUCES model is intended for ex ante evaluation of proposed land-use policies and calibrated with data from Kapuas and Kotawaringin Barat districts. The LUCES model provides land cover maps in raster file and Comma Separated Values (CSV) format as the main output, and the supply of seven ecosystem services in CSV format as an additional output.

1.2 Agents, their state variables and scales

The LUCES model comprises a human-environment landscape that consists of human (households and private companies) and landscape agents (congruent land patches) with the following details:

1. Human agents

The human agents in the LUCES model are characterised by their location and economic activities. Human agents represent individual households and private companies. The primary state variables of the households are their livelihood portfolio and their expectation of various land-use options (van Noordwijk, 2002; Suyamto et al., 2009), while the state variable of private companies is profit. The state variables of human agents also include social identity, land and natural resource access, financial and human capital, physical capital and policy access. The environmental variables and parameters that drive human agents' behaviour in the LUCES model are described below:

(a) Households: market prices, policy intervention through economic incentives for Non-Timber Forest Product (NTFP) collection and agroforestry rubber production, neighbourhood land-use and livelihoods, and labour allocation, and

(b) Private companies: market prices, government regulations on forest zonation, and policy intervention (forest moratorium)

2. Landscape agents

Landscape is described by congruent land patches with characteristics that correspond to GIS-raster layers covering the whole study area, consisting of two main components: (1) patch state variables (biophysical and socio-economic properties of the land) and (2) an internal ecological sub-model (i.e. forest succession model). Each time step in the LUCES model represents one year and each patch represents approximately 0.5 km^2.

1.3. Process overview and scheduling

The LUCES framework is programmed in NetLogo, version 5.0.5. NetLogo is the highest-level platform of ABM software that provides a simple yet powerful programming language, built-in graphical interface and comprehensive documentation (Railsback et al., 2006; Heppenstall and Crooks, 2012). NetLogo is designed primarily for ABM for mobile individuals with local interactions in a grid space that could produce an operational ABM Land-use Change and Cover (LUCC) model with functionalities of a decision support system (DSS) for particular land-use policies. Meanwhile, the engine of the operational LUCES system and simulation programme is coded using Unified Modelling Language (UML) to describe object-oriented software in a unifying format (Fowler, 2003).

The LUCES model is a spatially explicit representation of a land area (represented as a raster) with the potential for land cover change in each pixel governed by a combination of formally planned and unplanned change. Private companies that obtained government permits drive planned land-use change, while households drive unplanned land-use change. Private companies change land-use based on their interest in maximising profit, while households base their decisions on the income-expectations of particular livelihood options (Abram et al., 2014). In the LUCES model, the livelihood options for local households include non-timber forest products (NTFPs) collection (rattan and jelutong) and the production of agroforestry (rubber), paddy, oil palm and timber. Households will frequently change the current land-use to agroforests, agriculture or oil palm plantation, while the decision on NTFPs collection will not change the forest area.

The dynamic interaction in the LUCES model, under the simulation or scheduling programme, is developed based on a combination of the LUDAS model (Le et al., 2008; Le et al., 2010b) and the FALLOW model (Suyamto et al., 2009). The scheduling programme consists of 12 steps, as presented in Figure 1. The main time-loop of the simulation programme is an annual production cycle, which includes integrated patches of private company and household actions and decisions.

2 Design concepts

2.1 Emergence

Land-use patterns emerge through two micro-processes: (1) households and private companies change land-use and (2) natural succession of the vegetation (Villamor et al., 2014). In the LUCES model, economic incentives for communities to collect NTFPs and

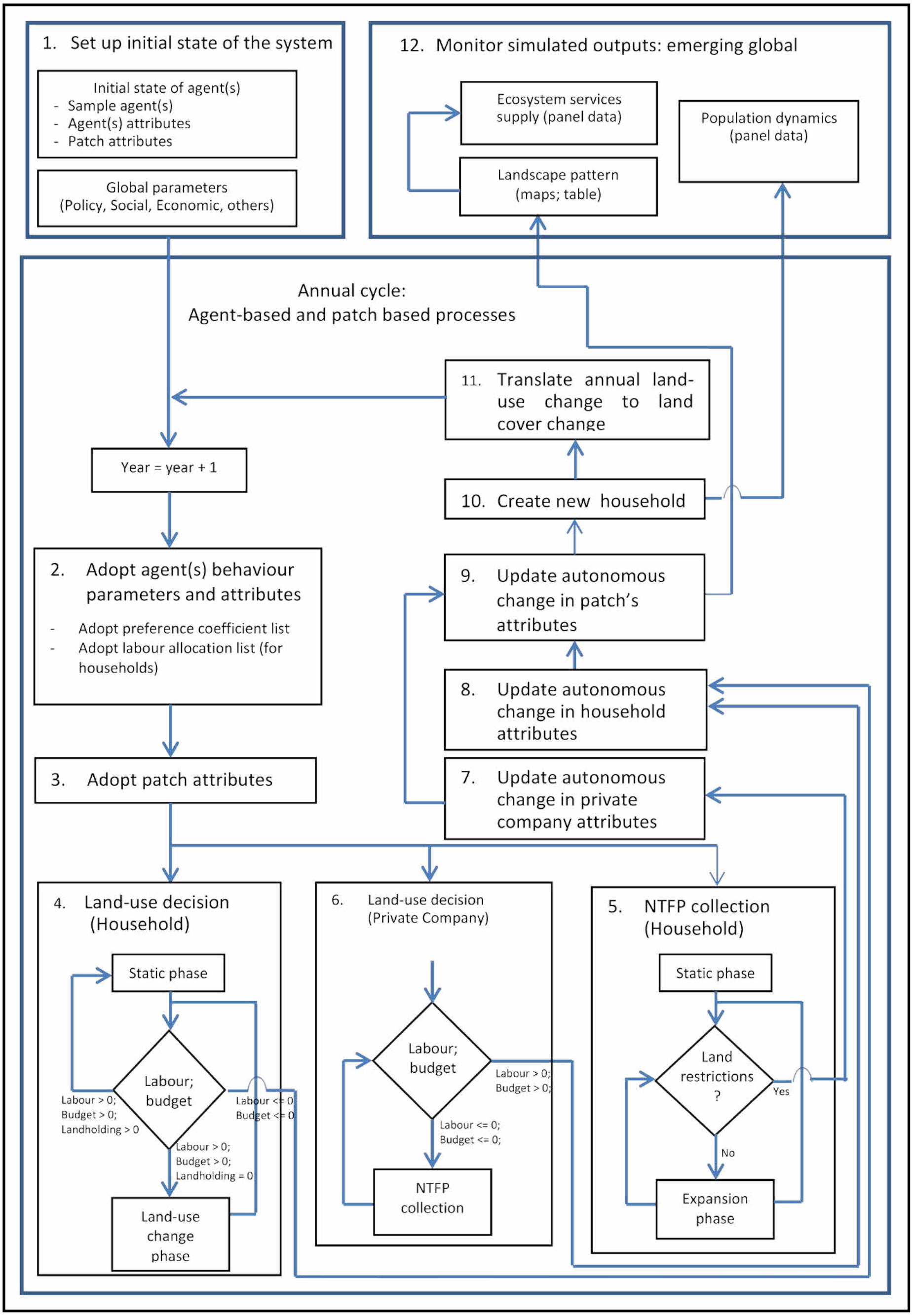

Figure 1. The main steps of the LUCES model simulation process for land-use decisions of households and private companies, as well as the impact of the land-use decisions on ecosystem services supply

produce agroforestry rubber are linked to the land cover type as an indicator of land-use and its capacity to provide ecosystem services. The emerging pattern of land-use in the LUCES model is a consequence of change in human agent decisions in response to change in the relative expected profitability of the land-use. In this case, decisions of households emerge from specific learning, while for private companies simply maximise profits.

2.2 Adaptation learning

Adaptive traits of each individual household are explicitly influenced by land-use decisions and changes in the preferences for different land-use options, structure of labour allocation and the effectiveness of policy intervention. The experiential learning equation of the FALLOW model was adopted in the LUCES model to express the dynamics of the household expectations and preferences for different land-use options. Each household is assumed to adjust expectations based on own experience, 'α learning', and experiences of others, 'β learning' (Mulia et al., 2013; Suyamto et al., 2009; van Noordwijk, 2002). In order to share the experience, each household is assumed to choose a number of partners in an undirected network (i.e. member agents within the network will reciprocally share their experiences with each other). This level of knowledge and the learning process will then determine the attractiveness and availability of land.

2.3 Objectives

The goal of human agents in their land-use decisions is explicitly modelled in the LUCES model. Households calculate the income from current land-use types and probability of changing the land-use based on the option with the highest potential income. This probability is linked to the availability of labour and the attractiveness of the new land which is defined by: (1) the most profitable product at the local market, (2) the availability of the land, including access and tenure status as well as other spatial rules. Meanwhile, the land-use decisions of private companies are calculated to maximise profits linked to the availability of new land for expansion with legal spatial regulations as constraints.

2.4 Prediction

In the LUCES model, the spatial information perceived by private companies and households is defined to generate their behaviour under different circumstances. Private companies recognise profitability based on market prices and adjust their expectations of profit contingent on this information and legal constraints. Households use spatial information from past experience, following the theory of adaptive expectation (Mulia et al., 2013). A single household will then adjust his/her expectations according to his/her own experiences (α learning) and the experiences of others (β learning) following the equation below:

$$e_{t(own)} = e_{t-1} + \alpha(r_{t-1} - e_{t-1}) \quad \text{...(1)}$$

$$e_{t(others)} = \bar{e}_t + \beta(e_t - e_t) \quad \text{...(2)}$$

where, $e_{t(own)}$ and $e_{t(others)}$ are adjusted expectations according to their own experiences and experiences of others, e_{t-1} is the expectation of a given household (in € per person/day) at time *t-1*, r_{t-1} is the remuneration of a particular livelihood option currently earned by a given household (in € per person/day), and $\bar{e}$ denotes the mean of the adjusted (at time *t*) expected wages of a particular livelihood option of other households (in € per person/day). Expectations adjustment rate is α ($0 \leq \alpha \leq 1$) and β is the expectation adjustment rate of a given household's experience of other households ($0 \leq \beta \leq 1$).

According to the α and β learning styles explained above, a household adjusts the allocation of labour according to the expectations of livelihood options based on the follow equation:

$$fi = \frac{(m_i e_i)^p}{\sum_{j=1}^{n}(m_j e_j)^p} \quad \text{...(3)}$$

where f_i is a fraction of labour allocated by a given household to livelihood option *i*, m_i is a multiplier of expected returns to labour of livelihood option i, and p is the prioritisation degree of a given household in deliberating some options ($p \geq 0$). In this case, when m=1 for all options or when p=0, a household has no prioritization, and will allocate labour equally to each available option; when p=1 a household will allocate labour proportionally according to expected income shares. Otherwise, when p>1, a household tends to give less weight to less rewarding options and allocates more labour to the better income options. The parameter *m* is introduced into the equation as a multiplier of expected income, which is beyond economic reasoning.

2.5 Sensing

In the LUCES model, households are assumed to have different levels of knowledge and styles of learning in determining the attractiveness and availability of land. The LUCES model combined and improved the levels of knowledge and learning (α and β learning) of households from the FALLOW model and Rogers (2003). The level of knowledge and learning of households are mostly influenced by the degree and radius of the sharing network, as explained in Table 1.

2.6 Interaction

The LUCES model includes direct or indirect interactions between households. For private companies there are only indirect interactions. Direct interactions between households occur when a single household transfers information and knowledge that may influence

Table 1. Households knowledge and learning level use in the LUCES

No	Household types	Population fraction within the households	α learning (expectation adjustment rate to self-experience)	β learning (expectation adjustment rate to others' experiences)	P (Prioritisation degree)	Degree of sharing network (persons of peers)	Radius of sharing network (km)
1.	Innovator	The one (1 %)	Very high (±1)		Very high (±2)	Very high (±10 persons)	Very far (≥50 km)
2.	Early adopter	Minority (3 %)	High (±0.75)		High (±1.5)	High (±8 persons)	Far (40-50 km)
3.	Early majority	Majority (45 %)	Medium (±0.5)		Proportional (±1)	Proportional (±6 persons)	Medium (30-40 km)
4.	Late majority	Majority (45 %)	Low (±0.25)		Low (±0.5)	Low (±4 persons)	Close (20-30 km)
5.	Laggard	Minority (≤ 6%)	Very low (±0.1)		Very low (±0.25)	Very low (±2 persons)	Very close (10-20 km)

the decision making processes of other households, while indirect interaction occurs when land-use change leads to changes in the decision space of other households. Indirect interaction also occurs between households and private companies when land-use change of households affects patches which are already occupied by private companies.

2.7 Stochasticity

The LUCES model incorporates stochasticity through: (1) the initialisation of a community's population; (2) initialisation of the first harvesting or planting blocks of private companies; (3) choosing the plot location of a new household and the harvesting or planting blocks of private companies during the simulation period; (4) the preference coefficient of the chosen land-use option; and (5) some status variables that are not affected by agent-based processes.

3 Details

3.1 Initialisation

The initial landscape in the LUCES model is determined by imported GIS-raster files on landscape variables that are produced by separate spatial analysis. The LUCES model imported current land-use map that included the forest function established by government regulation.

The initialisation of private company and household areas is defined as follows:

1. Private company area(s)

First, spatial data on private companies (timber concession, timber plantation and oil palm plantation) are imported. Next, decisions on harvesting and/or planting schedules are made based on the target time of the regulations. Harvesting and planting target times of a given concession will then determine the number of harvesting and planting blocks. Logging concessions or timber plantations should have 25 logging blocks and oil palm plantations have 1 to 5, as determined by the concession permits. The partition of delineating logging and planting blocks conducted by taking into account the possibility of cross boundary logging and plantation companies (e.g.. part of the logging/plantation concession boundary can be located within the neighbouring zones of the landscape). The size of each harvesting/planting block in the LUCES model is distributed to a uniform size by dividing the total area by the number of blocks (25 for logging and timber and 5 for oil palm).

A permit for a logging or plantation concession in Indonesia is valid for 25 years. The permit could be extended or terminated based on government decisions that potentially include modified views on environmental and economic development targets. The calculation of land demand for the extended permit is based on the equation below:

$$\Delta a_i = M \cdot \Delta y_i \cdot C_i \quad \text{...(4)}$$

where Δa_i denotes the demand for land expansion of sector i (in ha) due to an increase in the target 'monetary' demand of sector *i*, *M* is the Leontief inverse matrix, denoting the monetary multiplier (dimensionless), y_i is the target 'monetary' demand of sector *i* (in €) and C_i is the land input coefficient of sector *i* (in ha/€).

2. Household areas

First, initial population (*Nt*) and households (*Ht*) data in sub district and village are imported. Next, the dynamics of the households in time *t+1* ($H_{(t+1)}$) is then generated based on the equation below:

$$H_{(t+1)} = \frac{N_{(t+1)}}{int\,(N_t / H_t)} \quad \text{.......................................(5)}$$

where $H_{(t+1)}$ is the number of households in time *t+1*, that is generated by dividing the total population in time *t+1* by the size of the initial household (integer component of the initial ratio (*Nt/Ht*). The population dynamics in the LUCES model are generated based on the estimation of population growth provided by the Indonesian statistical bureau.

Further, new household land parcels are created using spatially bounded rules. These rules contain state variables representing the number of land parcels of new households and the corresponding locations based on certain spatial determinants (distance from road, distance from river, distance from centre of economic activities, etc). The new plots will be chosen based on perceived spatial attractiveness determined as follows:

$$attr_{x,y} = \frac{(1 - r_{x,y})}{1 + \sum_i W_i \cdot C_{i,x,y}} \quad \text{...(6)}$$

where $attr_{x,y}$ is perceived spatial attractiveness of a patch located at coordinates *x,y* for logging, NTFP gathering, or establishing new plots as land-based activities; $r_{(x,y)}$ is perceived spatial restrictions of a patch located at coordinates *x,y* for particular land-based activities; *r* is estimated based on community perceptions of land allocation according to government spatial planning, with values ranging from 0 (not restricted at all) to 1 (very restricted); $C_{i,x,y}$ are spatial determinants i of a patch located at coordinates x,y for a particular land-based activity; and W_i is perceived importance of spatial determinant i for a particular land-based activity.

3.2 Input

The LUCES model requires input of spatial data and parameter values to simulate the land change dynamics. The spatial data include: (1) land cover maps provided by Tropenbos International Indonesia Programme (TBI Indonesia) and World Agroforestry Centre (ICRAF); (2) maps of existing timber concessions and timber plantations provided by ministry of forestry; (3) maps of existing oil palm plantations provided by the Orangutan Foundation Indonesia (OFI); and (4) maps of soil and plantation suitability provide by Indonesian soil research centre (Balittanah) and ICRAF. The Parameter values related to the market price, returns on land and labour were obtained from Suwarno et al., (2016), while production, demographic and employment parameters were obtained from the statistical bureau. Parameters related to ecosystem services supply per different type of land-use were obtained from Sumarga and Hein (2014) and Sumarga et al., (2015). The parameters related to the perceptions and preferences of households on land-use decisions were generated based on a parameterisation framework introduced by Smajgl et al., (2011). According to this framework, we conducted a series of surveys, personal interviews and Focus Group Discussions (FGDs) during the period 2012 to 2014. These surveys, personal interviews and FGDs were conducted at the village, sub district and district levels, with about 25 to 50 participants. The results were then qualified to obtain the coefficient representing the behaviours of households and private companies in terms of land-use change. The list of data and parameters used in the landscape model are presented in Table 2.

3.3. Sub models

The LUCES model includes 13 main sub models that substantially constitute complex human-environment interactions and adaptions, as summarised in Table 3.

Table 2. List of data and parameters used in the landscape model

Data	Year	Source
Land cover map	1990, 2000, 2005, 2010	MoF, TBI Indonesia, ICRAF
Map of oil palm plantations (based on permit status)	2013	FNPF; OVI
Map of logging and forest plantation concessions	2010	MoF
Map of soil and plantations suitability	2012	Balittanah and ICRAF
Provincial spatial planning map	2003	Provincial government
Baseline map	2000	National governmnet
Statistic data on demography, production, price, market and employment at the sub district level	1990, 2000,2005, 2010	Statistical Bureau
Ecosystem supply per land-use type	2010	Sumarga et al., 2014; 2015
Returns on land and labour	2010	Suwarno et al., 2016
Perceptions, learning, knowledge and preferences of agents for land change and ecosystem services	2012, 2013, 2014	Survey, personal communications, FGDs, scientific assumptions

Table 3. Main sub models of LUCES model coded in NetLogo 5.0.5

Name	Brief functionalities/tasks	Involved entity
Initialisation	Import GIS data, population data, and household data. Generate the first harvesting/planting plot of private company areas, create household-pixel links	Household pixels; private company pixels
Set labour requirement	Annually set the labour list requirement for each household in community agent	Households
Choice in agriculture and agroforestry activities	Perform agricultural land-use (paddy field and oil palm plantation) choices; perform agroforestry land-use (rubber) choices. This step includes bounded-rational choice nested in rule-based decisions	Household pixels
Choice in NTFPs	Perform choice in NTFPs collection. This step includes bounded-rational choices nested in rule based decisions on expected income	Household pixels
Update agents state	Annually update change in household and private company profiles	Households and private companies
Agents categorised	Annually categorised agents into the most similar groups	Households and private companies
Generate agent coefficients	Generate behaviour coefficients of agents, allow variants within groups and stabilise the behaviour structure of the group	Households and private companies
Forest yield dynamics	Calculate basal area for forest stands in response to human interventions (logging)	Pixels
Natural transition	Perform natural transition among vegetation types based on ecological edge effects	Pixels
Create new community household	Create new household, controlled by empirical function and population	Households
Ecosystem services dynamics		
1. Provisioning service:		
Paddy and oil palm production	Calculate the economic yield of paddy fields and oil palm plantation in response to human investment and site condition	Household and private company pixels
Agroforestry rubber production	Calculate the economic yield of agroforestry rubber in response to human investment and site	Household pixels
Rattan and Jelutong collection	Calculate potential yield of NTFPs based on the basal area of the forest stand	Household pixels
2. Regulating service:		
Carbon sequestration	Calculate carbon stock and carbon emissions of each land-use type by assigning a time average for carbon density	Pixels

Appendix 4.2. Parameter of ecosystem services supply per land cover type used in the LUCES model

Land cover type	Succession	Time bound (yrs)	Stock per ha							
			Timber (m3)	Rattan (ton)	Jelu-tung (ton)	Rubber (ton)	Oil palm (ton)	Paddy (ton)	Above ground Carbon (ton CO_2e/ha)	Peat Carbon (ton CO_2e/ha)
Mineral soil forest	Primary	100	60	1	0	0	0	0	926	0
	Old secondary	50	45	0.79	0	0	0	0	787	0
	Young secondary	25	20	0.25	0	0	0	0	411	0
	Pioneer	0	0	0.125	0	0	0	0	110	0
Peat forest	Primary	100	30	0	2	0	0	0	463	7000
	Old secondary	50	25	0	0.2	0	0	0	394	3500
	Young secondary	25	10	0	0.1	0	0	0	206	1250
	Pioneer	0	0	0	0.025	0	0	0	25	750
Agroforest	Post production	50	15	0	0	0.25	0	0	412	0
	Late production	25	12.5	0	0	4	0	0	410	0
	Early production	5	1	0	0	3	0	0	242	0
	Pioneer	0	0	0	0	0	0	0	25	0
Timber plantation	Post production	10	30	0	0	0	0	0	515	0
	Late production	5	25	0	0	0	0	0	513	0
	Early production	2	5	0	0	0	0	0	303	0
	Pioneer	0	0	0	0	0	0	0	31	0
Oil palm plantation	Post production	25	0	0	0	0	17	0	206	0
	Late production	10	0	0	0	0	24	0	205	0
	Early production	5	0	0	0	0	10	0	112	0
	Pioneer	0	0	0	0	0	0	0	12	0
Agriculture		0	0	0	0	0	0	3	0	0

Summary

The rising global population has increased the demand for food, renewable energy and other materials. Yet at the same time to meet this demand requires land and the amount of available land is finite. Societies tend to maximise the use of land to contribute to global economic development and create unsustainable economic growth. This comes at the expense of natural resources and ecosystems. Many ecosystems are already severely degraded because of inappropriate and unsustainable land-uses, ineffective governance systems and a lack of strategies to restore and sustain remaining ecosystems.

Efforts to improve ecosystem management locally, regionally and globally have been provided through studies that have integrated the Ecosystem Services (ES) concept in ecosystem management. The ES concept is widely used to analyse the contributions ecosystems make to human wellbeing and broadly refers to the benefits people obtain from well-functioning ecosystems. This concept also highlights the importance of a land-use change model to support better ecosystem management. However, the ES concept is rarely applied in land-use decision-making processes, which define the boundaries for ecosystem management. The aim of my research was to empirically assess and test how ES and the land-use change model could be developed and applied to support ecosystem management through land-use optimisation in decentralised forest governance systems. For this research, I selected the Indonesian province of Central Kalimantan as my case study area. The challenges concerning the assessment of ecosystem benefits and the development of land-use change models and forest zonation are addressed in this research.

First, I further developed an analysis of ecosystem benefits through the link to the governance system. I analysed district deforestation rates for eleven districts in Central Kalimantan Province and linked them to the performance of district forest governance (Chapter 2). In my analysis of district deforestation rates, I compared forest areas using the land-cover maps for 1990, 1995, 2000, 2005 and 2010, provided by the Indonesian Ministry of Forestry. Further, I assessed the district forest government performance for the periods 2000-2005 and 2005-2010, following the local election period for the district heads (i.e. Bupati). This assessment incorporated the four principles of good forest governance (i.e. accountability, equality, transparency and participation) developed by PROFOR-FAO and World Bank. The results of this analysis and assessment show that decentralisation has led to marked differences in forest governance between districts. I show that deforestation rates are strongly related to the change in forest governance and that transparency has become the most important principle in good forest governance. Districts with a higher transparency score reduced deforestation rates more compared to other districts with a lower score. I also show the advantages of applying good forest governance and governance quality frameworks in assessing the districts forest government performance, and provide information on where governance is weak. This information is important to diagnose problems, advance reforms and monitor the impacts on environmental and socio-economic aspects. However, these frameworks require the willingness of local governments to undertake self-assessments and discuss their results with various stakeholders. These limitations need to be considered when forest governance frameworks are used to assess district forest governance in areas where there is a high potential for political conflict.

I also analysed the ecosystem benefits that different beneficiaries receive under different policy regulations (Chapter 3). In this analysis, I included provisioning (rattan and jelutong resin collection and the production of timber, paddy, oil palm and agroforestry rubber) and regulating (carbon emissions) services. The ES benefits and beneficiary groups were identified based on ecosystem accounting approaches that are consistent with the System of National Accounts. Ecosystem accounting captures spatial extent and bio-economic processes that can be used to identify beneficiaries of ecosystem services and calculate the benefits in line with the System of National Accounts. Accordingly, I used the resource rent method to obtain a monetary value for the provisioning services traded on the local, national and international markets (e.g. rattan and jelutong resin, timber, agroforestry rubber, oil palm and paddy). Further, I applied the social cost of carbon from the Interagency Working Group on Social Cost of Carbon to assess the potential loss of ecosystem benefits from carbon emissions. The assessment of benefits received by different groups of beneficiaries was conducted based on current forest and agricultural governance systems. It included government policies related to tax, provisioning and fees in forest utilisation, and agricultural production. I show that the benefits generated from these services differ markedly between the stakeholders grouped into private companies, public and household entities. The distribution of these benefits is strongly influenced by government policies and in particular benefit sharing mechanisms. Hence, land-use change and policies influencing land-use change can be expected to have different impacts on different stakeholders. I also show that the benefits generated by oil palm conversion, which is a main driver of land-use change in Central Kalimantan, are almost exclusively accrued by private companies and, at this point in time, are shared unequally with local stakeholders. Considering my findings, I recommend that additional policy instruments are setup to govern the sustainability of oil palm production and to ensure public entities receive monetary benefits through tax schedules.

Second, I developed a land-use change model based on an agent-based modelling approach. Agent-based models are powerful tools that can help us to understand the stakeholders' decision-making process in land-use and the impact of these decisions on ecosystems. They are primarily used for simulating socio-ecological processes, which incorporate the decision-making processes of all heterogeneous stakeholders. In this thesis, I developed the agent-based land-use change model "Land-Use Change and Ecosystem Service (LUCES)" to explore the possible effects of forest moratorium policies on the land-use decisions of private companies and communities and the impact of these decisions on land-use change and ecosystem services supply (Chapter 4). The land-use and ecosystem services supply dynamics in LUCES are predicted based on three different scenarios regarding the implementation of a forest moratorium policy in Indonesia that aims to decelerate land-use change and improve forest governance. The basic assumptions on forest governance (Chapter 2) and ecosystem benefits (Chapter 3) are used in this model to predict the land-use decisions of communities and private companies in responding to different forest moratorium scenarios (Chapter 4). LUCES includes unplanned land-use change driven by local communities and planned land-use change driven by private companies. The results of our simulations for the two districts in Central Kalimantan show that the forest moratorium, as implemented between 2009 and 2014, will not be able to fully stop forest conversion, in particular by local communities. In my case study area, extending the forest moratorium until 2025 is unlikely to result in significant deceleration or reorientation of land-use change. This is because companies will continue to invest in the conversion of secondary forests on mineral soils and the forest moratorium policy will not influence community decision-making. However, a scenario that combines this policy with livelihood support that increases farm-gate prices of forest and agroforestry products, could increase the attractiveness of conservation for local communities. Forest and agroforestry areas that are then more profitable and competitive, are more likely to be retained. The results for the two districts with different pressures on local resources differ in detail and suggest that appropriate additional measures require local fine-tuning. As a generic model, LUCES could be used to evaluate and enhance the effectiveness of policy implementation, such as the forest moratorium policy, at the district scale in other areas of Indonesia or elsewhere after further parameterization.

Fourth, the applicability of the ecosystem services concept and land-use change model in land-use optimisation needs to be tested. Land-use optimisation is important to address the problems of land-use change and environmental degradation, both which are mainly related to land-use policies and poverty. Thus, efforts in land-use optimisation should start with the improvement of forest and land management, with forest ecosystem benefits and local livelihoods as key considerations.

I further tested the application of the ecosystem services concept and land-use change model in optimising land-use in one forest management unit through adaptive forest zonation (Chapter 5). The adaptive forest zonation included conservation and economic development zones that were identified based on the ecosystem services concept, land-use change model and sustainable forest management framework. Part of the forest zonation development process also included the active participation of local communities and district governments to jointly define the zones and an agreement to clearly state the stakeholders' rights and responsibilities in managing each zone. In this chapter, I highlight the importance of negotiation between local communities and the district government to reduce threats to the forest ecosystem in this area. I also suggest options for providing more area for economic development in combination with the stakeholders' agreement. This could potentially increase the benefits local communities receive from forest ecosystems and subsequently increase their awareness of the importance of conserving forest ecosystems. Even though my results are specific to Kapuas District, Central Kalimantan, Indonesia, the methodology I have developed for this thesis could be included in the guidelines for zonation and management plans for other forest management units (FMUs) in Indonesia.

In conclusion, this thesis shows the applicability of the ES concept and land-use modelling in optimising land-use under certain decentralised forest governance systems. My thesis' results were obtained through the application of methods and steps that integrated a comprehensive set of qualitative and quantitative analyses to support land-use optimisation in the Kapuas Protected FMU. My results can inform decision makers on the options of land-use optimisation and the consequences of their management decisions regarding land-use intensification, nature conservation and local economic conditions. I show how land-use optimisation provides an important step in preventing further land degradation and ecosystem loss.

The results of my thesis have been disseminated and communicated with decision makers in the Central Kalimantan Province and in particular the Kapuas Protected FMU. The head of Kapuas Protected FMU has used my results, particularly the map on adaptive forest zonation, to optimise land-use in his management unit. The participatory process that was conducted in this study to allocate areas for community and village forests and stakeholder agreements have been implemented by three out of nine villages around this FMU area. The management of Kapuas Protected FMU is now expanding this process in the other six villages. This illustrates the societal relevance of my research.

Samenvatting

Door de stijgende wereldbevolking is de vraag naar voedsel, materialen en duurzame energie toegenomen. Om aan deze behoeften te voldoen is voldoende land nodig. De hoeveelheid land is echter eindig. De maatschappij probeert landgebruik te maximaliseren om bij te dragen aan de wereldwijde economische ontwikkeling, waardoor niet-duurzame economische groei ontstaat. Dit gaat ten koste van natuurlijke hulpbronnen en ecosystemen. Veel ecosystemen zijn al ernstig aangetast door niet-duurzaam of foutief landgebruik, ineffectieve governance en een gebrek aan strategieën om de overgebleven ecosystemen duurzaam te beheren of te herstellen.

Studies die het concept ecosysteemdiensten (ED) hebben geïntegreerd in ecosysteembeheer, dragen bij aan het verbeteren van ecosysteembeheer op lokaal, regionaal en globaal niveau. Het ES concept wordt breed gebruikt om de bijdragen die ecosystemen aan menselijk welzijn doen te analyseren. Het concept heeft betrekking op de baten die mensen halen uit goed functionerende ecosystemen. Het concept belicht ook het belang van modellen voor landgebruiksverandering voor het verbeteren van ecosysteembeheer. Desondanks wordt het ED concept weinig toegepast in besluitvorming rondom landgebruik, terwijl deze besluitvorming de randvoorwaarden voor ecosysteembeheer opstelt. Het doel van mijn onderzoek was om ED empirisch te analyseren en toe te passen in nieuw ontwikkeld landgebruiksmodel. Dit model diende gebruikt te kunnen worden om ecosysteembeheer te ondersteunen in gedecentraliseerde bosbouwsystemen, door middel van landgebruiksoptimalisatie. Voor het onderzoek heb ik de Indonesische provincie Centraal Kalimantan als studiegebied gebruikt. In mijn onderzoek worden de uitdagingen betreffende het analyseren van baten van ecosystemen, het ontwikkelen van een model voor landgebruiksverandering en boszonering aangepakt.

Allereerst heb ik de baten van ecosystemen geanalyseerd in relatie tot het governance systeem. In (Hoofdstuk 2) heb ik heb de ontbossingssnelheid voor elf districten in Centraal Kalimantan geanalyseerd en gekoppeld aan prestaties van de betreffende districten op het gebied van governance met betrekking tot bosbouw (hierna 'governance' genoemd). Voor de analyse van ontbossingssnelheden op districtsniveau, heb ik bosgebieden vergeleken op basis van landgebruikskaarten uit 1990, 1995, 2000, 2005 en 2010, die ter beschikking waren gesteld door het Indonesische Ministerie voor Bosbouw. De governance prestaties heb ik voor de periodes 2000-2005 en 2005-2010 geanalyseerd, vanwege de lokale verkiezingsperioden voor de districtshoofden ('Bupatis'). De analyses waren gebaseerd op de vier principes van 'good governance' die door PROFOR-FAO en

de Wereldbank ontwikkeld zijn: accountability, gelijkheid, transparantie en participatie. De resultaten van deze analyse tonen aan dat decentralisatie heeft geleid tot duidelijk verschillen tussen districten wat betreft governance . Mijn onderzoek toont aan dat ontbossingssnelheden sterk gerelateerd zijn aan veranderingen in governance, en dat transparantie het belangrijkste principe binnen 'good governance' is geworden. Districten die hogere transparantie scores behaalden, hebben ontbossingssnelheiden sneller weten te verminderen dan districten die lagere transparantie scores behaalden. Verder toon ik de voordelen van implementatie van 'good governance' aan, en het belang van kwaliteitsraamwerken voor governance om prestaties per district op het gebied van governance te analyseren, en om aan te geven op welke punten governance zwak scoort. Deze informatie is belangrijk voor het vaststellen van problemen, het doorvoeren van hervormingen, en het monitoren van impacts op mens en milieu. Voor het implementeren van deze kwaliteitsraamwerken moeten lokale overheden echter bereid zijn om zichzelf te beoordelen en met verschillende stakeholders in gesprek te gaan. Deze randvoorwaarden moeten in ogenschouw genomen worden bij de toepassing van governance raamwerken om governance te analyseren in districten waar de kans op politieke conflicten groot is.

Ik heb ook geanalyseerd welke ecosysteembaten verschillende begunstigden ontvangen onder verschillende regelgeving (Hoofdstuk 3). In deze analyse heb ik naar producerende ecosysteemdiensten (verzameling van ratan en jelutong hars, houtproductie, rijstproductie, palmolieproductie en rubberproductie in agro-bosbouw) en regulerende ecosysteemdiensten (beperken van koolstofemissies). De groepen van begunstigden en de baten die zij verkrijgen van ecosysteemdiensten zijn geïdentificeerd op basis van de 'ecosystem accounting' benadering, die consistent is met het systeem voor nationale rekeningen ('System for National Accounts'). De 'ecosystem accounting' benadering omvat de analyse van omgevings- en biologische processen en hun ruimtelijke verspreiding, welke nodig zijn om ecosysteemdiensten en begunstigden te identificeren. Vervolgens kunnen dandan de verkregen baten uitgerekend worden volgens de opzet van het 'System for National Accounts'. Ik heb de 'resource rent' methode toegepast om de monetaire waardes van de producerende diensten vast te stellen die op lokale, nationale en internationale markten worden verhandeld (bijvoorbeeld rattan en jelutong hars, hout, rubber uit agro-bosbouw, palmolie en rijst). Daarnaast heb ik de berekening van de maatschappelijke lasten van koolstof toegepast in lijn met de 'Interagency Working Group on Social Cost of Carbon' om de mogelijke verliezen aan ecosysteembaten uit koolstofemissies te berekenen. De analyse van baten die verschillende groepen begunstigden ontvingen is uitgevoerd op basis van huidige governance systemen van bos- en landbouw. Hierbij is overheidsbeleid in beschouwing genomen met betrekking tot belastingen, heffingen op en beschikbaarheid van boslandgebruik, en landbouwproductie. Ik toon aan dat baten die gegenereerd worden uit de ecosysteemdiensten duidelijk verschillen tussen marktpartijen, publieke partijen en huishoudens. De verdeling van de baten wordt sterk beïnvloed door overheidsbeleid en, met name, door mechanismen die de verdeling van goederen en diensten bepalen. Daardoor zullen landgebruiksveranderingen en beleid dat daar invloed op heeft verschillende stakeholdergroepen ook op verschillende manieren beïnvloeden. Ik toon ook aan dat baten die ontstaan door landomzetting naar oliepalm (de belangrijkste aanleiding voor landgebruiksveranderingen in Centraal Kalimantan), bijna volledig ten gunsten komen van private bedrijven. Deze baten worden op dit moment ongelijk gedeeld met lokale partijen. Op basis van mijn bevindingen, beveel ik aan dat er extra beleidsinstrumenten opgezet worden om duurzame productie van oliepalm te bevorderen, en om te zorgen dat publieke partijen monetaire baten ontvangen via belastingmaatregelen.

Ten tweede, heb ik een landgebruiksveranderingsmodel ontwikkeld op basis van een 'agent-based' modelleer aanpak. Agent-based modellen bieden een krachtige aanpak om besluitvormingsprocessen van stakeholders te begrijpen op het gebied van landgebruik en de impact op ecosystemen. Agent-based modellen worden met name gebruikt om sociaalecologische processen te simuleren, waarbij de besluitvormingsprocessen van een heterogene groep stakeholders wordt meegenomen. In dit proefschrift ontwikkel ik het agent-based landgebruiksveranderingsmodel "Land-Use Change and Ecosystem Services (LUCES)". Dit model wordt gebruikt om de mogelijke effecten van bosmoratoriumbeleid op landgebruiksbesluiten van private bedrijven en lokale gemeenschappen en de effecten van deze besluiten op landgebruiksveranderingen en ecosysteemdiensten in beeld te brengen (Hoofdstuk 4). De dynamiek van landgebruik en levering van ecosysteemdiensten wordt in LUCES voorspeld op basis van drie verschillende scenario's over de implementatie van een bosmoratoriumbeleid in Indonesië, die landgebruiksveranderingen moet afremmen en bos governance moet verbeteren. De basisaannamen over bos governance (Hoofdstuk 2) en ecosysteembaten (Hoofdstuk 3) worden in het model gebruikt om landgebruiksbesluiten van bedrijven en lokale gemeenschappen te voorspellen, in reactie op de verschillende bosmoratoriumscenario's (Hoofdstuk 4). Ongeplande landgebruiksveranderingen van lokale gemeenschappen en geplande landgebruiksveranderingen van bedrijven worden meegenomen in LUCES. De resultaten van onze simulaties voor twee districten in Centraal Kalimantan tonen aan dat het bosmoratorium, die tussen 2009 en 2014 is geïmplementeerd, niet voldoende is om ontbossing volledig tot stilstand te brengen, met name de ontbossing door lokale gemeenschappen. In het studiegebied zal het verlengen van het bosmoratorium tot 2025 hoogstwaarschijnlijk niet leiden tot een significante vermindering of ombuiging van landgebruiksveranderingen. Dit komt doordat bedrijven zullen blijven investeren in het omvormen van secundair bos op minerale bodems. Ook heeft het bosmoratoriumbeleid geen invloed op beslissingen van lokale gemeenschappen. Een scenario die het bosmoratoriumbeleid combineert met ondersteuning door het verhogen van boerderij-prijzen voor bos- en agrobosbouwproducten, zou de aantrekkelijkheid van natuurbehoud verhogen voor lokale gemeenschappen. Bos en agrobosbouw gebieden die dan een hoger rendement opleveren, zouden dan behouden kunnen worden. De verschillende resultaten voor de twee districten, met verschillende soorten druk op natuurlijke hulpbronnen, tonen aan dat lokale fine-tuning nodig is voor effectieve maatregelen. Als een generiek model kan LUCES gebruikt worden om effectieve beleidsimplementatie te evalueren en bevorderen, zoals bijvoorbeeld bosmoratoriumbeleid op districtsniveau in andere delen van Indonesië, of in andere gebieden na verdere parametrering.

De uitvoerbaarheid van het ecosysteemdienstenconcept en het landgebruiksveranderingsmodel voor landgebruiksoptimalisatie moest getest worden. Landgebruiksoptimalisatie is belangrijk bij het aankaarten van problemen rondom landgebruiksveranderingen en milieudegradatie, die beide gerelateerd zijn aan landgebruiksbeleid en armoede. Daarom moeten pogingen om landgebruiksoptimalisatie toe te passen beginnen met het verbeteren van bos- en landmanagement, waarbij baten uit bosecosystemen en lokale livelihoods de belangrijkste overwegen moeten zijn.

Ik heb de uitvoering van het ecosysteemdienstenconcept in combinatie met een model voor landgebruiksverandering voor landgebruiksoptimalisatie in één bosbeheer eenheid getest, door middel van adaptieve boszonering (Hoofdstuk 5). Natuurbehouds- en economische ontwikkelingszones werden meegenomen in de adaptieve boszonering. Deze zones werden geïdentificeerd op basis van het ecosysteemdienstenconcept, het landgebruiksveranderingsmodel en een raamwerk voor duurzaam bosbeheer. Lokale gemeenschappen en de districtsoverheid hebben actief geparticipeerd in het ontwikkelen van de boszonering. De zones zijn gezamenlijk gedefinieerd en afspraken zijn gemaakt om de rechten en plichten van stakeholders vast te leggen, bij het beheer van elke zone. Ik belicht in dit onderzoek het belang van onderhandelingen tussen lokale gemeenschappen en de lokale overheid om de bedreigingen van bosecosystemen te verminderen. Daarnaast draag ik opties aan om meer ruimte te bieden aan economische ontwikkeling, in combinatie met de stakeholderafspraken. Dit zou de baten die lokale gemeenschappen uit bosecosystemen krijgen kunnen verhogen en ook het belang van bosbehoud voor de lokale gemeenschap meer onder de aandacht kunnen brengen. Ook al zijn mijn resultaten specifiek voor het Kapuas District in Centraal Kalimantan, is de methode die in dit proefschrift ontwikkeld heb geschikt om op te nemen in richtlijnen voor zonering en beleidsplannen voor andere bosbeheereenheden in Indonesïe (FMU's).

Concluderend, laat dit onderzoek de toepasbaarheid van het ecosysteemdiensten concept en landgebruiksmodellering zien, bij het optimaliseren van landgebruik onder bepaalde gedecentraliseerde bos goverance systemen. De resultaten in dit proefschrift zijn behaald door het gebruik van methoden en processen die kwalitatieve en kwantitatieve analyses integreren om landgebruiksoptimalisatie in Kapuas Protected FMU te ondersteunen. Mijn resultaten kunnen beleidsmakers informeren over de landgebruiksoptimalisatie opties die ze hebben en de consequenties die hun beleidsbeslissingen hebben op intensifiëring van landgebruik, natuurbescherming en lokale economische omstandigheden. Ik toon aan dat landgebruiksoptimalisatie een belangrijke stap is in het voorkomen van landdegradatie en het tegengaan van verlies van ecosystemen.

De resultaten van mijn onderzoek zijn verspreid en gecommuniceerd met besluitvormers in de provincie Centraal Kalimantan en met name met de Kapuas Protected FMU. Het hoofd van de Kapuas Protected FMU heeft de resultaten gebruikt, met name de kaart over adaptieve boszonering, om landgebruik te optimaliseren in zijn management unit. Het participatieve proces dat is opgezet in dit onderzoek, om gemeenschaps- en dorpsbossen toe te wijzen en stakeholder afspraken vast te leggen, is in drie van de negen dorpen rondom dit FMU gebied uitgevoerd. Het management van de Kapuas Protected FMU is dit proces nu aan het uitbreiden naar de overige zes dorpen. Dit onderstreept het maatschappelijke belang van mijn onderzoek.

Ringkasan

Meningkatnya populasi manusia di bumi telah mengakibatkan terjadinya peningkatkan kebutuhan akan makanan, energy terbarukan dan material lainnya. Pada saat yang sama, pemenuhan akan kebutuhan-kebutuhan tersebut hanya dapat dilakukan melalui lahan yang sangat terbatas. Keinginan untuk memaksimalkan penggunaan lahan yang terbatas dalam peningkatan pertumbuhan ekonomi dimiliki oleh hampir semua pihak. Hal tersebut memacu terjadinya pertumbuhan ekonomi yang tidak berkelanjutan sebagi akibat dari penggunaan sumberdaya alam dan ecosystem yang tidak lestari. Banyak ekosistem yang kemudian menjadi rusak karena penggunaan dan pengusahaan lahan yang kurang lestari, sistem pemerintahan yang kurang efektif serta belum adanya strategy untuk memulihkan dan menjaga ekosistem.

Upaya untuk meningkatkan pengelolaan ekosistem secara lebih lestari pada tingkat local, regional dan local telah banyak ditelaah melalui studi yang menggabungkan konsep jasa lingkungan dalam pengelolaan ekosistem. Konsep jasa lingkungan telah banyak digunakan untuk mengalisa kontribusi ekosistem terhadap kehidupan manusia yang secara luas diterjemahkan dalam bentuk keuntungan yang diterima oleh manusia dari ekosistem. Konsep jasa lingkungan ini juga menitik beratkan pada pentingnya model perubahan lahan untuk mendukung pngelolaan ekosistem yang lebih baik. Meskipun demikian, konsep jasa lingkungan masih jarang digunakan pada proses pengambilan keputusan dalam penggunaan lahan yang merupakan hal terpenting dalam menentukan batas pengelolaan ekosistem. Tujuan penelitian ini adalah untuk mengkaji secara empirik serta mengimplementasikan penggabungan antara konsep jasa lingkungan dan model model penggunaan lahan untuk mendukung pengelolaan ekosistem secara berkelanjutan melalui optimisasi penggunaan lahan dalam sistem pemerintahan yang terdesentralisasi. Penelitian ini dilakukan di propinsi Kalimantan Tengah, Indonesia. Tantangan terkait dengan kajian terhadap keuntungan dari ekosistem dan penyusunan model perubahan lahan dan zonasi areal hutan menjadi fokus utama dalam penelitian ini.

Pertama, saya melakukan analysis terkait dengan keuntungan yang diberikan oleh ekosistem dalam kaitannya dengan sistem pemerintahan yang saat ini sedang dijalankan. Saya melakukan analisis laju deforestasi di sebelas kabupaten di Propinsi Kalimantan Tengah dan mengkaitkannya dengan kinerja pemerintahan di bidang kehutanan (Bab 2). Analisis laju deforestasi ini saya lakukan dengan membandingkan luas hutan yang diperoleh dari peta penutupan lahan tahun 1990, 1995, 2000 dan 2005 dari Kementrian

Kehutanan Republik Indonesia. Selanjutnya, saya melakukan assessment terhadap kinerja pemerintahan di bidang kehutanan untuk periode 2000-2005 dan 2005-2010. Pemilihan periode ini dilakukan dengan mengikuti periode pemilihan kepala daeran (Bupati dan atau Walikota). Assessment terhadap kinerja pemerintahan kehutanan ini melibatkan empat prinsip tata pemerintahan kehutanan yang baik (akuntabilitas, ekualitas, transparansi dan partisipasi) yang disusun oleh PROFOR-FAO dan Bank Dunia. Hasil dari analisis dan assessment yang saya lakukan menunjukkan adanya keragaman respon dalam tata kelola kehutanan di tingkat kabupaten sebagai akibat dari pelaksanaan otonomi daerah. Saya melihat bahwa laju deforestasi lebih sangat terkait dengan perubahan tata kelola kehutanan dan transparansi merupakan prinsip terpenting dalam tata kelola kehutanan yang baik. Kabupaten dengan skor transparansi yang tinggi mampu untuk mengurangi laju deforestasi dibandingkan dengan kabupaten lain dengan skor yang lebih rendah. Saya juga melihat keuntungan penggunaan framework tata kelola kehutanan yang baik dan kualitas pemerintahan dalam melakukan assessment terhadap kinerja tata kelola kehutanan dan memberikan informasi terkait kelemahan pemerintah. Informasi tersebut sangat penting untuk mendiagnosa masalah, langkah yang akan diambil dan memonitor akibat yang ditimbukan dalam kaitannya dengan lingkungan dan social-ekonomi. Meskipun demikian, keberhasilan penggunaan framework tersebut sangat tergantung dengan kemauan pemerintah daerah untuk melakukan assessment terhadap kinerjanya sendiri dan mendiskusikan hasilnya dengan pihak-pihak terkait lainnya. Keterbatasan tersebut menjadi catatan penting pada saaat framework tata kekola kehutanan digunakan untuk melakukan assessment tata kelola kehutanan di area-area yang memiliki konflik politik.

Analysis terkait dengan jasa lingkungan (diantaranya adalah rotan, jelutung, kayu, padi, kelapa sawit, karet serta karbon) juga menjadi fokus penelitian saya dalam thesis ini. Analisis mengenai keuntungan yang diterima berbagai pihak terkait dengan jasa lingkungan tersebut dilakukan dengan menggunakan pendekatan akutansi ekosistem yang sejalan system perhitungan nasional. Akutansi lingkungan mencakup aspek spasial dan proses bio-ekonomi yang dapat digunakan untuk mengidentifikasi penerima keuntungan dari jasa lingkungan dan menghitung keuntungan tersebut sesuai dengan system perhitungan nasional. Terkait dengan hal tersebut, saya menggunakan metode resource rent untuk menghitung nilai moneter jasa lingkungan yang dapat diperdagangkan di pasar local, nasional maupun internasional (missal rotan, jelutung, kayu, karet, kelapa swit dan padi). Selanjutnya, untuk perhitungan keuntungan dari carbon, saya menggunakan pendekatan biaya sosial yang diadopsi dari kelompok kerja biaya sosial karbon. Pendekatan biaya sosial ini dihitung dengan mempertimbangkan kerugian yang mungkin ditimbulkan dari adanya emisi karbon. Kajian terkait dengan keuntungan dari jasa lingkungan ini dilakukan dengan mempertimbangakan kebijakan pemerintah di bidang kehutanan dan pertanian yang berlaku saat ini, termasuk diantaranya adalah kebijakan mengenai perpajakan, provisi serta biaya lain terkait dengan pengusahaan hutan dan pertanian. Hasil kajian saya menunjukkan adanya keragaman keuntungan dari jasa lingkungan yang diterima oleh perusahaan, public dan rumah tangga, sebagai akibat dari implementasi kebijakan-kebijakan di bidang kehutanan dan pertanian, utamanya adalah kebijakan yang terkait dengan sistem bagi hasil. Sebagai contoh, keuntungan yang diberikan oleh kelapa sawit, yang merupakan pemicu terbesar dari perubahan lahan di Propinsi Kalimantan Tengah, justru lebih banyak diterima oleh perusahaan dan bukan oleh masayarakat local. Karenanya, saya merekomendasikan untuk melengkapi kebijakan yang terkait dengan pengusahaan kelapa sawit yang lestari dengan pasal yang dapat menjamin adanya keuntungan yang diterima oleh masyarakat lokal baik melalui sistem bagi hasil ataupun perpajakan.

Kedua, saya membangun model perubahan lahan yang berbasis pada pendekatan agent-based modelling. Agent-based model merupakan perangkat lunak yang bias digunakan untuk mempelajari proses pengambilan keputusan terkait dengan penggunaan lahan dan memprediksi akibat yang mungkin ditimbulkan oleh keputusan tersebut pada ekosistem. Agent-based model lebih banyak digunakan untuk melakukan simulasi pada proses social-ekologi yang melibatkan proses pengambilan keputusan oleh multi pihak. Pada thesis ini, saya membangun model perubahan lahan berbasis agent-based model dengan nama "Land-Use Change and Ecosystem Services (LUCES)" untuk melihat akibat dari kebijakan forest moratorium (penghentian ijin penggunaan lahan hutan untuk keperluan lain) pada keputusan perusahaan dan masayarakat terkait dengan penggunaan lahan dan akibatnya pada jasa lingkungan (Bab 4). Perubahan penggunaan lahan dan jasa lingkungan di LUCES diprediksi berdasarkan tiga scenario terkait dengan pelaksanaan kebijakan forest moratorium din Indonesia yang bertujuan untuk mengurangi laju perubahan lahan dan meningkatkan tata kelola hutan. Saya menggunakan asusmsi dasar terkait dengan tata pemerintahan kehutanan (Bab 2) dan keuntungan dari ekosistem (Bab 3) untuk memprediksi keputusan penggunaan lahan yang dilakukan oleh masyarakat dan perusahaan sebagai respon mereka terhadap kebijakan forest moratorium tersebut. (Bab 4). LUCES mencakup perubahan lahan yang tidak terencana yang dilakukan oleh masyarakat serta perubahan lahan terencana yang dilakukan oleh perusahaan. Hasil simulasi dari LUCES pada dua kabupaten di Propinsi Kalimanta Tengah menunjukkan bahwa pelaksanaan kebijakan forest moratorium, yang telah dilakukan sejak tahun 2009 hingga 2014, belum bisa sepenuhnya menahan konversi hutan, terutama yang dilakukan oleh masyarakat. Pada study area yang saya gunakan untuk membangun LUCES, perpanjangan forest moratorium sampai tahun 2025 sepertinya tidak memberikan hasil yang signifikan dalam mengurangi laju perubahan lahan. Hal ini dikarenakan perusahaan akan tetap melakukan pembukaan lahan pada hutan-hutan sekunder di tanah mineral sedangkan masyarakat, yang tidak tercakup dalam kebijakan tersebut, akan terus melakukan perubahan lahan pada lokasi-likasi yang mereka kehendaki. Namun demikian, hasil simulasi LUCES dengan menggunakan scenario yang menggabungkan kebijakan moratorium dan peningkatan ekonomi lokal menunjukkan adanya ketertarikan masyarakat untuk lebih memilih menjaga hutan dan kebun mereka. Hasil yang diberikan oleh LUCES untuk dua kabupaten contoh memiliki keragaman yang dihasilkan oleh adanya perbedaan permasalahan yang dihadapi. Hal tersebut menjadi dasar perlunya penyusunan metode yang lebih baik dalam pengambilan data lebih lanjut yang dapat digunakan untuk penyempurnaan LUCES. Sebagai model yang generic, LUCES menunjukkan kemampuannya untuk mengevalusi effektifitas akan pelaksanaan sebuah kebijakan, seperti forest moratorium, pada tingkat kabupaten di Indonesia setelah proses parameterisasi ditingkatkan.

Ketiga, saya menguji penggunaan konsep jasa lingkungan dan model perubahan lahan dalam optimalisasi penggunaan lahan. Optimalisai penggunaan sangat penting untuk mejawab permasalahan terkait dengan perubahan lahan dan penurunan kualitas lingkungan yang ditimbulkan dari implementasi suatu kebijakan dan adanya factor kemiskinan. Upaya untuk optimalisasi penggunaan lahan hendaknya dimulai dengan peningkatan kualitas pengelolaan lahan dan hutan, dengan menitik beratkan pada keuntungan yang diperoleh dari jasa lingkungan sebagai sumber penghidupan.

Selanjutnya saya menguji aplikasi dari ES konsep dan land-use change model dalam mengoptimalkan penggunaan lahan di salah satu Kesatuan Pengelolaan Hutan (KPH), melalui penyusunan zonasi hutan adaptif (Bab 5). Zonasi hutan adaptif ini mencakup zona konservasi dan zona pembangunan ekonomi yang pembagiannya dilakukan berdasarkan konsep ES, model perubahan lahan dan kerangka pengelolaan hutan lestari. Proses penyusunan dari zona hutan adaptif ini juga juga melibatkan partisipasi aktif dari masyarakat local dan pemerintah Kabupaten Kapuas dalam menentukan batas zona dan menyusun kesepakatan terkait dengan hak dan kewajiban dalam mengelola zona-zona tersebut. Negosiasi antara masayarakat local dan pemerintah kabupaten sebagai upaya untuk pengurangi tekanan terhadap hutan menjadi titik berat dari bab ini. Opsi terkait dengan alokasi area untuk zona pembangunan ekonomi serta kesepakatan antar pihat jusa saya sajikan dalam bab ini. Opsi tersebut memungkinkan adanya peningkatan keuntungan yang dapat diperoleh masayarakat lokal dari ekosistem yang secara tidak langsung akan meningkatkan kesadaran masayarakat untuk menjaga kelestarian ecosystem. Meskipun hasil penelitian saya khusus untuk Kabupaten Kapuas di Propinsi Kalimantan Tengah, namun demikian metodologi yang digunakan dalam thesis ini sangat direkomendasikan untuk bisa masuk dalam pedoman penyusunan zonasi hutan di kawasan KPH se Indonesia.

Sebagai kesimpulan, thesis ini menunjukkan bahwa konsep ES dan model perubahan lahan dapat digunakan untuk mengoptimalkan penggunaan lahan dalam system tata kelola hutan yang terdesentralisasi. Kesimpulan ini diperoleh dari penggunaan metodologi yang mengintegrasikan kualitatif dan kuantitatif analysis untuk mendukung upaya optimalisasi penggunaan lahan di KPHL Kapuas. Hasil penelitian ini selanjutnya dapat digunakan sebagai masukan kepada pengambil keputusan terkait dengan intensifikasi penggunaan lahan, konservasi alam serta peningkatan ekonomi local. Thesis ini juga menunjukkan kontribusi optimalisasi penggunaan lahan dalam mengurangi laju kerusakan lahan dan ekosistem.

Lebih lanjut, hasil dari thesis ini telah dikomunikasikan terhadap pembuat keputusan di Propinsi Kalimantan Tengah, khusunya di KPHL Kapuas. Hasil dari penelitian dalam thesis ini, utamanya adalah peta zonasi hutan adaptif, telah digunakan oleh kepala KPHL Kapuas untuk memperbaiki peta zonasi hutan yang saat ini telah mereka miliki. Pada penelitian di thesis ini saya bekerjasama dengan pihak KPHL Kapuas dalam pelaksanaan proses partisipatori untuk penyusunan rencana alokasi area untuk hutan rakyat dan hutan desa serta kesepatakan dalam hal hak dan tanggung jawab dalam pengelolaan hutan rakyat dan hutan desa, untuk tiga desa. Saat ini pihak KPHL Kapuas meneruskan proses partisipasi ini ke enam desa lain yang berlokasi di sekitar wilayah KPHL Kapuas. Hal tersebut menunjukkan relevansi sosial dari penelitian yang telah saya lakukan.

About the Author

Aritta Suwarno was born in small city in east Java, Indonesia, namely Blitar. She start her first environmental job with WWF Indonesia about six month before she got her bachelor degree in Forestry. After that she continued her study in environmental science and natural resource management in Bogor Agricultural University. Since then she specialised herself in environmental modelling and her first modelling work was to develop and test fire danger rating model for Indonesian land and forests. This work conducted by Canadian Forest Services (CFS) in collaboration with Ministry of Forestry and Environment and Ministry of Research and Technology, Indonesia. She contributed in developing, testing, disseminating and communicating Fire Danger Rating System in two provinces in Indonesia (Riau and West Kalimantan). After that, she decided to jump to research world by joining CIFOR as a simulation modeller. Her main task was to develop participatory system dynamic model for land use dynamic to balance conservation and economic development. This work brought her curiosity about the gap between scientists and decision makers. She then joins Tropenbos International as an outreach and communication manager to bridge the communication between decision makers, local people, scientists and researchers in addressing environmental problems, particularly in land use and forest ecosystems. In 2011, she made an opportunity to start her PhD on modelling ecosystem benefits and land use dynamics with the Ecospace project at the Environmental Systems Analysis (ESA) group and the Environmental Economics and Natural Resources (ENR) group at Wageningen University. She conducted her PhD research in Central Kalimantan Province, Indonesia, to develop the model for ecosystem benefits and land-use dynamics and test the application of ecosystem services concept and land-use dynamic model to support local decision makers in optimising their land use. The outcome of this PhD research has been use by one Forest Management Unit (FMU) in Central Kalimantan Province to keep improving their management plan. By that time, Aritta also contributes in designing and developing small-scale business on non-timber forest products in this area that involved local people and the management of FMU. This business will soon expand to ecotourism that (hopefully) involves Dutch investment. This business plan was designed under support of Prof. Lars Hein (one of her promotor) to make ecosystems services business works for people and forest ecosystem.

List of Selected Publications

Suwarno A., Hein, L., Sumarga, E., 2015. Governance, decentralisation and deforestation: The case of Central Kalimantan Province, Indonesia. Quarterly Journal of International Agriculture 54 (1): 77-100.

Suwarno, A., Hein, L,m Sumarga, E., 2016. Who benefits from ecosystem services? A case study for Central Kalimantan, Indonesia. Environmental Management (57): 331-344

Sumarga, E., Hein, L., Edens, B., Suwarno, A., 2015. Mapping monetery values of ecosystem services in support of developing ecosystem accounts. Ecosystem Services 12: 71-83.

Suwarno, A., van Noordwijk, M., Weikard, H.-P., Suyamto, D., 2016. Effectiveness of forest moratorium policies in reorienting land-use change in Indonesia: a multi-agent model. Mitigation and Adaptation Strategy for Global Climate Change. In press.

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Wageningen, 2 September 2016

the Chairman of the SENSE board	the SENSE Director of Education
Prof. dr. Huub Rijnaarts	Dr. Ad van Dommelen

The SENSE Research School has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW)

The SENSE Research School declares that **Ms Aritta Suwarno** as successfully fulfilled all requirements of the Educational PhD Programme of SENSE with a work load of 40.9 EC, including the following activities:

SENSE PhD Courses

- SENSE writing week (2012)
- Environmental research in context (2012)
- REDD Science Governance: Opportunities and Challenges (2012)
- Research in context activity: 'Initiating and organising workshop on: Ecosystem services and ecosystem accounting to support sustainable land management in central Kalimantan Province', Palangkaraya University, Indonesia (2015)

Other PhD and Advanced MSc Courses

- MSc Economic for natural resource management, Wageningen University (2012)
- MSc Cost benefit analysis, Wageningen University (2013)
- MSc Advance econometric, Wageningen University (2013)
- MSc Agent based modelling, Wageningen University (2014)
- Scientific writing, Wageningen University (2014)

External training at a foreign research institute

- Training in the FALLOW model, World Agroforestry Centre (ICRAF), Indonesia (2014)

Oral Presentations

- *Deforestation and decentralisation: A case study for Central Kalimantan Province, Indonesia.* Global Land Project Open Science Meeting (GLP-OSM2014) - 'Land Transformations: between global challenges and local realities', 19-21 March 2014, Berlin, Germany
- *Ecosystem services benefits in decentralised forest governance.* The Economics of Ecosystems & Biodiversity for Agriculture & Food (TEEBAgriFood) Expert Workshop, 8-11 September 2015, Brussel, Belgium

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Artwork cover page and illustration: Aritta Suwarno and Radipa Wardhana

The research for this thesis was financially supported by the European Research Council (grant 263027, "Ecospace" project).

Financial support for printing this thesis was kindly provided by Wageningen University.

Printed by GVO drukkers & vormgevers B.V. www.gvo.nl