Pro-environmental behavior among Indonesian oil palm smallholders: Understanding perceptions, intentions and actions

Dissertation

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Summary

The conversion of biologically rich areas into agricultural land undermines the capacity of these lands to sustain and maintain vital ecosystem functions. This is mostly the case when the conversion includes the simplification to a monoculture system such as that of oil palm. Oil palm grows best in tropical humid areas where the most biodiverse forests are located, which can threaten local biodiversity and natural ecosystems. At the same time, oil palm represents an economic opportunity for the local community. Today, globally, oil palm is the most important and productive vegetable oil, grown on more than 13.5 million hectares of tropical areas. Indonesia is the world's largest producer of this oil and houses rainforests and rich biodiversity. Recognizing these economic benefits and the environmental externalities, there is a need for policies that reconcile trade-offs of growing oil palm. This is particularly urgent in Indonesia, since the country plays a crucial role in mitigating global warming. Furthermore, the expansion of oil palm in the country is expected to continue as the national government envisages large investments in the oil palm sector and adoption of the crop is rapidly increasing among smallholder farmers.

Given the economic gains associated with high return-to-labour, adoption of oil palm is multiplying among smallholder farmers. Often, these farmers have production systems that support biodiversity and related ecosystem functions, or retain remnant forest in their oil palm plantations. These remnant forests are valuable habitat for biodiversity. Indonesian oil palm farmers therefore have an important role in restoring or maintaining biodiversity. Policies that foster pro-environmental behaviors by adopting biodiversity-friendly practices in oil palm plantations are urgently needed. Such policies can draw on social-psychological theories, which argue that behavioral change is influenced by cognitive processes that involve intrinsic factors such as perceptions and intentions. These factors are less examined in the context of agricultural innovation adoption.

This dissertation contributes to this gap by analyzing the connection between perceptions, intentions, and actions taken, based on the case of Indonesian oil palm farmers. Specifically, we address four research objectives. First, we analyze farmers' perception of changes in ecosystem

functions in oil palm plantations, and their respective subjective valuation. Second, we explore factors that are correlated to the farmers' environmental concerns. Third, we investigate the causal effects of two environmental policies on tree planting behavior. Lastly, we explore mediation pathways that explain how the provision of information and the combination of information with delivery of free seedlings can increase the adoption of tree planting through changes in the perceptions and intentions a person holds.

The present dissertation consisting of four chapters is organized as follows. Chapter 1 presents an overview of the context in which the dissertation was conducted. It provides a background on the current environmental global challenges caused by land use change and outlines the research gaps and objective of this dissertation.

Chapter 2 addresses the first and second research questions. Drawing on environmental psychology studies, I provide a descriptive analysis on oil palm farmers' perceptions on the change of ecosystem functions in oil palm cultivation and explore factors that shape farmers' concern for the environment. I employ 5-point Likert scales to construct these psychological measures and use a multivariate probit and an ordinary least-squares model to perform the econometric analysis. I start by exploring farmers' perceptions towards these ecosystem functions in oil palm, and then link these perceptions to observe the relationship with the construct of environmental concern, and finally, I examine factors that influence environmental concern of oil palm smallholders. The empirical analysis provides evidence that farmers value and perceive a decrease on water and soil-related ecosystem functions. At the same time, farmers perceive an increase on provisioning services which is linked to the economic gains for cultivating oil palm. Our analysis further indicates that the perceived increase of provisioning services might outweigh farmers' ecological motives to conserve areas with high biodiversity value.

Chapter 3 provides experimental evidence from a randomized controlled trial to evaluate two environmental policies to promote the adoption of tree planting in oil palm cultivation. The policies address knowledge gaps by disseminating information about this practice through a movie and an illustrative manual, and addresses structural constraints by distributing seedlings for free in addition to information. We focus on three outcomes: changes in perceptions of the ecosystem regarding oil palm, the intention to plant, and actual adoption. I estimate intent-to-treat effects and conduct a path analysis on psychological components to understand the mediating channels through which the interventions influence the adoption of tree planting. We find that both interventions have a positive and significant effect on changing perceptions, intentions, and the actual adoption of tree planting. The results of the path analysis suggest that perceptions and intention fully explain the effect of information dissemination, while partially explaining the effect of the combination of information and delivery of seedlings.

Chapter 4 presents and summarizes the findings on the previous chapters to draw feasible policy implications and outlines the main limitations of this study. It also suggests future research directions.

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1 General introduction

1.1 Background: Context of the research

The extraction of natural resources for the production of food and non-food products often comes at the cost of degrading environmental conditions (Foley et al., 2005). Some essential ecosystem functions provided by nature, for instance clean air, fresh water, fertile soil, carbon sequestration, pollination etc. are lost when natural landscapes are transformed and particularly, converted to intensified agricultural land use (Clough et al., 2016; Klasen et al., 2016). The expected growth on population aligned with a change in dietary patterns with higher calorie intake indicate a further demand for food and related agricultural products (CBD, 2015). It is estimated that by 2050, the world's population will exceed 9 billion people, driving an increase of food production (approximately by 70 – 100 percent) and biomass production for energy (CBD, 2015; FAO, 2011; Foley et al., 2005). To cover this demand at a minimum biodiversity loss, it has been proposed that land should combine agricultural production with conservation areas (land sharing) or increase yields in the same area of agricultural land (land sparing) (Koh, Levang, & Ghazoul, 2009; Phalan, Onial, Balmford, & Green, 2011). However, these approaches need a careful design to effectively conserve biodiversity (Phalan et al., 2011). The protection of biodiversity is therefore crucial for the long-term security of ecosystem functions (Immerzeel, Verweij, van der Hilst, & Faaij, 2014; Newbold et al., 2015). Forests are the largest host of biodiversity, they provide habitats for more than 80 per cent of all terrestrial species of animals, plants and insects (CBD 2015). At the same time, forests ensure the life of 1.6 billion rural people, from which 70 million are indigenous (FAO, 2014; OECD, 2009). Yet thirteen million hectares of forests are lost every year and the persistent degradation of drylands has led to the desertification of 3.6 billion hectares (Liniger et al. 2017). This land degradation affects 1.5 billion people and those depending on forest resources (Margono, Potapov, Turubanova, Stolle, & Hansen, 2014; Seymour & Busch, 2016), altogether aggravate the situation of global species and biodiversity loss (Ceballos et al., 2015; Newbold et al., 2015). Such trends show worldwide challenges to sustain, maintain and preserve the biospheres' capacity to provide us with ecosystem functions (Carpenter & Folke, 2006; Foley et al., 2005; IPCC, 2014; Rockström et al., 2009). These challenges are scientifically well established and provide evidence that we live today in a new geological period, “Anthropocene”, in which humans are the driving force of change (Rockström et al., 2009; Westley et al., 2011). Actions to be resilient were globally addressed in 2015 with the universal Sustainable Development Goals (SDG) of the 2030 Agenda for Sustainable Development (CBD 2015) and continue being part of international agendas (Marco, Watson, Venter, & Possingham, 2016). Biodiversity and ecosystems have a prominent role to achieve many SDG and associated targets (CBD, 2016).

Currently, biodiversity in tropical forest is largely threated by the expansion of monoculture cash crops, particularly by oil palm cultivation (Burgess, Hansen, Olken, Poapov, & Sieber, 2012; Byerlee, Walter, & Naylor, 2017; Warren-Thomas et al., 2018). Oil palm is best grown in tropical humid areas where the most biodiverse forest are located (Byerlee et al., 2017). Tropical forests harbor various endemic, rare species (Koh & Wilcove, 2008) and arthropods, which are key animals to enhance and maintain ecosystem functions but are lost during the conversion of forest to oil palm monoculture plantations (Foster et al., 2011). The transformation to this land use destroys soil structures and causes severe changes to soil morphology leading to compaction and sedimentation (Pye & Bhattacharya, 2013). Consequently, these changes on the soil structures alter water cycles and affect ground water sources (Merten et al., 2016). In addition, the simplification to a monoculture system, such as that of oil palm, reduces species richness and diversity of taxa (Barnes et al., 2014). It also reduces significantly tree species diversity leading to an inevitable loss of animals that depend on trees (Foster et al., 2011). Altogether, oil palm cultivation leads to a notable decline on ecosystem functions such as climate regulation, pest control, pollination, decomposition and soil fertility (Azhar et al., 2015; Dislich et al., 2016; Edwards et al., 2010; Foster et al., 2011). However, palm oil is the most important and productive vegetable oil globally, grown in more than 13.5 million hectares of tropical areas (Corley & Tinker, 2016; MA, 2005), it represents 45 percent of total vegetable oil consumption and currently is one of the most extensively cultivated biodiesel feedstock (Koh et al., 2009). Oil palm (Elaeis guineensis) is a perennial oil seed crop grown in monoculture systems, sometimes exceeding 20,000 hectares, mostly in Indonesia and Malaysia (CBD, 2015). The global production reached 300 million tons just in 2016 (FAOSTAT 2018). The economic benefits drawn from its cultivation, such as improving food security and wealth, aligned with an increase on demand for food products and biofuels are among the main drivers of this expansion (Krishna, Euler, Siregar, & Qaim, 2017).

Indonesia produces 53 percent of the global palm oil production (FAOSTAT 2018) and since 2008 on has been ranked as the world's largest producing country (Fitzherbert et al., 2008). First introduced by the Dutch colony, the oil palm production has increased 171 fold since 1961 (Pye & Bhattacharya, 2013). The harvested area increased from 70,000 hectares to 9 million hectares in 2016, while the production increased 935,000 tonnes to 160 million tonnes in the same period (FAOSTAT 2018) and with a significant participation of smallholders (Deininger et al., 2011). The envisioning national plans to expand oil palm production has been highlighted since 2008 (Rist, Feintrenie, & Levang, 2010), and more recently under the *Masterplan: Acceleration and Expansion of Indonesian Economic Development 2011-2025* which prioritizes investments in the oil palm sector (Coordinating Ministry of Economic Affairs, 2011). All things considered indicates that further expansion of oil palm cultivation is likely to happen in the country. Indonesia plays a crucial role on mitigating global warming, not only by reducing land conversion to oil palm plantations, but also because almost 84 percent of all peatlands in South East Asia are in this country (Hornung, 2017). Peatlands are ecosystems that host large biodiversity and support the provision of water and water regulation (Hapsari et al., 2018). However, peatlands are also converted to oil palm and cause degradation which leads to incidences of severe fires, flooding and affect the wellbeing of local communities.

In the light of these environmental issues, there is an urge for policy instruments that promote sustainable practices that reconcile economic and ecological trade-offs in an impoverished biodiverse system. This highlights the importance of designing policies to encourage pro-environmental behaviors that reduce negative environmental impacts (Steg & Vlek, 2009). This means, changing behaviors of people to cause little harm or even benefit the environment (Steg & Vlek, 2009). From a policy perspective, to effectively influence a change, it is crucial to select which behaviors can improve the quality of the environment, to identify factors that limit, facilitate and motivate the adoption of these behaviors, and then implement and monitor well-tuned interventions (Geller, Wientt, & Everett, 1982; Graumann, 2003; Klöckner, 2013). For example, in agriculture, the adoption of environmentally friendly practices could improve productivity and food security, while at the same time improve soil fertility, reduce soil erosion and maintain biodiversity (Zeweld, Van Huylenbroeck, Tesfay, & Speelman, 2017). The likelihood to adopt pro-environmental behavior increases when policy interventions address and integrate underlying motivations that make agents to engage in those (Steg, Bolderdijk, Keizer, & Perlaviciute, 2014). It is commonly assumed that people are motivated by economic self-interest, and thus environmental campaigns are often designed to appeal their economic concerns (J. . Bolderdijk, Steg, Geller, Lehman, & Postmes, 2012). However, several studies have shown that beyond the economic gains, people are driven by intrinsic motivations, such as those reflected as their moral values, environmental concerns, beliefs, attitudes and social norms (Ajzen, 1991; Barr & Gilg, 2007; Kollmuss & Agyeman, 2002; Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2014). People also care about presenting themselves with an environmental-friendly view to be seen as “green” rather than “greedy”, indicating that people have more basic motivations (Bolderdijk et al., 2012). This indicates that policies should be designed to shape perceptions or contextual factors that inhibit pro-environmental behaviors (Steg & Vlek, 2009). These interventions will be promising to induce behavioral changes. Thus, to attain the future demands for natural resources, combat hunger, poverty and desertification, people need to be agents of change (Liniger et al., 2017). This is a global responsibility that involves all stakeholders, consumers, farmers, scientists, and practitioners; those who only collectively could succeed to live in a sustainable world.

1.2 Research gaps

As described earlier, the expansion of oil palm cultivation in Indonesia threats tropical forest and biodiversity. Forest conversion or land degradation would negatively affect the function of important ecosystems that provide essential natural services for human well-being. At the same time, oil palm cultivation has the potential to boost rural development and reduce poverty. In Indonesia, the recent increase on oil palm cultivated area and palm oil production has been driven by smallholder farmers, accounting for 41 percent and 36 percent, accordingly (Euler et al. 2016). This highlights the important role that farmers could have on restoring or maintaining biodiversity, particularly as the Indonesian government aims to invest in the palm oil sector in the future. This trend calls for the design of policies focused on smallholders' management that promote biodiversity-friendly practices in oil palm plantations. An important body of literature sheds light on the socio-ecological and economic impacts of land use transformation to oil palm (Euler et al. 2016; Clough et al. 2016; Dislich et al. 2016; Margono et al. 2014; Krishna et al. 2017). Yet, there are still some remaining unexplored research gaps within this literature that are crucial, specifically, for the protection of biodiversity. These are explained as follows.

1.2.1 Understanding the role of environmental related perceptions and concern for the environment

Commonly, individual choices are analyzed by revealed preferences. However, these standard choice models often ignore intrinsic motivations such as perceptions and expectations, assuming that individuals make rational decisions (Manski, 2004). To better understand the underlying factors that can predict behavior, Manski (2004) proposes to elicit individuals' subjective probabilities and perceptions about that specific behavior. The reason is that individuals have preferences that are different from their subjective beliefs, and this may greatly influence their final choice of behavior (Lusk, Schroeder, & Tonsor, 2014). Despite the valuable information that belief elicitation can add to the analysis of preference behavior, their use is just recently growing (Manski, 2018). Mostly because to elicit beliefs is challenging (Delavande, Giné, & Mckenzie, 2010). Concepts of probabilities may be not well understood or perceptions questions are not framed correctly, leading to ambiguous answers and undermining internal validity (Bruine de Bruin & Fischhoff, 2017). To respond to this challenge, Delavande, Giné, and Mckenzie (2010) suggest the use of visual aids to improve the accuracy on the elicitation for subjective beliefs, while Manski (2018) calls for a careful design on perceptions surveys.

In the context of this thesis, that is the understanding of pro-environmental behaviors among oil palm smallholder farmers, the comprehension of perceptions and expectations is important since farmers may prefer environmental protection but few may be willing to pay the associated cost (Laurène; Feintrenie, Chong, and Levang 2010). It might also be the case that farmers believe their actions do not have any significant effect on the environment (Bolderdijk, Gorsira, Keizer, & Steg, 2013). Drawing from social-psychological theories, the decision to adopt an innovation or behavior is a cognitive process shaped by knowledge, information exposure and contextual factors (Steg & Vlek, 2009). This in turn, would shape perceptions and intentions and eventually drive adoption. This process would then reveal farmers perceptions and expectations towards the adoption of a pro-environmental behavior.

In the research area, that is Jambi Province, Sumatra Indonesia, the historical oil palm expansion has led to different plantation management practices among smallholders (Euler et al. 2016). Combined with the heterogeneity in landscapes, this is expected to cause variation in the loss of ecosystem functions in the region, and reflected in farmers' perceptions of ecosystem losses. Most studies address the negative environmental effects associated with oil palm cultivation, and little about how farmers perceived and experienced those and the extent to which farmers are concern for the environment (Byerlee et al., 2017; Clough et al., 2016; Dislich et al., 2016; Fitzherbert et al., 2008; Margono et al., 2012, 2014; Wilcove & Koh, 2010). To the best of our knowledge no study has analyzed oil palm farmers' perceptions towards environmental-friendly practices, neither their concern about the environment nor the perceived ecosystem functions drawn in oil palm plantations. The available literature on farmers' perceptions reveals that farmers are responsive to economic opportunities and that ecological motives play a minor role over their ecological values (McCarthy et al. 2012; Feintrenie et al. 2010; Feintrenie et al. 2010; Feintrenie & Levang 2011; Feintrenie & Levang 2009; Therville et al. 2012). That is, farmers are more likely to convert forest or agroforest systems to oil palm plantations. This indicates that the remaining forest patches, agroforest and secondary forests are under threat if farmers have this preference (Clough et al., 2016). Thus, only by understanding farmers' perceptions and how these are shaped, policies can be designed in a way that are of relevance for farmers as well as enhancing biodiversity. In addition to identifying perceptions, policies would also be benefitted by exploring the extent to which farmers are concern about the environment and which factors contribute to this concern (Steg & Vlek, 2009). Environmental concern captures the degree to which individuals show their awareness to the environment and their support to or activism towards alleviating environmental degradation (Schmuck, Schultz, & Milfont, 2003). Thus individuals may behave more pro-environmentally if their concern is high (De Groot & Steg, 2010; Kollmuss & Agyeman, 2002; Van der Werff, Steg, & Keizer, 2013).

1.2.1 The case of biodiversity enrichment in smallholder oil palm plantations

To a certain degree, oil palm monoculture supports the biodiversity of species in forest fragments within the plantation and buffer zones of natural vegetation (Edwards et al., 2011; Koh & Wilcove, 2008; Lamb, Erskine, & Parrotta, 2005). This retained forests in the oil palm plantations, if managed as agroforestry system, have the potential not only to restore biodiversity but enhance local economies (Bhagwat & Willis, 2008). Adjacent forest patches function as "stepping stones" for forest dependent species, allowing positive spill over into oil palm plantations, i.e. bird species richness (Azhar et al., 2011). One approach that has been proposed to balance the ecological cost of oil palm and its economic advantages is the design of heterogeneous landscapes through the enrichment of oil palm plantations with native trees (Teuscher et al., 2016). Growing oil palm with mixed trees can create habitat for forest-dwelling species, act as a buffers and corridors to nearest forest, while the tree based products, e.g. fruits and timber, can benefit local livelihoods (Bhagwat & Willis, 2008; Koh & Wilcove, 2008). Additionally, tree planting could improve ecological conditions such as soil fertility, drought resistance, weed and biological pest control, pollination and litter decomposition (Tscharntke et al., 2011). Trees planted in islands inside the oil palm function as nuclei of biodiversity by increasing bird activity and hence seed dispersal of trees (Teuscher et al., 2016). However, some evidence suggests that intercropping in oil palm may cause yield loss due to nutrient competition (Corley & Tinker, 2016), as oil palm is a water and light demanding crop that can even draw nutrients from a radius of 15 meters (Koh et al., 2009). Altogether indicates that biodiversity enrichment by tree planting in oil palm could reconcile ecological functions with small economic trade-offs (Kueffer & Kaiser-Bunbury 2014). Yet, there is limited empirical knowledge on how best to promote tree planting among smallholder oil palm farmers.

In the research area, it is often the case that oil palm plantations are established on jungle rubber systems, which is characterized by a mix of rubber trees and other tree species, allowing a structure that is similar as that of a secondary forest (Teuscher et al., 2015). This land conversion permits smallholders to retain trees in their oil palm plantations which benefit biodiversity. Only few farmers are found to intentionally plant trees (Muryunika, 2015; Teuscher et al., 2016). At the same time, focus group discussions reveal that farmers lack information about the management and establishment of this practice while access to seedlings is not always available. This indicates that information constraints and missing markets for seedlings prevent adoption of tree planting in oil palm.

Much of the knowledge that oil palm farmers have today about plantation management was acquired from extension services and working in these plantations (Therville et al., 2012). However, in the case of Indonesia, extension services do not seem to adequately address farmers' needs and the diffusion of information is often limited (Anderson & Feder, 2004; Andersson, 2006; Feder, Murgai, & Quizon, 2004; Woittiez et al., 2017). Social-psychological literature shows that educational campaigns and environmental related interventions lead to motivational crowding-in (Frey & Stutzer, 2007; Torgler, García-Valiñas, & Macintyre, 2009). Similarly, information provided in the form of movies or illustrations may increase the likelihood of behavioral change. In addition, role models involving emotional engagement prompt the adoption of those behaviors (Zelenski, Dopko, & Capaldi, 2015). Certainly, the role of providing accurate and timely information is crucial to produce a change, but rarely results in adoption of pro-environmental behaviors. This is because information most likely changes perceptions or intentions, and unless these are strong, there will not be eventually a change in behavior (Bolderdijk et al., 2013). In the case when individuals face costs and external constraints, rewards and incentives may be a pathway to increase adoption (Steg & Vlek, 2009). For example, Abrahamse et al. (2005) found that rewards increase the likelihood to reduce energy comsumption, while Bamberg (2003) emphasizes that only situation-specific cognitions determine adoption of pro-environmental behaviors. To the best of my knowledge no study has combined and analyzed the effect of such interventions to encourage tree planting in oil palm adoption. We only find experimental evidence from analyzing the effects of Payments for Ecosystem Services (PES) on tree planting adoption (Cole, Holl, & Zahawi, 2010; Jack et al., 2013; Leimona, Joshi, & van Noordwijk, 2009). Yet, these studies only shed light on interventions including financial rewards, without looking at other motives or evaluating other policy instruments. Thus, it seems important to explore which policy instruments can induce tree planting behavior among oil palm farmers.

1.3 Research objectives

The overall objective of this dissertation is to empirically assess an analysis of perceptions, environmental concern and adoption of tree planting behavior among oil palm smallholder farmers in Indonesia. In particular, I explore the following research objectives:

1. What are the perceived ecosystem functions in oil palm plantations by smallholders?
2. What factors help to explain the environmental concern from oil palm farmers?
3. How can tree planting in oil palm plantations be promoted among smallholder farmers?
4. What psychological mechanisms mediate tree planting adoption?

The empirical evidence from the analysis of these questions provides insights about the perceived ecosystem functions from oil palm plantations and factors that influence farmers' environmental concern. In addition, we provide evidence on the effects of environmentally friendly policies. These results can support the design of interventions aimed at reconciling economic and ecological trade-offs in oil palm cultivation.

1.4 Study area

To address the research objectives of this dissertation, the study is set in 36 villages in Jambi Province, on the Island of Sumatra in Indonesia. In the past decades, Jambi has experienced a rapid transformation of lowland areas to oil palm and rubber plantations (Drescher et al., 2016). In the period of 1996 to 2014, the oil palm cultivated area is estimated to have expanded from 150,000 hectares to 590,000 hectares large (Gatto et al. 2015; Drescher et al. 2016) while by 2013 only 30% of total area in Jambi was still covered by rainforest (Drescher et al. 2016). This expansion has been largely encouraged by the resettlement *transmigrasi* (transmigration) program, whose beneficiaries from densely populated areas have migrated to islands with abundant land (J. F. McCarthy, 2010). The transmigration program supported the population redistribution policy, aiming at spreading Javanese hegemony while boosting rural economies (McCarthy et al. 2012; Budidarsono et al. 2013; Gatto et al. 2015). Migrant families were relocated near the newly established oil palm plantations and were provided with cultivated land, technical knowledge and market access for input and output. Given the rapid economic gains from the cultivation, smallholders spurred a spontaneous migration by attracting their relatives and friends from other regions to migrate to their newly established homes (Therville et al. 2012; Feintrenie & Levang 2011; Gatto et al 2015; Feintrenie et al. 2010). The plantations managed by the companies are therefore homogenous with a standard structure, giving little space for other crops or trees to plant. These plantations differ from those smallholder farmers in traditional villages in structure and management (Teuscher et al., 2015).

1.5 Collaborative Research Center 990: EFForTS

My dissertation was conducted within the Collaborative Research Center 990, as a sub-group of the interdisciplinary project “Ecological and Socio-economic Functions of Tropical Lowland Rainforest Transformation Systems (EFForTS)” in Jambi Province, Sumatra Indonesia.[1] The primary focus of this project is to integrate research to understand socio-economic and ecological impacts from rainforest conversion to jungle rubber, and monoculture plantations of rubber and oil palm (Drescher et al., 2016). A sub-group of natural scientists have set up a long-term biodiversity enrichment experiment that combines tree islands, that vary in plot size, tree density and diversity, with oil palm (Gérard et al., 2017; Teuscher et al., 2016). After a year of establishment, tree planting has shown to increase bird and invertebrate communities within the plantation (Teuscher et al., 2016). In addition, two years after planting, the net effect on oil palm yields is positive, however this result may be associated with a thinning effect driven and affected by positive spillovers from adjacent tree islands (Gérard et al., 2017). To answer the research questions of how tree planting in oil palm plantations can be promoted among smallholder oil palm farmers and which psychological mechanisms mediate adoption, I designed policy interventions based on these experimental results.

1.6 Dissertation outline

The present dissertation consisting of four chapters is organized as follows. Chapter 2 addresses the first and second research questions. Following environmental psychology studies, I provide a descriptive analysis on oil palm farmers’ perceived ecosystem functions

[1] http://www.uni-goettingen.de/en/310995.html (Date of access: 19-05-2018)

of oil palm cultivation and explore factors that shape farmers' concern for the environment. I compare my findings with studies that have recently quantified and reviewed ecosystem functions of oil palm plantations. Chapter 3 provides experimental evidence from a randomized controlled trial on the evaluation of two environmental policies to promote the adoption of tree planting in oil palm cultivation. The policies address knowledge gaps by the provision of information about this practice through a movie and an illustrative manual; and structural constrains by distributing seedlings for free in addition to information. I also provide a path analysis on psychological components to understand the mediating channels through which the treatments influence adoption of tree planting. Chapter 4 presents and summarizes the findings on the previous chapters to draw policy implications and outlines main limitations of this study. It further suggests future research directions.

2 Understanding oil palm farmers' concern for the environment

Abstract

We provide a descriptive analysis of how smallholders in Indonesia perceive a change in ecosystem functions of oil palm. In addition, we linked these perceptions to explore their influence on environmental concern and employ psychological constructs to measure it. The data analyzed is from a farm-household survey collected in Jambi Province, Indonesia, a biodiversity hotspot. Our results suggest that the natural environment experienced by farmers in their oil palm plots shapes their perceptions. Farmers perceive a decrease on regulation functions (e.g. soil fertility, water availability), while provisioning services are perceived as increasing with oil palm cultivation. Furthermore, we find that the larger the share of oil palm cultivated in the village, the more concerned smallholder farmers are about the environment. At the same time, the closer the village is to forest the less environmentally concerned smallholders are. Given that oil palm expansion continues in Indonesia, policies aiming at the conservation of biodiversity are urgently needed. One way is by understanding farmers' environmental perceptions and concern, which can provide valuable information about farmers' ecological motives, and these can guide policies that aim at better planning of ecological landscape restoration.

Key Words: ecosystem functions, oil palm, environmental concern, smallholders, Indonesia

2.1 Introduction

Jambi Province on the island of Sumatra, Indonesia, is a biodiversity hotspot while also experiencing a massive boom in oil palm cultivation (Barnes et al., 2014). In the period of 1996 to 2014, the oil palm cultivated area is estimated to have expanded from 150,000 hectares to 590,000 hectares large (Gatto et al. 2015; Drescher et al. 2016). This land use transformation decreased lowland rainforest and agroforestry systems to the extent that by 2013 only 30 percent of total area in Jambi remained as rainforest, from the 66.52 percent in 1990 (Clough et al., 2016). This threatens the unique biodiversity of the Island of Sumatra, which hosts over 10,000 plants species, 201 mammal species, and 580 avifauna species (Margono et al. 2012). Gradually, this biodiversity has begun to disappear as a consequence of the conversion of forests to monoculture plantations of timber, rubber and oil palm across the island (Burgess & Olken 2012).

In the past three decades, Jambi has undergone an agricultural transition from cultivating "*ladang*" (i.e. upland rice) and rubber agroforests to monoculture plantations of timber, rubber and oil palm (Burgess & Olken 2012; Feintrenie et al. 2010). The landscape simplification to monoculture, and in particular the specialization in oil palm cultivation, has come at the expense of ecosystem functions (Klasen et al., 2016). Oil palm monoculture systems generally reduce ecosystem functions compared to more complex land use systems, such as forest or rubber agroforesty.[2] The loss of ecosystem functions is associated with the extent to which the plantation was established, the physical structure and management. The largest environmental impact is caused during the establishment of a new plantation, particularly on peat soils, due to large carbon losses (Chambers, 2003; Dislich et al., 2016). This process implies the fragmentation of soil structures, by the use of heavy machinery or by slash-and-burn practices, causing severe changes to its morphology through decomposition, compaction and sedimentation (Dislich et al., 2016; Pye & Bhattacharya, 2013). Beyond the physical destruction, oil palm monoculture plantations support fewer invertebrates and vertebrate species than primary or secondary forests, due to their

[2] Accordingly to de Groot et al. (2002, 354), ecosystem functions are defined as *"the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly"*. These are grouped into regulation, habitat, provisioning and information services.

homogenous structure. In addition, the oil palm plantations structure leads to a fragmentation of remaining habitats, thereby further deteriorating biodiversity (Corley & Tinker, 2016; Fitzherbert et al., 2008). In combination, these factors affect water availability, pollination success, soil fertility, and carbon storage, thus putting human well-being at risk (Cardinale et al., 2012; Clough et al., 2016; Dislich et al., 2016). Altogether, regulatory and habitat functions are reduced in oil palm systems. The only ecosystem function that appears to increase with the cultivation of oil palm is the provision of marketable goods and associated economic benefits (Dislich et al., 2016). This provisioning service has increased farmers' income, food security and well-being, although these economic benefits have not been equally distributed among all local people or smallholders (Clough et al., 2016; Euler, Krishna, Schwarze, Siregar, & Qaim, 2015; Kubitza, Krishna, Alamsyah, & Qaim, 2018; Therville et al., 2012).

Literature shows that economic gains are a major driver for farmers' decisions to cultivate oil palm. Yet, little is known about farmers' perceptions of ecosystem functions associated with oil palm, the extent to which farmers are concerned about the environment and which factors contribute to this concern. Environmental concern captures to what degree individuals are aware of the environment and their support of, or activism towards, alleviating environmental degradation (Schmuck et al., 2003). Therefore, individuals may behave more pro-environmental if their concern is high (De Groot & Steg, 2010; Kollmuss & Agyeman, 2002; Van der Werff et al., 2013). From a policy perspective these aspects are important. This is because individual adoption decisions are analyzed by revealed preferences and observed choices. The analysis of choices often ignores intrinsic factors such as perceptions, assuming that individuals make rational decisions (Manski, 2004). However, individuals have perceptions and beliefs that can largely influence adoption choices (Lusk et al., 2014). Therefore, perceptions hold valuable information that can help to predict behavior. While the present study does not assess adoption decisions, literature also shows that focusing on perceptions and how these are shaped gives us a better understanding about how famers experience their natural environment (Meijaard et al., 2013). In turn, this will provide insights to design policies or create incentives that aim at environmental protection while being of relevance for farmers (Meijer et al., 2014; Steg & Vlek, 2009; Tomich, Thomas, & Noordwijk, 2004).

Despite the importance of these psychological measures for the design of sound policies, little effort has been made to address farmer's perceptions towards environmental degradation associated with oil palm cultivation and their environmental concern. In this regard, only Merten et al. (2016) combined villager's perceptions with scientific data about water availability. The present study contributes to this limited amount of literature by analyzing environmental perceptions of oil palm farmers. We examine the perceived changes in ecosystem functions, which are due to oil palm cultivation, and link these to farmers' environmental concern. In addition, we explore socio-economic factors that may play an important role in shaping farmers' environmental concern.

The remainder of this chapter is organized as follows. We provide our aims and hypotheses in section 2.2, followed by the study design in section 2.3. Sections 2.4 -2.8 present the data and discuss our estimated results. We end with concluding remarks in section 2.9.

2.2 Conceptual Framework

We are interested in exploring two psychological measures: 1) perceptions of ecosystem functions of oil palm landscapes and; 2) farmers' environmental concern. We followed environmental psychology studies to define and capture these measures. Perceptions can be defined as the process of obtaining information from direct observation of the physical environment (Gifford, 2016), which then facilitates or impedes behavioral changes towards sustainability (Gifford, 2011). We define environmental concern as "*the affect (i.e. worry) associated with beliefs about environmental problems*" (Schultz et al. 2004 p.31). In our study, we investigate at how the natural environment affected by the cultivation of oil palm shapes the perceptions of farmers of ecosystem functions of oil palm systems. Furthermore, we explore how these perceived functions and other external factors relate with farmers' concerns towards the environment.

In our research area, Jambi Province in Indonesia, the historical patterns of oil palm expansion lead to differences in farmers' plantation management across the region (Euler et al. 2016). This, in addition to the differences in landscape physiography might influence the way farmers experience environmental impacts of oil palm. We expect that this heterogeneity is also reflected in farmers' perceptions of changes in ecosystem functions associated with oil palm cultivation. From this assumption, we derived our first hypothesis:

Hypothesis 1 (H1): *Farmers' ecological context (at plot and village level) shapes their perceptions of ecosystem functions of oil palm cultivation.*

Next, to measure environmental concern, we follow Ellis & Thompson's (1997) work.[3] Their measure captures an individual's concern about the negative environmental effects from human activities (i.e. deforestation), and their desire to help mitigating these (Ellis & Thompson, 1997). We seek to explore external factors and perceptions associated with farmers' concern for the environment as shown in Figure 2-1.

We first explore personal values and perceptions. Since the natural environment influences the extent to which an individual is concerned about the environment, we explore the link between the perceived change in ecosystem functions of oil palm and environmental concern (Clayton, 2012; Gifford & Nilsson, 2014; Zelenski et al., 2015). This relationship follows the idea that more positive perceptions or subjective valuation of ecosystem functions could indicate higher environmental concern (Kollmuss & Agyeman, 2002). At the same time, perceptions may be shaped by the extent to which a person is concern for the environment, indicating reciprocal influence. We focus on perceptions and values, since we are interested on knowing how farmers' perceive changes on ecosystem functions. This perceived change indicates environmental awareness of, severe or subtle, impacts of environmental degradation, which will translate into higher environmental concern (Kollmuss & Agyeman, 2002). This leads to our second hypothesis:

Hypothesis 2 (H2): *Farmers' concern for the environment is correlated with perceptions of their natural environment*

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[3] There is a large number of studies addressing factors that affect environmental concern. For example, Olofsson & Ohman (2006); Stern & Dietz (1994); Bamberg & Moser (2007); Bamberg (2003); Fransson & Garling (1999); Schultz et al. (2005); Schmuck et al. (2003); Schultz (2000); Castro (2006). However, there is not yet a consensus on which factors are universally affecting concern for the environment. In some studies some factors seem to have a positive and significant correlation with environmental concern, in other studies the sign of the correlation is contrary (e.g. age). Therefore, the choice of factors analyzed here is based on some of these studies and on observations from the fieldwork of factors that might affect farmers' perceptions and environmental concern.

Then, we hypothesize that individual and contextual factors affect farmers' environmental concern. According to some studies, environmental concern is positively influenced by a sense of connectivity to nature (Dutcher et al., 2007; Martin & Czellar, 2017). This hypothesis is based on the idea that an individual's concern towards the environment is shaped by the extent to which a person feels he/she is part of nature (Schultz et al., 2004). Other studies have also found similar links and conclude that connectivity to nature reflects biospheric values of an individual (Dutcher et al., 2007; Martin & Czellar, 2017). Biospheric values is defined as an "*orientation in which people judge phenomena on the basis of costs or benefits to ecosystems or the biosphere*" (Stern & Dietz 1994 p.70). In addition to perceptions, we further expect that socio-demographic factors capturing knowledge and experience such as age, education and migration status affect environmental concern positively (Fransson & Garling, 1999; Robert Gifford & Nilsson, 2014). We further expect farmers cultivating a larger area of oil palm to be less concerned about the environment (Stern, 2004), and that a major environmental problem such as drought will increase farmers' concern for the environment as in Arcury (1990). Based on the above, we derive our third hypothesis:

Hypothesis 3 (H3): *Farmers' concern for the environment is influence by external factors*

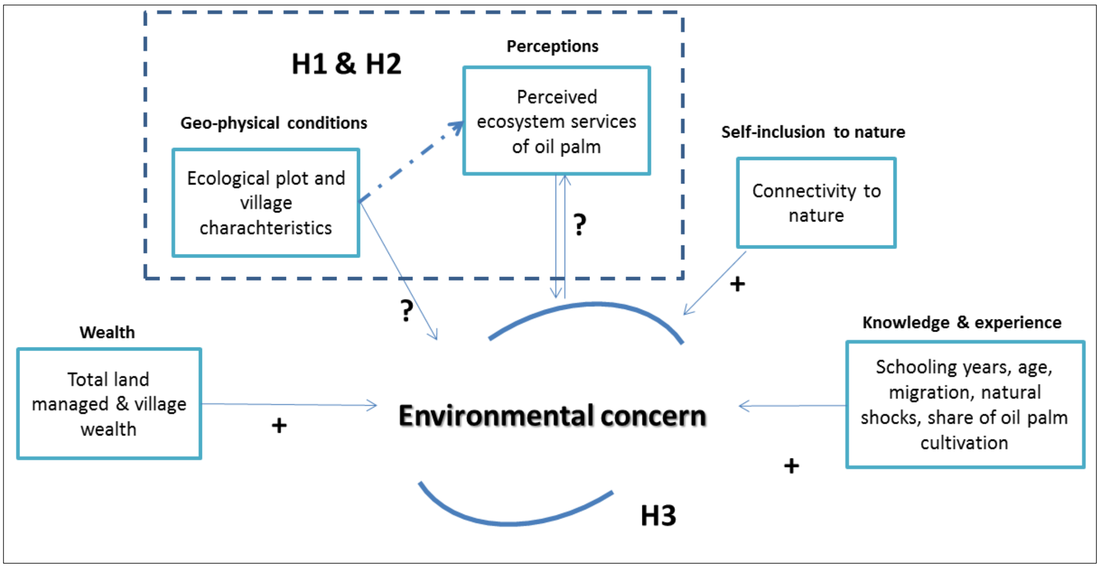

Figure 2-1 Conceptual Framework
Note: Adapted from: Gifford & Nilsson 2014; Martin & Czellar 2017; Fransson & Garling 1999
Environmental concern is measured as in: Ellis & Thompson 1997 and Dutcher et al. 2007
Each arrow represents a hypothesis and its expected sign.

2.3 Data and study design

2.3.1 Research site

Our research was conducted in Jambi Province, Indonesia. Jambi is located in central Sumatra. In recent years it has experienced a fast and almost complete conversion of non-protected lowland rainforests into mono-cultural plantations (Laumonier et al., 2010). We selected five districts for the study (Muaro Jambi, Batanghari, Sarolangun, Tebo and Bungo), which have been subject to this massive transformation to oil palm plantations (Drescher et al., 2016) (see Figure 2-2).

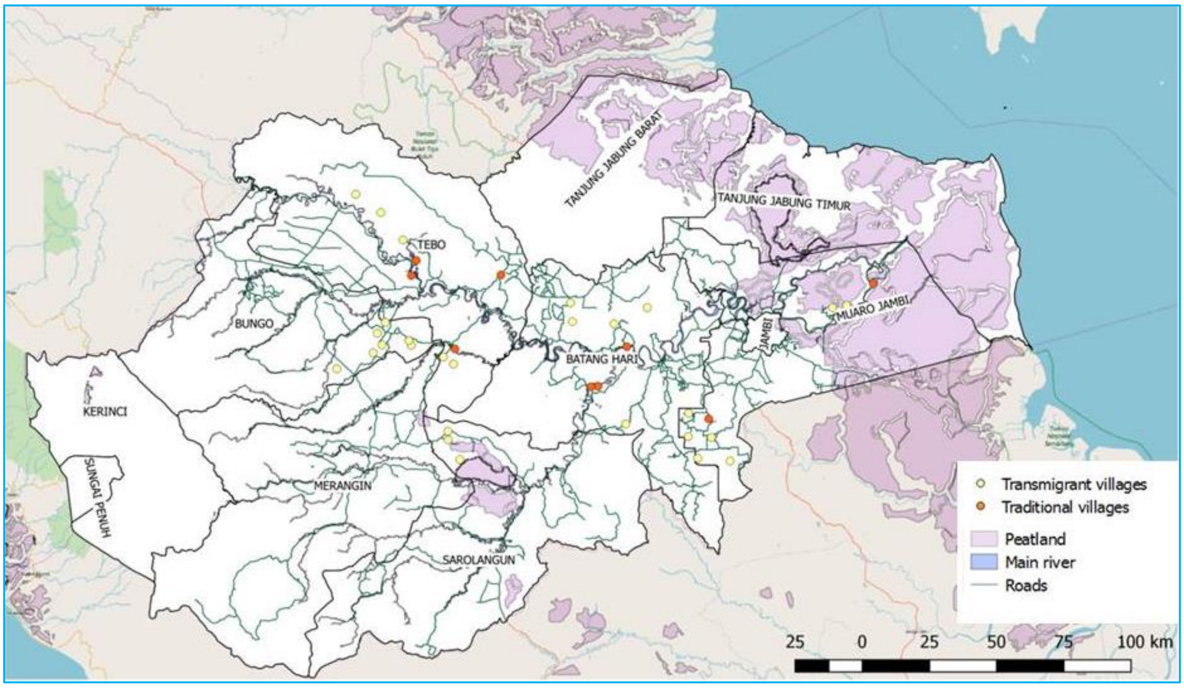

Figure 2-2 Village sample in Jambi Province

2.3.2 Sampling

From a national village census conducted in 2008 (PODES), we extracted information on the total number of households engaged in oil palm cultivation in each village. We randomly selected 27 villages out of 94 villages, which reported that more than 70 percent of the main economic activity was from cultivating oil palm. All of these villages are "transmigrant villages", meaning that their establishment was supported by a governmental resettlement program aiming, amongst other goals, to expand oil palm cultivation.[4] In traditional villages, engagement in oil palm is generally lower and the majority of households cultivate rubber (Zen, Barlow, & Gondowarsito, 2005). We therefore lowered the threshold to 30 percent of households engaged in oil palm cultivation for traditional villages and identified nine traditional villages fulfilling the criterion in the study region. In total, our sample includes 36 villages (see Figure 2-2).

Our data builds on a sample of 817 oil palm farmers that were randomly selected in the 36 oil palm growing villages.[5] We interviewed 22 to 24 households per village. To construct the sampling frame, we obtained a household list from the village head or the staff of the village with the names of independent oil palm farmers. Independent farmers are not linked by contract to a company and are thus free to manage their plantations. Our household survey captured detailed information on oil palm management, environmental perceptions, and socio-demographics. Data was collected from October to December 2015 with the support of 12 enumerators. In addition, we relied on village level data drawn from the mentioned national census.

2.4 Description of key outcome indicators

2.4.1 Perceptions of ecosystem functions

We examine farmers' perceptions of provisioning, habitat and regulating ecosystem functions of oil palm. Perceptions are measured on a five-point Likert scale where 5 represents "*increases very much*" and 1 "*decreases very much*". Respondents were asked to rate twelve items related to changes in ecosystem functions associated with oil palm cultivation (see Table 2-1). Out of these 12 perceptions three items were reversed for the

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[4] The oil palm boom in Indonesia started with the transmigration program in the 1990's. The transmigration program initiated by Suharto's government consisted of reallocating families from overcrowded islands to less populous areas, leading to an important migration flow from Java to Sumatra (Fearnside 1997). Those families were sponsored by the government and placed near to government-managed oil palm estates. They also received land (2-3ha), inputs and technical assistant through loans and a formal land title once this loan was repaid (Rist et al. 2010).

[5] Table 2-6 in the Appendix 1 section shows descriptive statistics from our sample.

analysis to represent an improvement in the respective ecosystem function. These were: erosion prevention, temperature regulation and pest control.

Table 2-1 Perceptions of ecosystem functions of oil palm

Perception on the change of ecosystem functions in oil palm	Mean	Std. deviation
Regulating functions		
soil fertility	2.08	1.04
erosion prevention	2.87	1.04
water availability	1.59	0.83
water quality	2.56	0.98
temperature regulation	2.51	1.16
pest control	2.81	1.24
Habitat functions		
bird diversity	3.21	1.31
insect diversity	3.39	1.08
Provisioning functions		
income	4.52	0.68
income stability	3.87	0.85
well being	4.30	0.73
food availability	3.85	0.88
Observations	817	

Notes: The statements are measure on a scale of 1 to 5, where 1 = Decreases very much; 2= slightly decrease, 3= no change, 4= slightly increase and 5 = Increases very much.

2.4.2 Environmental concern

To capture environmental concern, we adapted the scale from Dutcher et al. (2007) to the context of oil palm expansion in Jambi Province and measure it on a 5-point Likert scale of agreement (see Table 2-2). We then employed exploratory factor analysis to group three statements based on their common variance. This approach is performed by transforming the correlated statements into factor loadings through a covariance matrix (Yong & Pearce 2013). As suggested by Yong & Pearce (2013), we used factors with eigenvalues higher than 1. The internal validity is observed with the Kaiser–Meyer–Olkin (KMO) indicator that measures sampling adequacy. While it is recommended that the KMO measure is close to 1 (e.g. above 0.70), studies analyzing perception scales often only achieve values of 0.50 (Shivakoti & Thapa 2005; Hansson et al. 2012). Our scale yields a KMO of 0.66. We further explored reliability, which is the degree of accuracy in our measurement, by looking at the inter-item correlation. Our inter-item correlation shows a value of 0.395 which is consider reliable (Ray & Bhattacharya, 2004). Finally, we standardized the obtained factor score to range from 0 to 1, with higher values representing higher environmental concern.

Table 2-2 Environmental concern

	Mean	Std. deviation
1. If oil palm expansion continues at the current speed, problems of haze and air pollution will soon become unbearable in Jambi	3.32	1.36
2. Oil palm cultivation in Jambi has no effects on global environmental problems	3.22	1.26
3. The expansion of oil palm will soon lead to the exhaustion of natural resources in Jambi	3.48	1.18
Total factor (normalized from 0 to 1 range)	0.589	0.245
Observations	816	

Note: Mean values of each statement employed to measure the scale of environmental concern. The statements were measured by the Likert Method on a scale of 1 to 5, where 1 = strongly disagree, 2=slightly disagree, 3 = Indifferent, 4 = slightly agree, and 5 = strongly agree. Statement 2 was reverse for the analysis.

2.5 Local perceptions of ecosystem functions in oil palm

In a first step, we present an assessment of the subjective value that farmers place on each ecosystem function. We capture these values by asking farmers to provide their evaluation of 12 statements measured on a 5-point Likert scale, where 5 represents “extremely good” and 1 “extremely bad. [6] Each statement represents the degree to which performance of the ecosystem function is positively or negatively valued (Ajzen, 1991). The individual valuation of each ecosystem function allows us to capture not only how these functions are subjectively perceived, but also the extent to which they would be salient to the individual in a given situation (Steg et al., 2014). Figure 2-3 shows the mean value for each ecosystem

[6] Table 2-7 in the in the Appendix provides the mean values and the related statements that were asked to farmers to assess their subjective valuation of each ecosystem function.

function. Overall, we observe that farmers attach a positive value to the environmental and economic services. However, it appears that farmers tend to be neutral or slightly negative towards insect diversity and pest control.

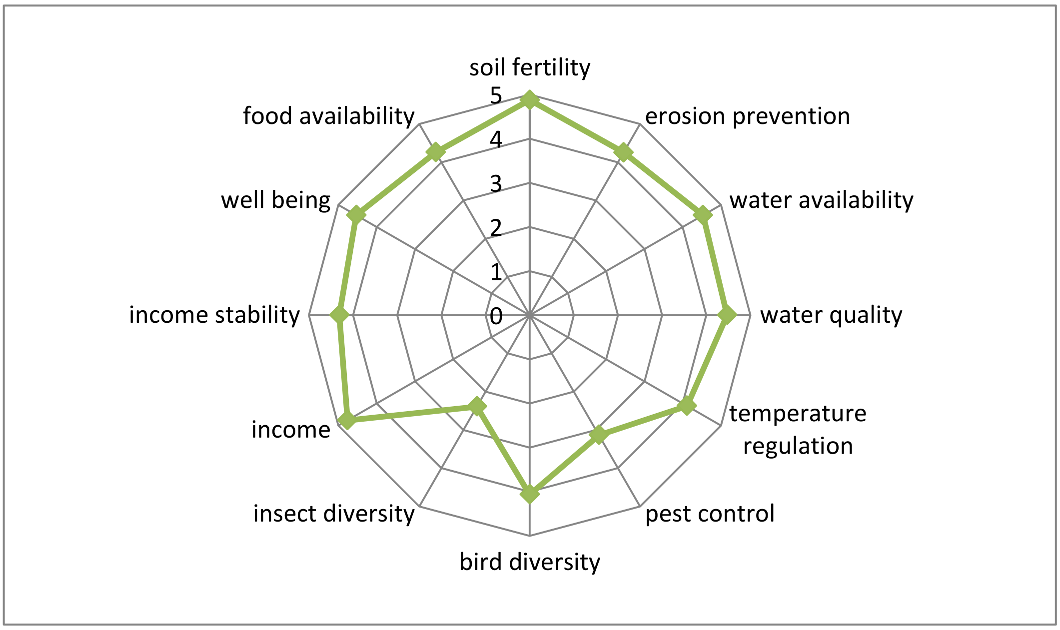

Figure 2-3 Farmers' subjective valuation of ecosystem functions
Note: Diagram to illustrate mean values for each perception on the change of ecosystem functions in oil palm (See Table 2-7). Measured by the Likert method on a scale of 1 to 5, where 1 = extremely bad, 2= slightly bad, 3 = Neither good or bad, and 5 = extremely good.

To analyze the perceptions towards ecosystem functioning in oil palm, we explore the empirical evidence provided by Dislich et al. (2016) and Clough et al. (2016) and compare their findings to our results. The first study was a systematic and comprehensive literature review of all ecosystem functions in oil palm plantations using natural forest as a reference (Dislich et al., 2016). The second study quantified the ecological and economic impacts of forest, jungle rubber, rubber and oil palm (Clough et al., 2016). Drawing on these two studies we focused on three categories of ecosystem functions: 1) ***regulating functions*** which relate to the capacity to maintain the stability of biogeochemical cycles; 2) ***habitat functions*** which provide natural environment that allows biological diversity succession; and 3) ***provisioning functions*** which ensure that an ecosystem provides natural resources for human use. The mean score of each ecosystem function captured on our scale is illustrated in Figure 2-4.

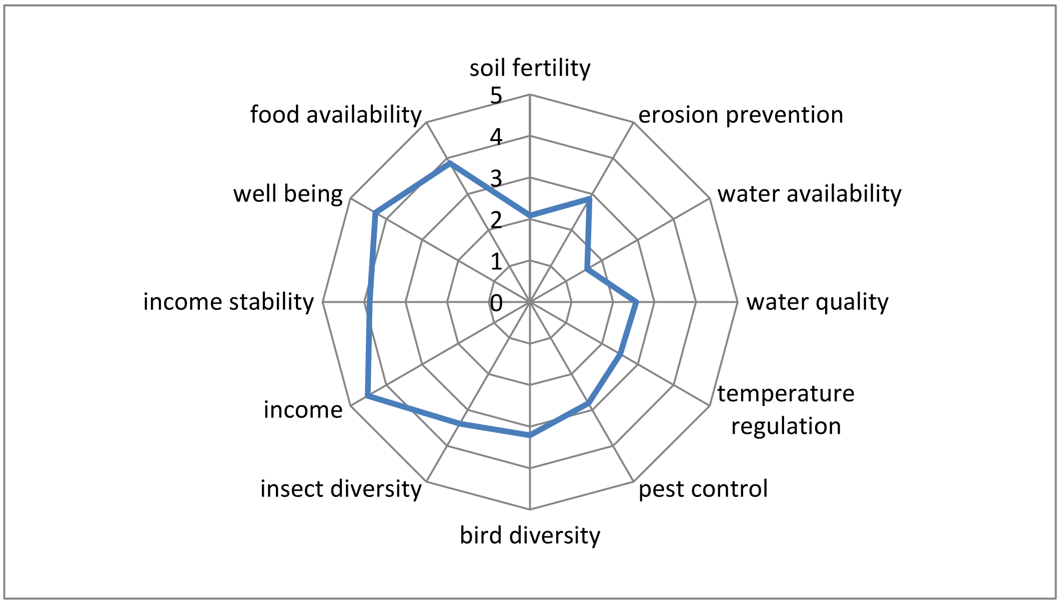

Figure 2-4 What are farmers' perceptions of ecosystem functions of oil palm?

Note: Diagram to illustrate mean values for each perception on the change of ecosystem functions in oil palm (See Table 1). Measured by the Likert method on a scale of 1 to 5, where 1 = decreases very much, 2= slightly decrease, 3 = no change, and 5 = increases very much.

2.5.1 Regulating functions

In monoculture oil palm systems, nutrient and water cycling as well as climate regulation are altered compared to natural forests. Soil fertility decreases due to the large amount of nutrient leaching and loss of organic matter (Clough et al., 2016). This occurs when slash and burn practices are used by farmers who remove ground vegetation that stores large amounts of nutrients (Dislich et al., 2016). This is further aggravated by soil erosion, occurring when soil structures disaggregate. Disaggregation can be caused by sedimentation of the soil or when rainfall, wind or tillage causes soil runoff (Corley & Tinker, 2016; Dislich et al., 2016). Erosion depends, among other things, on ground vegetation cover and soil conservation practices that can improve soil cover and water infiltration (Dislich et al., 2016).

In addition to soil fertility and erosion, oil palm expansion has been largely associated with water availability problems (Clough et al., 2016; Corley & Tinker, 2016; Dislich et al., 2016; Merten et al., 2016). The decrease in water accessibility is explained by rainwater run-off from the eroded and compacted soil, reducing the water available for groundwater recharge (Merten et al., 2016). This is reflected in the livelihoods of farmers, who have experienced water scarcity more prominently during the dry season, for drinking, washing and bathing

(Clough et al., 2016; Merten et al., 2016). Besides the decrease in water availability, oil palm has a negative impact on water quality. Sediment run-off is one of the largest problems for water quality and can be aggravated by the reduction of ground vegetation (Dislich et al., 2016).

Another ecosystem function that has decreased in oil palm systems is biological or pest control. Biological control "*refers to the ability of an ecosystem to regulate organisms in a way that those do not act as disease"* (Dislich et al. 2016 p.1555). The homogenous structure of oil palm plantations reduces resilience to pest outbreaks (Dislich et al., 2016; Lin, 2011) as biocontrol agents do not find hospitable conditions inside the plantation. The most commonly found pest in oil palm plantations are usually insects (i.e. leaf-eating insects) or mammals (i.e. rats), largely depending on the age of the plantation (Woittiez, Wijk, Slingerland, Noordwijk, & Giller, 2016). The direct impact of pest can cause up to 80 percent yield reduction (Dislich et al., 2016).

The conversion of forest to oil palm also affects the microclimate. In the literature reviewed by Dislich et al. (2016) the temperature in an oil palm plantation was found to be on average 6.5°C warmer than in primary forest and 4°C warmer than in logged forest. In addition, oil palm plantations show to have a lower micro-climatic stability compared to forest, affecting temperature and humidity in air and soil (Clough et al., 2016).

Our results show that farmers in our study area perceive similar changes in ecosystem functions associated with oil palm cultivation. In particular, farmers perceive a strong decrease in water availability and soil fertility, on the average. This is in line with previously documented perceptions of water scarcity (Merten et al., 2017) and with our previous result that farmers attach particular importance to soil fertility (see Figure 2-3). Smaller negative changes are also perceived with respect to water quality and temperature regulation. Regarding erosion prevention, the average assessment of farmers ranges around three, indicating that they have not observed major erosion problems due to oil palm cultivation.

2.5.2 Habitat functions

In oil palm plantations, the simplified and homogenous structure decreases taxa diversity, negatively affecting richness of birds, invertebrates and protists (Clough et al., 2016). In general, the abundance and richness of species is much lower in oil palm plantations compared to forests (including ants, beetles, moths, mosquitos, birds and small mammals). This is a consequence of the loss of habitat, making it difficult for species to survive (Cardinale et al., 2012; Dislich et al., 2016; Edwards et al., 2010; Foster et al., 2011; Margono et al., 2014; Wilcove & Koh, 2010). Fitzherbert et al. (2008) found that oil palm could only support up to 15 percent of forest species. Despite this, our data suggest that on the average farmers have perceived no change in bird diversity and even a small increase in insect diversity. The fact that farmers do not perceive any problems regarding biodiversity may be related to the fact that they also attach lower value to these ecosystem services (see Figure 2-3). Indeed, insect diversity is even valued slightly negatively on the average, suggesting that farmers do not distinguish between insect diversity and abundance, which they may relate to pest problems.

2.5.3 Provisioning functions

Accordingly to Dislich et al. (2016), the provision of marketable goods is the only ecosystem function that appears to increase compared to natural forest. The economic effects on farmers' livelihoods have increased their wealth and contributed to food security for those with access to land (Euler et al., 2015). Oil palm has higher returns-to-labor than e.g. rubber, the main alternative cash crop in the study region (Krishna et al., 2017). This gives farmers more time to allocate their labor force to other economic activities (Clough et al., 2016). Our findings suggest that farmers perceive all economic welfare-related functions to increase with the cultivation of oil palm. Income and family well-being are perceived as increasing, while income stability and food availability are also viewed as slightly increasing. While at first sight it might be surprising to find that farmers associate oil palm cultivation with an increase in food availability, this perception can probably be explained by the increase in income that enables farmers to purchase more food (Euler et al., 2015).

Overall, we find that in most of the cases, farmers' perceptions are in line with the findings of Dislich et al. (2016) and Clough et al. (2016). It is evident however, that farmers' perceptions of bird and insect diversity to some extent diverge from those studies. Furthermore, we observe that the perceptions associated with soil fertility, water availability and quality appear to be quite pronounced when compared to the other perceptions. Therefore, we focus on these five perceptions and investigate factors that help to explain individual heterogeneity in these perceptions in the following section.

2.6 What factors determine local perceptions of ecosystem services?

To explore our first hypothesis, we focus on the role of physiographic factors to explain heterogeneity in perceptions related to soil fertility, water availability, water quality, as well as bird and insect diversity. Given that these perceptions are likely to be correlated, we employ a multivariate probit model to account for possible correlations of the error terms amongst the set of equations (Cappellari & Jenkins, 2003):

$$Y_{miv} = \beta'_m X_{miv} + \varepsilon_{miv}, \qquad m = 1, \ldots, M \tag{1}$$

where Y represents a dummy variable that equals one if farmer i in village v perceives an increase (or no change) in the specific ecosystem function m, and zero if the farmer perceives a decrease. We convert the 5-point Likert scale into a dummy to facilitate interpretation. For this, we consider values from 3 to 5 to represent an increase (or no change). X_{miv} is a vector of household head, plot, and village characteristics. To allow for inclusion into the model, the plot level information is aggregated at the household level. ε_{miv} are error terms, clustered at village level. Following standard assumptions, we assume that they follow a multivariate normal distribution with zero mean and unit variance (Cappellari & Jenkins, 2003).

Table 2.3 presents the results of the multivariate probit model. As can be seen, ground vegetation in oil palm plots is associated with a higher likelihood that farmers perceive an increase in soil fertility and water regulation due to oil palm cultivation. This might be the case as ground vegetation binds nutrients that benefit soil fertility and helps to conserve soil structures. It also increases the amount of leaf litter releasing nutrients to the soil when decomposing (Foster et al., 2011). Ground vegetation maintains high levels of water infiltration, which contributes to groundwater recharge (Corley & Tinker, 2016; Dislich et al., 2016). While overall, farmers tend to perceive a decrease in soil fertility and water regulation in oil palm (see Figure 2-4), we observe that farmers who have ground vegetation in their plantation are less likely to report such decreases in these ecosystem functions.[7] Furthermore, we observe that farmers in villages with access to rivers and where most

[7] It is important to keep in mind that the perceptions scale employed in the present study captures the opinion of the farmer from a general landscape. Yet, while these perceptions do not only reflect what is happening on their plot, we assume that plot characteristics are an important driver of farmers' perceptions.

families use drinking water from wells are more likely to perceive a decrease in water quality.

The role of ground vegetation has also been found to be crucial to the restoration of biodiversity in oil palm plantations. Amongst other things, it supports the abundance and richness of beetles as well as birds (Foster et al. 2011; Haddad et al. 2015). Similarly, ecosystems such as forests and peatlands support a higher abundance of birds than oil palm does. Therefore, the proximity to those systems might influence a migration of birds and insects into oil palm plantations (Azhar et al. 2011). The literature indicates that bird abundance and diversity in oil palm are also associated with having trees in the plantation (Teuscher et al. 2016). In Figure 2-4 we observe that on average farmers perceive an increase (or no change) in bird and insect diversity. At the same time, we find a positive correlation of having trees in the plantation with a perceived increase (or no change) in bird diversity. However, trees in the plantations are also associated with a perceived decrease in insect diversity. The latter may be driven by the number of trees and their distribution over space to reduce pest incidence (Tscharntke et al., 2011).[8] As we see in Figure 2-3, and alternative explanation is that, farmers tend to value a lower insect diversity, and this may influence that farmers pay less attention to any change.[9]

Finally, our findings also suggest that higher levels of education are related to a perceived decrease in ecosystem functions, particularly, a decrease in soil fertility and bird diversity. This might indicate that education can be an entry point to increase the knowledge of the importance of biodiversity and ecosystem functions.

[8] It is found that insect pests are less frequent in agroforestry systems, such as the mix of shade-trees with cacao (Tscharntke et al., 2011). This may explain the correlation found between the number of trees and the perceived decrease on insect diversity.

[9] An alternative explanation may be that farmers associate insect diversity with insect pests. A separate correlation test reveals that farmers who perceive an increase in pests to affect their oil palm are significantly more likely to perceive that insect diversity increases (ρ=0.1706). This finding might be explained by the fact that the incidence of damages from insect pests increases in oil palm (Clough et al. 2016; Corley & Tinker 2016; Dislich et al. 2016).

Table 2-3 Multivariate probit model for relations to ecosystem functions

	(1) Soil fertility no change/inc	(2) Water availability no change/inc	(3) Water quality no change/inc	(4) Bird diversity no change/inc	(5) Insect diversity no change/inc
Plot level characteristics					
=1 if at least one plot has ground vegetation	0.236* (0.122)	0.419*** (0.134)	0.644***(0.122)	0.248*(0.130)	0.598***(0.144)
=1 if at least one plot has clay soils	-0.0203 (0.140)	-0.144 (0.226)	-0.163 (0.147)	-0.225 (0.146)	-0.121 (0.149)
Slope on average[1]	0.022 (0.041)	-0.020 (0.044)	0.036 (0.040)	0.004 (0.041)	0.0223 (0.0389)
Age of the plantation (years)	-0.010 (0.010)	0.0108 (0.009)	-0.0131 (0.008)	0.007 (0.008)	-0.006 (0.010)
Average number of trees per hectare, baseline	0.001 (0.001)	-0.001 (0.001)	-0.0002 (0.001)	0.003** (0.001)	-0.003** (0.001)
Village charactheristics					
=1 if the village is near natural forest area[2]	0.117 (0.195)	-0.175 (0.255)	-0.233 (0.219)	0.320** (0.157)	0.199 (0.126)
=1 if the village is near peatlands	-0.198 (0.188)	0.013 (0.286)	-0.077 (0.151)	0.386** (0.180)	0.376** (0.181)
=1 if there is a river in the village	0.110 (0.143)	0.173 (0.193)	-0.273** (0.124)	0.046 (0.118)	-0.052 (0.180)
=1 if most families drink water from a well	0.010 (0.168)	0.053 (0.220)	-0.360*** (0.132)	0.0007 (0.004)	0.004 (0.004)
Household head charactheristics					
Age	-0.0009 (0.005)	-0.0001 (0.005)	-0.004 (0.004)	0.182 (0.168)	0.184 (0.140)
Years of education	-0.038***(0.012)	-0.008 (0.021)	0.0001 (0.012)	-0.034***(0.012)	0.0213 (0.017)
Constant	-0.249 (0.316)	-1.375** (0.591)	0.821** (0.347)	0.179 (0.318)	-0.017 (0.359)

Note: Standard errors are cluster-corrected at village level, shown in parentheses. Likelihood Ratio Test H0: 72.5314, p-value = 0.0000.
[1] Categorical variable measured on a scale of 0 to 7, where higher values represent a 10° degree increase of the slope
[2]Defined as on the edge or surrounded by the forest.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

2.7 How do perceptions of ecosystem functions relate to farmers' concern for the environment?

As mentioned in Section 3.3, we measure environmental concern with the help of a scale that captures perceptions of environmental degradation using statements adapted to the local context of Jambi Province. This scale was normalized to a range of 0 to 1 with higher values representing higher concern.[10] As can be seen from Table 2-2, the mean of the factor is 0.589, which indicates that on average farmers are moderately concerned about the environment. To explore how the perceived changes in ecosystem functions of oil palm are correlated with environmental concern, we estimate Spearman's rank-order correlation coefficients. This non-parametric correlation method measures the strength and direction of the correlation between two variables by testing the null hypothesis h_o that there is no monotonic association between the two variables. Given that our perception variables are measured on an ordinal scale from one to five, Spearman's correlation is preferred over Pearson's correlation coefficient, which tests for a linear relationship between two continuous variables (Mukaka, 2012). Based on the statistical significance of the correlation coefficient we accept or reject the hypothesis that environmental concern increases/decreases with each specific perception.

Table 2-4 displays the Spearman's correlation coefficients. We observe that perceived changes in soil fertility, water availability and water quality are negatively correlated with environmental concern. These results indicate that farmers perceiving decreases in soil fertility, water availability and water quality in oil palm are characterized by higher levels of environmental concern. These are also the ecosystem functions for which farmers have perceived most pronounced changes as a result of oil palm expansion and on which they have placed higher values (see Figure 2-3 and Figure 2-4). This suggests that these ecosystem functions and associated problems are comparatively more salient to farmers, and therefore crucial target functions for policy making. Furthermore, perceived changes in income and income stability are significantly correlated with environmental concern. Farmers perceiving income increases associated with oil palm cultivation are also more environmentally

[10] Figure 2-6 in Appendix 1 shows the distribution of the construct of environmental concern.

concerned indicating that these farmers are aware of the trade-off between economic and ecological functions delivered by oil palm.

Table 2-4 Spearman' correlations between perceived ecosystem functions and environmental concern

Ecosystem function	Environmental concern r_s	p-values
soil fertility	-0.1799	0.000
erosion prevention	0.0048	0.891
water availability	-0.1506	0.000
water quality	-0.0957	0.006
temperature regulation	-0.0104	0.766
bird diversity	-0.0574	0.101
Insect diversity	0.0019	0.957
pest control	0.0512	0.144
income	0.0732	0.036
income stability	-0.0697	0.046
well being	-0.0194	0.581
food availability	-0.0079	0.821
N=816		

Note: The sample size is reduced to 816 since one farmer did not respond to the statements of the scale to measure environmental concern.

2.8 What factors determine farmers' concern for the environment?

To examine factors that influence environmental concern amongst oil palm smallholders, we estimate the following model by ordinary least squares (OLS):

$$EC_{iv} = \beta_1 + \beta_2 H_{iv} + \beta_3 V_v + \alpha_v + \varepsilon_{iv} \tag{2}$$

where EC_{iv} represents the environmental concern of farmer i in village v. H captures household head and household level characteristics, V is a vector of village characteristics, while α_v are village fixed effects to control for unobserved heterogeneity amongst villages, and ε is the error term. Standard errors are clustered at the village level to account for geography related heteroscedasticity (Cameron & Miller, 2013; Deaton, 1997).

Table 2-5 presents the results. As hypothesized, we find a positive and significant association between the connectivity to nature and environmental concern.[11] This finding is in line with studies, which show that biospheric values, as reflected in the extent to which an individual believes to be part of nature, are a strong driver of the development of environmental concern (Dutcher et al., 2007; Martin & Czellar, 2017; Wesley Schultz et al., 2004). In turn, persons with higher environmental concern have been shown to be more likely to eventually adopt sustainable behaviors (Van der Werff et al., 2013). Our results also suggest that farmers who increase the share of their area under oil palm, tend to be less concerned about the environment.

Regarding village characteristics, we find that farmers living close to the forest show significantly lower concern about the environment than those who live further away. This might be explained by the fact that access to natural resources makes negative environmental effects of oil palm cultivation less noticeable, as also confirmed by our findings in Table 3. These observations contradicts the idea that with geographical proximity to nature, individuals are more concerned about the environment (Beery & Wolf-Watz, 2014). Having a river in the village, however, is positively and significantly associated with environmental concern, highlighting the water-related issues perceived by farmers (e.g. water quality and pollution) (Merten et al., 2016). This is consistent with our finding in Table 2-3, which indicates that the presence of rivers is likely to be correlated with the perception that water quality decreases with oil palm. Furthermore, our results suggest that as the share of households cultivating oil palm in the village increases, farmers' concern for the environment increases as well. This may be explained by the fact that the negative effects associated with oil palm are more pressing in these villages (Clough et al., 2016; Dislich et al., 2016). Similarly, experiencing a drought in the village increases farmers' concern for the environment. This finding is not surprising, since it is commonly the case that when individuals face a natural shock, they become more concerned about the environment (Olofsson & Ohman, 2006). We further observe that farmers living in better-off villages are characterized by higher levels of environmental concern. This is in line with previous studies

[11] Connectivity to nature is measured on a scale of 1 to 7, where higher values reflect an individual's perception to be embedded in nature. We present an illustration to the farmers that help them to select their perceived connectivity with nature (see Figure 2-5 in the Appendix 1).

that have shown that environmental concern increases with economic development and income (Diekmann & Frazen, 1999; Franzen & Meyer, 2010). The main explanation for this phenomenon is that the protection of the environment may be considered as a superior good, for which demand rises over-proportionately with income increases (Diekmann & Frazen, 1999).

Table 2-5 Determinants of Environmental concern

	Environmental concern
Household head characteristics	
Age (years)	-0.050 (0.049)
Years of education	0.029 (0.041)
Relation to nature[1]	0.030*** (0.008)
Household characteristics	
Total hectare oil palm managed	-0.003*** (0.001)
=1 if migrate from outside Sumatra	-0.014 (0.021)
Village characteristics	
=1 if near to peatlands	-0.016 (0.010)
=1 if near to forest	-0.156*** (0.016)
=1 if there is a river in the village	0.042*** (0.014)
Share of households cultivating oil palm	0.047**(0.022)
=1 if experience a drought in the past three years	0.033***(0.006)
Village wealth index	0.491***(0.034)
Village fixed effects	Y
Constant	0.329***(0.052)
N=816	

Note: Standard errors are cluster-corrected at village level, shown in parentheses.
The number of observations is reduced to 816 since one farmer did not respond to the statements for the construct of environmental concern.
[1] Measured on a scale of 1 to 7 where higher values reflect and individual's perception to be embedded in nature.
Six village dummies were dropped due to multicollinearity with the six village characteristics in the model.
* p < 0.1, ** p < 0.05, *** p < 0.01

2.9 Conclusion

This study aimed at exploring perceived ecosystem functions of oil palm and the extent to which farmers are concerned about the environment. With the exception of habitat functions (bird and insect biodiversity), the findings of this study show that farmers' perceptions are in line with systematic studies that have reviewed and quantified the ecosystem functions of oil palm (Clough et al., 2016; Dislich et al., 2016). On the one hand, we find a pattern among farmers to perceive an increase of provisioning services which can be explained by the economic benefits from oil palm cultivation. On the other hand, we observe that regulating services are perceived to decrease (or to remain constant). In particular, the perceived soil fertility, water availability and water quality show a pronounced decrease compared to other regulating services. Our study further shows that these regulating services have a positive correlation with environmental concern. At the same time, farmers perceiving an increase in income are also likely to be more concerned about the environment. This suggests that farmers are aware of the economic-ecological trade-offs associated with oil palm cultivation. However, as shown in other studies, farmers favor the conversion of forest to oil palm cultivation even though they appear concerned about the environment (Therville et al. 2012; Feintrenie & Levang 2009; Feintrenie et al. 2010).

Based on our study, we infer that farmers with stronger biospheric values appear to be more concerned for the environment. In addition, proximity to forest and peatlands, although being threatened by the expansion of oil palm, do not necessarily lead to higher concern for the environment. A possible explanation might be that farmers close to these natural environments may experience less of the negative impacts of oil palm. Our results have shown that proximity to forests, peatlands, and the number of native trees growing in the oil palm plantations positively influences perceived bird and insect diversity. This suggests positive spillovers of biodiversity from neighboring natural environments, like remnant forest. In line with this, we find that as the share of households that cultivate oil palm increases in the village, farmers tend to be more concerned as they may experience more of the negative environmental effects of oil palm. At the same time, farmers who manage larger oil palm plantations themselves, tend to be less concerned, *ceteris paribus*.

Overall, we conclude based on our findings that farmers show their concern about the environment, and that they perceive a decrease of important ecosystem functions (e.g. soil fertility, water availability, water quality). The perceived increase of provisioning services might outweigh farmers' ecological motives to conserve areas with high biodiversity value. Policy makers should design policies that provide alternatives of income diversification together with strategies to conserve biodiversity areas or promote environmentally-friendly practices. Environmental programs that aim at increasing the knowledge on biodiversity may create higher values towards these ecosystem functions among the local population. Finally, further research on the connection of environmental concern with pro-environmental behavior can provide insights on the intrinsic motivations that farmers have towards environmental conservation.

2.10 Appendix 1

Table 2-6 Summary statistics of the households

	Mean	Std. deviation	min	max
Household head characteristics				
Age (years)	49.52	10.45	23	80
Years of education	7.53	3.61	0	18
Total hectare oil palm managed	4.45	6.16	0.5	105
=1 if migrate from outside Sumatra	0.52	0.50	0	1
Relation to nature[1]	4.95	1.31	0	7
Plot characteristics				
=1 if at least one plot has ground vegetation	0.21	0.40	0	1
=1 if at least one plot has clay soils	0.20	0.40	0	1
Slope on average[2]	1.97	1.09	1	5
Age of the plantation (years)	14.72	6.55	0	37
Number of trees per ha	3.43	26.76	0	503
Village characteristics				
=1 if drinking water is from a well	0.81	0.40	0	1
=1 if near to peatlands	0.14	0.35	0	1
=1 if the village is near natural forest[3]	0.14	0.34	0	1
Share of households cultivating oil palm	0.69	0.20	0.32	0.97
=1 if experience a drought in the last 12 months	1.88	0.47	0	2
Village wealth index[4]	0.24	0.18	0	1
Observations	817			

Note: [1] Measured on a scale of 0 to 7, where higher values reflect an individual's perception to be embedded with nature.

[2] Measured on a scale of 0 to 7, where higher values represent a 10° degree on the slope

[3]Defined as on the edge or surrounding by the forest

[4] We construct a factor with seven variables at village level. Internal validity was confirmed with Cronbach's alpha (ρ=0.764).

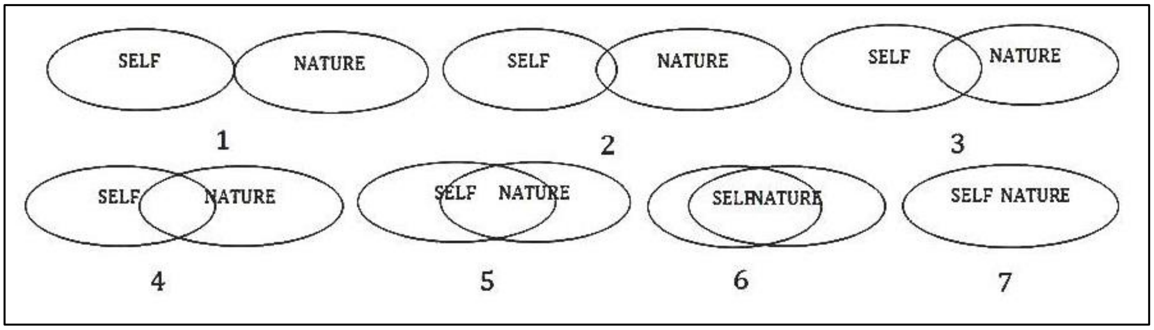

Figure 2-5 Connectivity to nature

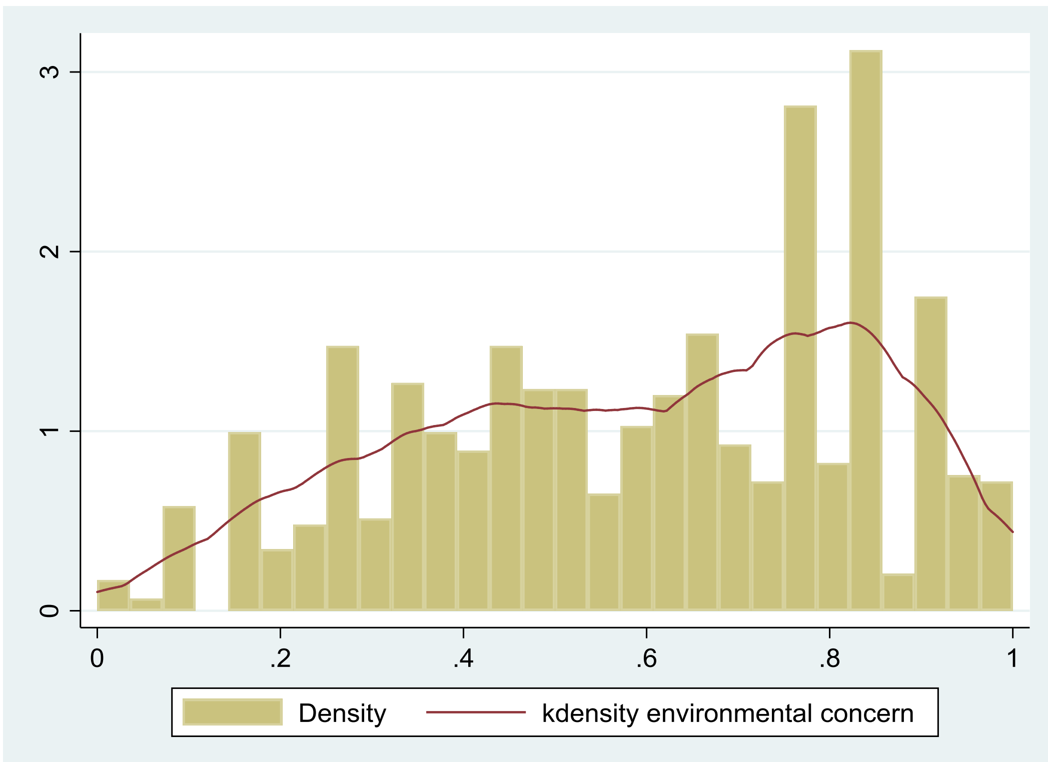

Figure 2-6 Distribution of the scale for environmental concern

Table 2-7 Evaluation on the subjective values of ecosystem functions

	Mean	Std. Deviation
1. For me, having improved soil fertility is…	4.874	0.375
2. For me, having less soil erosion is…	4.253	0.800
3. For me, experiencing less water availability on my land is…	4.529	0.804
4. For me, experiencing higher water quality is…	4.471	0.667
5. For me, experiencing warmer temperature on my plantation is…[1]	4.410	0.838
6. For me, having less pests and diseases in my oil palms is…	3.134	1.553
7. For me, having more bird diversity on my oil palm plots is…	4.065	0.819
8. For me, having more insect diversity on my plots is…	2.391	1.101
9. For me, having a higher income is…	4.763	0.572
10. For me, having a more stable income is…	4.308	0.793
11. For me, improving the well-being of my family is…	4.532	0.639
12. For me, having nutritious food available for my family is…	4.259	0.754

Note: Measured by the Likert method on a scale of 1 to 5, where 1 = extremely bad, 2= slightly bad, 3 = Neither good or bad, and 5 = extremely good.

[1]statement was reversed for the analysis.

3 Tree planting adoption among oil palm farmers: the role of perceptions and intentions

Abstract

We address the question of how tree planting in oil palm plantations can be promoted among smallholder farmers and which psychological mechanisms mediate adoption. Guided by social-psychology theories we designed and implemented a Randomized Controlled Trial (RCT) in Jambi Province, Indonesia, a global biodiversity hotspot. We test two environmental policies. The first policy tries to close knowledge gaps by providing information about tree planting in oil palm plantations. The second policy tries to overcome missing access for seed material by distributing seedlings for free additionally. We look at the causal effect of these two policies on the change of perceptions towards ecosystem functioning from tree planting in oil palm, intention to plant and actual adoption of tree planting. Data of perceptions and intention was collected right after the intervention. Actual tree planting adoption was collected six months later. Intent-to-treat effects indicate that both interventions have a positive and significant effect on these outcomes. In addition, we examine if perceptions and intention are mediators that help to explain the causal effects of the interventions on actual adoption. We employ a mediation analysis to observe this relation. Our results suggest that perceptions and intentions fully explain the effect of providing information and partially explain the effect of the combination of information and additional seedlings delivery for free on actual adoption. These findings indicate that overcoming structural barriers is critical to adoption of technology. Furthermore, these results provide evidence that psychological mechanisms, such as reflected in perceptions and intentions, are important channels to influence adoption decisions.

Keywords: tree planting, oil palm, RCT, perceptions, intentions, Indonesia

3.1 Introduction

Conversion of land into intensive agricultural systems is a major threat to biodiversity and degradation of ecosystem services (Foley et al., 2005). Particularly, oil palm cultivation is rapidly expanding across the tropics leading to global environmental concern on the account of biodiversity and ecosystem functioning reduction (Carter, Finley, Fry, Jackson, & Willis, 2007; Corley & Tinker, 2016). Oil palm is one of the most important vegetable oils and given its multiple uses it is termed as *"flexcrop"* (Alonso-fradejas, Liu, Salerno, & Xu, 2015). The processed palm kernel oil (PKO) and crude palm oil (CPO) are used as edible oil for cooking, margarine, confectionery fat, but also for soaps, detergents, pharmaceutical products, and cosmetics (Corley & Tinker, 2016). Likewise the empty fruit husks and palm oil mill effluent (POME) is used for power generation at the oil palm mills, and the fiber is processed for different products such as paper or furniture (Alonso-fradejas et al., 2015). This flexibility, combined with a relatively low price in international markets results in a comparatively high demand for oil palm products, compared to other major oil crops (Carter et al., 2007). Oil palm is largely grown by private companies in plantations that sometimes exceed 20,000 ha, mostly concentrated in Indonesia and Malaysia (CBD, 2015). Oil palm is also produced among smallholders as the return to labor is high (e.g. compared to rubber, the main alternative crop in these two countries) and the trees have a long economic lifespan (Byerlee et al., 2017). On the one hand oil palm cultivation thereby leads to higher welfare and food security among smallholder farmers. On the other hand it is associated with negative environmental impacts (Euler et al., 2015).

While it aims to increase the technical efficiency of production, the shift to a monoculture system, such as that of oil palm, reduces important ecosystem functions that can potentially affect human well-being (e.g. water availability, soil fertility, pollination, temperature regulation, etc.) (Dislich et al., 2016). At present, tropical biodiversity is facing an unprecedented threat driven by forest transformation into such intensive agricultural systems (Burgess et al., 2012; Clough et al., 2016; Fitzherbert et al., 2008). Among tropical countries, Indonesia has the second highest rate of deforestation (Margono et al., 2012). From 2000 to 2012 approximately 6 million hectares of primary forest were lost (Margono et al., 2014). At the same time, monoculture timber, rubber, and oil palm plantations have been rapidly expanded (Burgess et al., 2012). In the period between 1961 and 2016 the oil palm cultivated area increased 106 fold reaching about 9 million hectares (FAOSTAT, 2018). Today, Indonesia is the world's leading producer of palm oil accounting for 53 percent of global production (FAOSTAT, 2018). Current investment plans from the Indonesian government indicate that palm oil area and production levels are likely to increase in the future (Coordinating Ministry of Economic Affairs, 2011). This scenario calls for policy instruments that promote sustainable practices that reconcile ecological and economic functions in oil palm plantations.

Biodiversity enrichment of monoculture systems can restore important ecosystem functions (Klasen et al., 2016; Teuscher et al., 2016).[12] In monoculture oil palm systems, biodiversity enrichment can be achieved by the integration of native trees in the plantation. This can provide habitat for pollinators, reduce soil erosion, improve water conservation and stimulate bird activity, which act as seed dispersal agents (Chazdon, 2008; Teuscher et al., 2016). While there is little empirical evidence on the performance of tree planting in oil palm, a recent biodiversity enrichment experiment in Sumatra shows that at an initial stage of one year after planting, native trees have a positive effect on abundance and diversity of birds and invertebrate communities at the plantation scale (Teuscher et al. 2016). After two years of establishment, the researchers find positive effects on yields per oil palm on and adjacent to the experimental plots. Furthermore, based on a survey of 120 oil palm farmers in Jambi Province, Sumatra Teuscher et al. (2015) show that abundance and diversity of birds increases with the number of native trees maintained on oil palm plantations, which however comes at the cost of farmers' revenue. Overall, this evidence supports that biodiversity enrichment is a promising practice to reconcile economic and ecological trade-offs in an impoverished biodiverse plantation such as oil palm (Gérard et al., 2017). Yet, there is limited evidence on how best to promote the planting of multi-purpose native trees in smallholders' oil palm plantations.

In the context of Indonesia, environmental education was introduced into agricultural training programs in the country, however, it appears that knowledge and environmental-

[12] Earlier research on biodiversity conservation in oil palm plantations also shows that the management of ground vegetation, conservation of forest fragments inside the plantation or having forest at the edge of the plantation have positive effects on species richness (Azhar et al., 2015; Edwards et al., 2010; Fitzherbert et al., 2008; Koh & Wilcove, 2008).

friendly techniques were not well diffused and adopted among farmers (Martaamidjaja & Rikhana, 2001). Among the reasons are that information is complex and not properly conveyed through informal farmer-to-farmer communication (Woittiez et al. 2017; Feintrenie et al. 2010; Feder et al. 2004). This indicates that environmental extension programs should be designed in a way to facilitate adoption. Furthermore, in the case of oil palm, qualitative studies show that the perceived economic gains from this crop are higher than the economic gain from other agricultural systems, e.g. rubber agroforestry (McCarthy et al. 2012; Feintrenie & Levang 2011; Feintrenie & Levang 2009; Clough et al. 2016; Therville et al. 2012; Feintrenie et al. 2010). Indicating that while farmers favor conservation areas and recognize the benefits from agroforestry, they are also willing to convert these areas into a more profitable production system, suggesting that environmental concerns often come secondary to economic interests (Feintrenie et al. 2010; Therville et al. 2012; Clough et al. 2016). This highlights the importance of designing interventions that combine biodiversity enhancement and economic benefits. Considering that smallholders are increasingly adopting oil palm in Indonesia, and that only few forest patches remain in Jambi Province, protecting this biodiversity is crucial to maintain important ecosystem functions (Clough et al., 2016). In addition, as described earlier, Indonesia is the largest oil palm producing country, hosting large biodiverse rainforest (FAOSTAT, 2018; Koh & Wilcove, 2008). Therefore, it becomes even more important to induce native tree planting in oil palm among smallholder farmers.

To promote tree planting in oil palm, we follow social-psychology theories which proposes that attitudes, perceptions and intentions determine the adoption of pro-environmental behaviors. However, this relation has been less examined in the context of agricultural technology adoptions, particularly on tree planting adoption (Bamberg & Moser, 2007; Klöckner, 2013; Meijer et al., 2014; Meijer, Catacutan, Sileshi, & Nieuwenhuis, 2015). We find some evidence provided by Meijer et al. (2015a) and Zubair & Garforth (2006). Both studies follow the theory of planned behavior to predict tree planting adoption. The former study evaluates the behavioral intention to plant trees among farmers in Malawi and finds that positive attitudes and intentions are associated with a higher probability of an actual adoption of this strategy. The latter study suggests that perceived economic gains from trees may increase adoption among smallholder farmers in Pakistan. Similar findings are highlighted by Ndayambaje et al. (2012) who conclude that farmers’ motivations to plant trees are influenced by economic gains rather than by environmental benefits in Rwanda. These studies however have relatively small sample size and employ cross-sectional data analysis and cannot statistically claim causality. Furthermore, little effort has been made to examine which policy instruments are effective in promoting tree planting in monoculture plantations. To the best of our knowledge, with one exception, experimental evidence only comes from analyzing the effects of Payments for Ecosystem Services (PES) on tree planting adoption (Cole et al., 2010; Jack et al., 2013; Leimona et al., 2009). Yet, these studies only shed light on interventions including financial rewards, without looking at other motives or evaluating other policy instruments.

This study fills this gap by evaluating the effect of two environmental policies to encourage adoption of native tree enrichment in oil palm plantations. The policies address knowledge gaps by providing information about this practice through a movie and an illustrative manual. This informational intervention is based on the assumption that farmers lack knowledge on the benefits and handling of the new technology, in our case tree planting in oil palm. In the second intervention, structural barriers are addressed by additionally distributing free seedlings of native trees. This structural intervention is based on the assumption that (in addition to information barriers) farmers face structural barriers that prevent adoption. We implement a randomized controlled trial to estimate causal inferences. Our study area is Jambi Province, on the island of Sumatra, Indonesia. Jambi Province is a biodiversity and oil palm hotspot. The novelty of our study is that we look at the underlying mechanisms of adoption, specifically studying how our interventions shape perceptions, intentions, and eventually adoption.

The remainder of this paper is organized as follows: Section 3.2 presents the theoretical framework. In a next step, we introduce the experimental design and data in Section 3.3. Section 3.4 provides the econometric approach. We discuss and present the results in Section 3.5. We conclude in Section 3.6.

3.2 Theoretical Framework

We define pro-environmental behavior as "*the behavior that harms the environment as little as possible, or even benefits the environment*" (Steg & Vlek 2009, p.309). In this study we refer at the adoption of tree planting in oil palm as a pro-environmental behavior. Existing studies show that pro-environmental behaviors are conditioned on intrinsic factors, (i.e.

motivations, moral values, self-image, attitudes, etc.) and extrinsic factors (i.e. characteristics of the adopter, environment) under which these behaviors are performed (Barr & Gilg 2007; Steg et al. 2014; Ray 2016). The idea is that an individual will evaluate the perceived costs and benefits of adopting such behaviors, considering also social norms and perceived control (Ajzen, 1991; Steg & Vlek, 2009). This decision, is a cognitive process shaped by knowledge, information exposure and contextual factors (Ajzen, 1991; Steg et al., 2014). Social-psychology theories suggest that the antecedent knowledge an individual has about the benefits, use and cost of the technology shape perceptions and intentions, and eventually drive adoption (Campos et al., 2017; Hansson, Ferguson, & Olofsson, 2012; Klöckner, 2013; Meijer et al., 2015; Ndayambaje et al., 2012; Rogers, 1983; Sood, Paul, Head, Sood, & Mitchell, 2004). However, individuals are also constrained by the cost and structural barriers associated with the adoption of new behaviors (Bamberg, 2003; Steg & Vlek, 2009). For example, individuals may not be engaged in recycling without the facilities or they might not adopt sustainable consumption patterns without adequate market supply and prices of goods that comply with this (Steg & Vlek, 2009).

The understanding of these underlying factors is important to steer a change in behavior. Especially in the case where rewards or incentives are no longer present, it is essential to internalize the motivations to sustain the behavior (Osbaldiston & Sheldon, 2003). Therefore, the design of policy instruments aiming at changing behaviors should identify the relevant factors that prevent its adoption (Graumann, 2003; Klöckner, 2013). In this line, Steg and Vlek (2009) suggest if behaviors are linked to attitudes, interventions should be framed to change those attitudes or if there are structural barriers that strongly constraint adoption, interventions should be designed to remove those. In this context, information provision is an effective mechanism to change attitudes or perceptions, while structural changes reduce costs associated with adoption.

Figure 3-1 illustrates the theoretical framework of this study. Based particularly on the findings from Steg & Vlek (2009) and Meijer et al. (2014), we follow that the characteristics of an individual, the environment and the technology to be implemented create knowledge, new experiences and perceptions that in turn will shape intentions, and directly affect actual behavior. The hypothesized effects of two types of interventions tested here are:

1. information provision can induce a positive and significant change in perception and intentions, but the effect on actual behavior may be limited
2. information provision combined with a structural intervention can help to overcome barriers to adoption and induce a change in actual behavior
3. perceptions and intentions mediate the effect of the informational and structural intervention to explain actual behavior

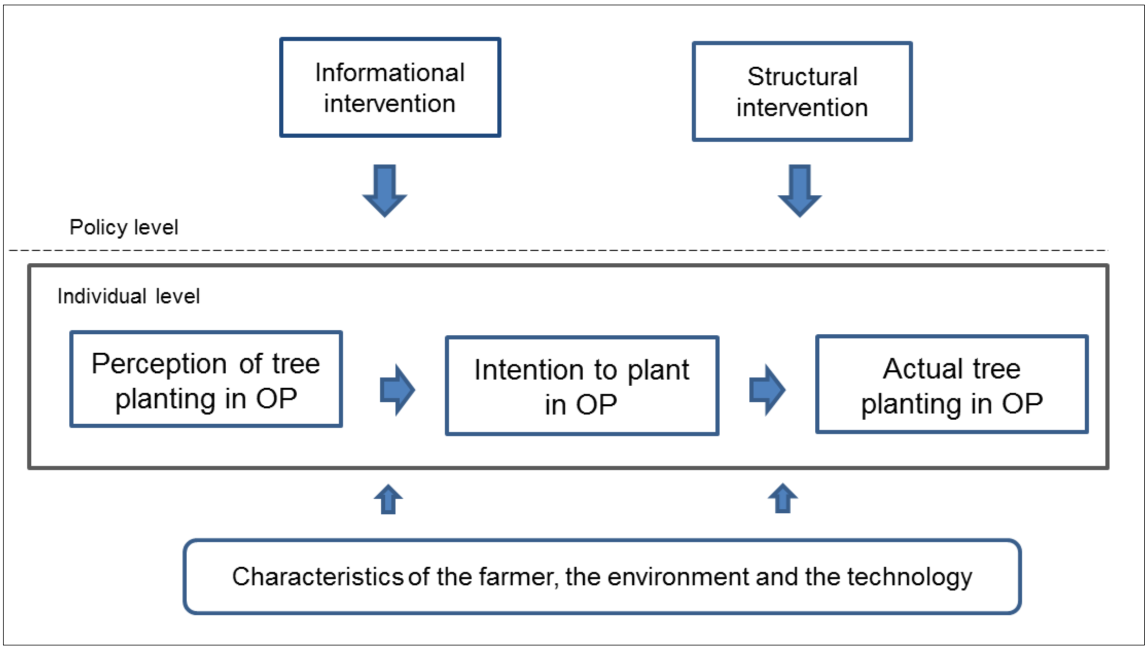

Figure 3-1 Conceptual framework
Note: Adopted from Meijer et al. (2014) and Steg & Vlek (2009)

3.3 Experimental Design and data

3.3.1 Research area

Our research was carried out in Jambi Province, Sumatra Indonesia within the scope of the Collaborative Research Center 990 "*Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation System*".[13] The province of Jambi has experienced a rapid transformation of lowland rainforest into monoculture oil palm and rubber plantations

[13] The CRC 990 is a multi-interdisciplinary project that aims to assess ecological and socioeconomic effects of land use transformations in Jambi Province (Drescher et al. 2016). It is a collaboration between the University of Göttingen in Germany and University of Bogor, University of Jambi and Tadulako University in Indonesia.

(Drescher et al., 2016). It is a hotspot of oil palm cultivation and biodiversity loss. In the period of 1996 to 2014, the oil palm cultivated area is estimated to have expanded from 150,000 hectares to 590,000 hectares large (Gatto et al. 2015; Drescher et al. 2016), while by 2013 only 30% of total area in Jambi was still covered by rainforest (Drescher et al. 2016). The oil palm boom in Jambi started in the late 1980s with the establishment of state-owned large plantations followed by private companies (Euler et al. 2016). It is associated largely with the oil palm transmigration program (Rist et al. 2010; Euler et al. 2016; Feintrenie et al. 2010). This program sponsored families from Java to migrate into less populous areas such as Sumatra to boost rural development (Fearnside, 1997). These migrant families received land, credit and technical support. The oil palm management is therefore standard and the plantations have a homogenous structure, giving little space for other crops or trees to plant. In traditional villages, farmers are gradually adopting oil palm, yet most of them continue cultivating rubber as their traditional main agricultural crop (Gatto et al. 2015; Euler et al. 2016). Farmers also cultivate complex agricultural systems such as jungle rubber, which is a mix of trees with rubber trees. Thus, it is more likely that farmers in traditional villages have more experience and knowledge with tree planting (Teuscher et al., 2015).

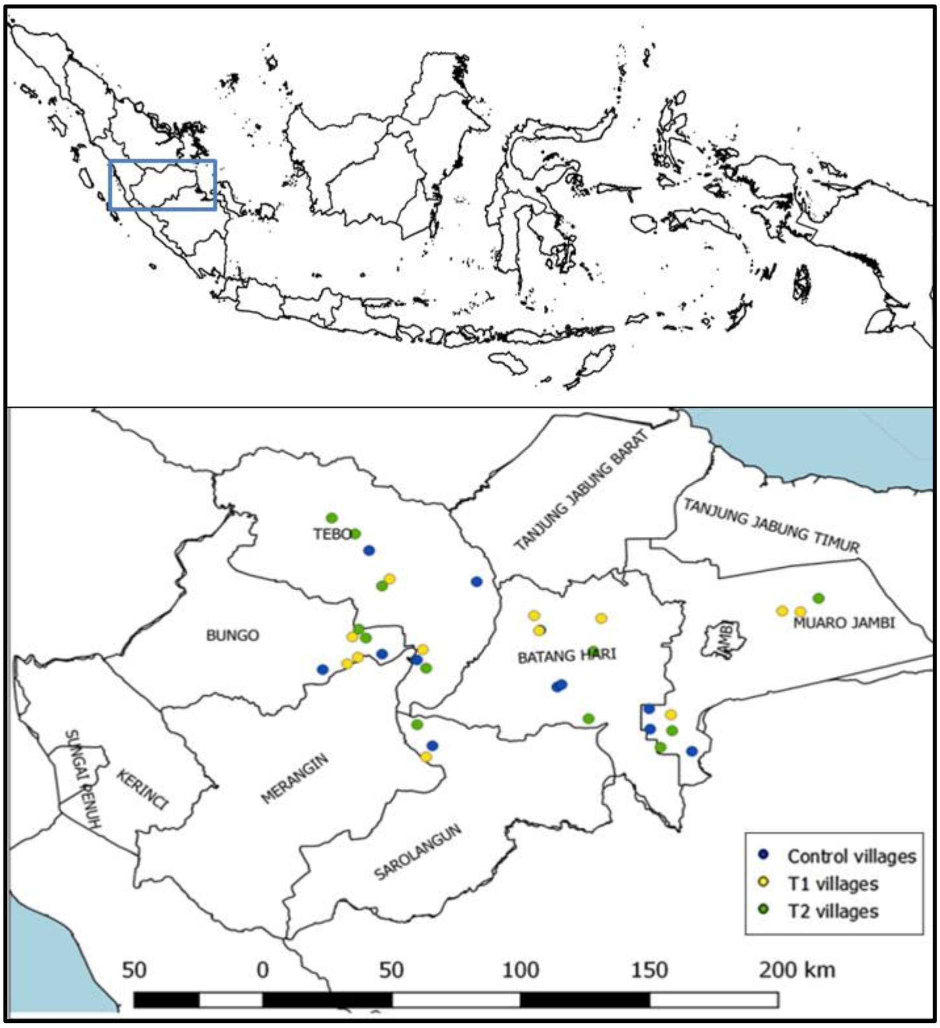

Figure 3-2 a) Location of Jambi in the Island of Sumatra and b) sampling villages in Jambi Province

3.3.2 Sampling procedure

In total, our sample includes 36 villages in five districts (Muaro Jambi, Tebo, Sarolangun, Batanghari and Bungo) (See Figure 3-2). Our selection includes transmigrant and local villages to account for the heterogeneity of oil palm management between the different types of villages in Jambi Province. 27 villages were randomly chosen from a list of transmigration villages drawn from a national village census (PODES 2008) where more than 70 percent of the households report oil palm cultivation as the main economic activity.

We lowered the threshold to 30 percent in traditional villages given that the majority of the households are engaged in rubber cultivation, and slowly are adopting oil palm (Zen et al. 2005). We identified 9 local villages under this criterion. We complement village level data with a village survey collected in September 2015 to gather information on extension services and access to seedlings.

We conducted a baseline survey from October to December 2015. Our data includes independent oil palm smallholder farmers selected through a multi-stage random sampling procedure. This means that our sample does not include farmers with contractual ties to companies. We randomly selected 22 to 24 farmers per village. When one farmer was not available, we substituted him with the following farmer from the sampling list. In total, we interviewed 817 households. We collected detailed information on oil palm management, tree planting activities, environmental perceptions, subjective expectations and socio-economic data. The questionnaire was pre-tested with the help of one local translator in four villages which are not included in the sample. After pre-testing, an intensive theoretical and practical training was given to a group of students (12 in total) from the Universities of Jambi (UNJA) and Bogor who assisted with the household survey collection.

The interventions (see Section 3.3.4) were implemented from February to March 2016. Afterwards a short follow-up survey was collected to capture immediate effects on perceptions and intentions. 745 farmers were interviewed by nine assistants. Finally, an endline survey was carried out from October to December 2016. The same survey as in the baseline was implemented with a team of 12 assistants while about 90 percent of farmers from the baseline sample were found. This provides data, from the endline survey, available for 738 farmers.

3.3.3 Randomization approach

Treatment allocation was performed at village level. Villages were randomly assigned by stratification to two treatment arms and one control group, each group containing 12 villages. As stratification variables, we used the share of oil palm farmers in the village (cut-off 73.5%), access to tree seed markets (=1 if yes) and type of village (=1 if traditional). To test for balance between the groups, we conduct 45 tests of mean differences and Kolmogorov–Smirnov tests (see Table 3-6 in Appendix 2). Household size and cutting trees in oil palm were statistically different between treatment groups at the 5 percent and 1 percent level accordingly. To further explore balance, we provide Kolmogorov–Smirnov tests that assume under the null hypothesis that the sample is drawn from the same distribution.

The results of this test show that household size is only statistically significant between treatment groups at 5 percent level. Given the random chance of errors, this supports the idea of balance in our random allocation (Bloom, 2006; Duflo, Glennerster, & Kremer, 2008; Morgan & Rubin, 2012).

3.3.4 Environmental informational campaign and provision of seedlings

We designed two environmental policy instruments to test the effectiveness to promote the adoption of tree planting in oil palm. Based on qualitative insights from focus groups in the research area, we find that lack of knowledge on the management of trees and missing markets on seed material inhibit adoption.[14] Furthermore, these insights show that farmers were skeptical about tree planting in oil palm due to nutrient competition and the consequent impact on yields. However, farmers mentioned that trees are beneficial for the environment and for the provision of wood and fruits. For those reasons, some farmers did not cut their remnant trees in their plots. Similarly to other studies in our research area, it was found that technical constraints and uncertain economic returns from trees may prevent actual adoption (Feintrenie et al. 2010). We considered these findings for the design of the treatments.

Treatment 1 (Henceforth, T1) is an environmental information campaign designed to close knowledge gaps on the benefits and management of tree enrichment in oil palm plantations. The campaign was designed as a video-based intervention. We filmed an eleven-minute video where, a lecturer from UNJA explained in detail the establishment and management of tree enrichment in oil palm plantations, the ecological benefits and economic risks. Based on a role model approach, the video features three testimonies from farmers that have trees in their oil palm plantations. These farmers are from Jambi and describe their experiences with tree planting in oil palm. In addition, participants of the session were provided with an illustrative manual that they could take home for future reference. This manual was designed by a local artist and describes through story-telling how Jambi Province has undergone a land use transformation and how tree enrichment could restore biodiversity in oil palm plantations.

[14] I conducted in-depth interviews and focus groups to understand farmers' experience with tree planting in oil palm in June 2015.

Treatment 2 (Henceforth, T2) combines the information campaign (as in T1) with the provision of native tree seedlings. In addition to the informational campaign, farmers received a package of six seedlings (six different species) to facilitate seed access. All six tree species are native to Jambi and well-known and valued by local people (Gérard et al., 2017; Teuscher et al., 2016). We delivered three fruit trees ("Jengkol" (*Archidendron pauciflorum)*, "Durian" (*Durio zibethinus)* and "Petai" (*Parkia speciosa)*), one natural latex ("Jelutung" (*Dyera costulata*)), and two timber trees ("Sungkai" (*Peronema canescens*) and "Meranti" (*Shorea leprosula*)).[15] In addition to the market goods produced by these trees (e.g. fruits, timber, natural latex), Petai and Jengkol also function as nitrogen fixing and provide nutrients to the soil that can benefit the oil palm (PROSEA, 2016).

The interventions were performed at village level and carried out in February 2016 before the rainy season ended. With the assistance of five enumerators with a university degree, we organized and implemented the interventions through extension sessions. These sessions took place in the administrative office of the village. A list of our respondents was provided three days prior to the session to the village head. Then, the staff of the village office invited farmers through an official letter indicating that information on tree planting will be given. To ensure the attendance of assigned farmers, we send a text message to the farmers as a reminder about the session one day before. The video screening occurred during the extension session; afterwards, there was an open discussion about the content of the movie. Attendance was controlled by a list that farmers signed before or after the session. Farmers in our sample that did not attend the session were visited in their home afterwards and were provided with a manual in T1 and a manual and seedlings in T2.

3.3.5 Compliance

Compliance is ensured when all participants assigned to the interventions comply with the treatment, and when individuals in the comparison group do not take it up (Duflo et al., 2008; Newcomer, Hatry, & Wholey, 2015). In our study, none or partial compliance may have occurred at individual level. Given the design of the interventions, full-compliance can be observed only if the farmers have attended the extension session (and therefore be

[15] Scientific name in italics and local name in quotation marks.

exposed to the video screening) and received the manual in T1, and if in addition they received the seedlings in T2. During the implementation of the interventions we ensure that all participants have received a manual and seedlings where applicable (regardless if they have not attended the extension session). Therefore, we only observe non-compliance with respect to the attendance to the session. Overall, we see a rate of attendance to the extension session of 68 percent in T1 and 74 percent in T2. We do not find a statistical significant difference between treatment groups (See Table 3-1 column 4b).

Table 3-1 Attendance to the extension session

	(1)	(2)	(3)	(4)	(4a)	(4b)
	Farmers assigned to treatment	Farmers who received manual	Farmers who received seedlings	Farmers attending the video session	Compliance rate	T2-T1 p-value
T1	274	258	-	186	67%	0.384
T2	273	262	262	203	74 %	

Note: Column 4b reports p-values for a test of mean difference based on a linear regression model.

3.3.6 Attrition

As can be seen in Table 3-2, we encounter attrition at two points in time during our data collection: during the follow up and during the endline survey. In the follow-up survey, about 9 percent of farmers from the overall sample were not found. The control group reports the largest share of attrition in comparison to the treatment groups, which leads to a statistically significant difference between treatment groups and control group at the 1 percent significance level. In the endline survey, about 10 percent of farmers were not found from the baseline sample. A test of mean differences reveals the existence of a statistically significant difference between control group and T2 at the 5 percent significance level. These attrition rates are at a similar level as in other RCT studies (Pamuk, Bulte, & Adekunle, 2014). Considering the attrition in the follow-up and the in endline, data is available for 679 farmers from the 817 farmers that were interviewed in the baseline. For the analysis, our sample is reduced to 670 since we do not have complete information for 9 farmers.

Table 3-2 Attrition rates

	Farmers interviewed at baseline survey	Attrition % Follow-up	Attrition % Endline
Treatment group			
Control	270	17	11
Treatment 1	274	6	10
Treatment 2	273	4	7
Full sample	817	9	10
C-T1[1]		0.003	0.827
C-T2[1]		0.000	0.047
T1-T2[1]		0.144	0.225

Note: 59 farmers interviewed in the follow-up were not interviewed in the endline. While, 65 farmers interviewed in the endline were not interviewed in the follow-up. 14 farmers interviewed in the baseline were not interviewed in any of the sub-sequent surveys.
[1]p-values for a test of mean difference based on a linear regression.

To control for possible biases in our estimates due to differential attrition, we employ the inverse probability weights approach (Fitzgerald, Gottschalk, & Moffitt, 1997). We focus on the attrition between baseline and endline. First, we estimate probabilities of selection on observables into the endline based on a set of auxiliary variables that are associated with attrition but not necessarily with the outcome. Second, we re-estimate the probabilities excluding those auxiliary variables that explain attrition. We construct weights by the ratio of those predicted probabilities.[16] The auxiliary variables include household head and household characteristics, and a set of enumerator proxies to control for interview quality.

3.4 Econometric approach

3.4.1 Intent-to-treat (ITT)

We estimate Intent-to-treat (ITT) effects of our interventions on perceptions, intention and actual adoption. The model is specified as follows:

$$Y_{iv} = \beta_1 + \beta_2 T1_v + \beta_3 T2_v + \beta_4 X_{i,v} + u_{i,v} \quad (1)$$

Y_{iv} represents a vector of outcome variables, i.e. perceptions, intention and actual adoption decision of farmer i in village v. $T1$ = 1 if village v was assigned to receive the environmental information campaign only and $T2$ = 1 if village v was assigned to receive seedlings for free

[16] The estimated results for both probit models are given in Table 3-8 in the Appendix 1.

in addition to the information campaign. To increase the precision of our estimates, vector $X_{i,v}$ contains household characteristics and stratification variables . u_{iv} is the error term. The effects are estimated using OLS in the case of perceptions and intentions, and using logit regression in the case of the binary adoption decision. For the analysis, we employ the inverse probability weights to control for non-attrition to estimate three models.

3.4.2 Mediation analysis

We employ a structural equation model (SEM) to explore causal mediation analysis in order to find the mechanisms that explain treatment effects. Following our conceptual framework (see Figure 3.2), we test if the causal effect of the interventions on actual adoption is mediated by perceptions and intention. When conducting evaluation studies, it is recommended to explore mechanisms that explain causal effects from the interventions (Acharya, Blackwell, & Sen, 2016; Imai, Keele, Tingley, & Yamamoto, 2016). Frequently, mediation analysis draws on Baron & Kenny (1986)'s work, however it is often highlighted that this framework does not fulfill the identification assumption (sequential ignorability and conventional exogeneity). Given the randomization of treatments in our study, the assumption is fulfilled here (de Brauw, Hotz, Kumar, & Meenakshi, 2015; Imai, Keele, & Yamamoto, 2010). The mediation analysis basically examines a conceptualized mechanism through which an independent variable might affect a dependent variable through an intervening process (Lacobucci, 2008).

We estimate following two-mediator model:

$$Y = i_1 + cX + e_1, \tag{2.1}$$

$$Y = i_2 + c'X + b_1M_1 + b_2M_2 + e_2, \tag{2.2}$$

$$M_1 = i_3 + a_1X + e_3, \tag{2.3}$$

$$M_2 = i_4 + a_2X + e_4, \tag{2.4}$$

where i_i are the intercepts (and e_i the model fit errors). We are interested in $a, b, and\ c'$ which are the regression coefficients that capture the relation between the focal variables (Lacobucci, 2008). Y is our outcome of interest, X refers to the independent variables, while M_1 and M_2 represents the two mediators. a_1 and a_2 represents the relations between the independent variable and the two mediators, respectively (Hayes, 2018). With two mediators in model, we have now three mediated effects for X. This means, the effect of X to Y through M_1, the effect of X to Y through M_2, and the total mediated effect of X to Y through M_1 and M_2 (MacKinnon, Cheong, & Pirlott, 2012). It is assumed that M_1 and M_2 are causally located between the interventions and the outcomes. This means that the X would have an effect on the mediators, and in turn will have an effect on Y (Hayes, 2018). M_1 and M_2 cannot transmit $X's$ effect on Y if they are not causally located between X and Y (Hayes, 2018).

To say that a mediator is likely to have an effect it is necessary that:

1. a_i in eq 2.3 and eq 2.4 is significant, i.e., there is a linear relationship between X and M_i
2. c in eq 2.1 is significant, i.e., there is a linear relationship between X and Y
3. b_i in eq 2.2 is significant, i.e., M_i helps to predict the outcome variable Y.
4. Finally, c' in eq 2.2 is significantly smaller in size compared to c in eq 2.1.

We can then conclude that if a or b are not significant, there is no mediation, and assume that the variance of Y is attributable to the direct effect of X. If 2.1, 2.2, 2.3. and 2.4 holds, we conclude that there is full or partial mediation. This means that, the variance of Y attributable to X is explained partly by an indirect effect mediated by M. If c' is no longer significant, we assume that all the effect runs through M. M has only a partial effect when c' is smaller than c, but still significant (Lacobucci, 2008).

Figure 3-3 shows the mediation analysis explored in this study. This model has three specific mediating effects and one direct effect per each treatment. These are explained in the following way: the causal effect of T1 on adoption can be mediated through perceptions ($a_{T11}b_1$), mediated by intention ($a_{T12}b_2$), and mediated through perceptions and intention (a_{T11}*d_{pi}*b_2). The sum of these mediating effects gives the total indirect effect of T1 on actual adoption. The direct effect of T1, without the mediators, on actual adoption is observed in c'_{T1}. The sum of the direct and indirect effects will be our total effect c_{T1}.

To observe the mediation mechanism for T2, we follow the same relations as in T1. The causal effect of T2 on actual adoption is mediated by perceptions ($a_{T21}b_1$), by intention ($a_{T22}b_2$), and by perceptions and intentions together (a_{T21}*d_{pi}*b_2). The direct effect of T2 on actual adoption is observed in the bottom part of the diagram (c'_{T2}).

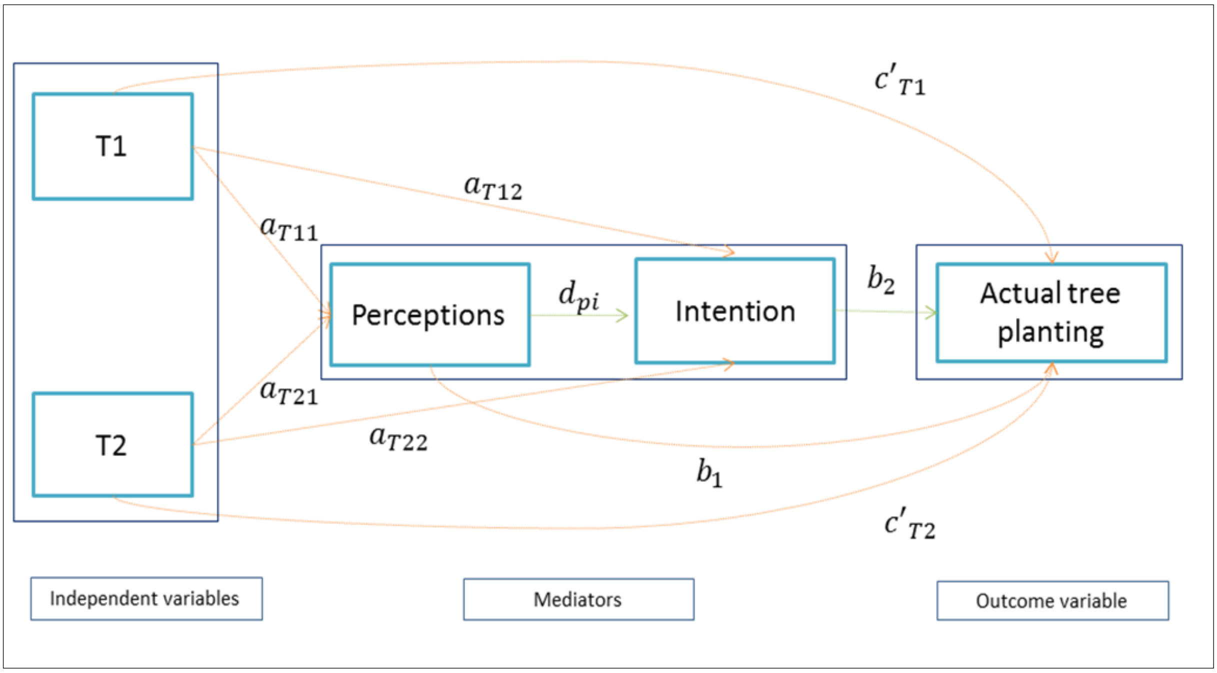

Figure 3-3 Schematic representation of mediation analysis
Note: Adapted from Hayes (2018).

3.4.3 Measurement of key outcome variables

We measure three outcomes in this study. First, we are interested in farmers' perceptions of the provision of ecosystem functions by trees in oil palm. The scale was designed according to similar studies on tree planting (Meijer et al., 2015) including 17 items assessed by the Likert method. For the analysis we constructed a total score using exploratory factor analysis. Second, the intention to plant was elicited by the subjective belief that the farmer will plant trees in his or her oil palm plantation. To elicit this information, farmers were asked to assess the probability that they will decide to plant using elicitation methods recommended by Delavande et al. (2011). Third, actual adoption was measured as self-reported tree planting in oil palm plantations. Chandon et al. (2005) suggest capturing changes in perceptions and intentions before observing actual adoption to improve the analysis of behavior. Therefore, we elicited perceptions and intentions in the follow-up survey in February 2016, shortly after the intervention was completed. Data on actual adoption stems from the endline survey, which was implemented in October 2016.

3.4.4 Perceptions of the provision of ecosystem functions by trees in oil palm

The scale employed to assess farmers' perceptions capture regulation, habitat, information and provisioning functions following the classification of Groot et al. (2002). Using their definition, an ecosystem function is "*the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly*" (Groot et al. 2002 p.394). The category of regulation functions includes those that maintain and regulate ecosystems through bio-geochemical and biosphere processes. Habitat functions provide refuge and reproduction of wild plants and animals allowing succession of biological and genetic diversity. Provisioning functions provide ecosystem goods for human consumption (e.g. food and raw materials). Information functions support cultural services such as spiritual enrichment, reflection, recreation and aesthetic experience. Table 3-3 shows each statement included in the scale with their corresponding mean value. The scale is measure on a 5-point-Likert scale where 5 represents strongly agree. As can be seen, farmers perceive that trees have positive association with regulation and provisioning functions. Similarly, on average farmers agree that trees provides habitat for bird and insect diversity. Yet, it seems that farmers do not perceive that trees provide aesthetic services in oil palm. Generally, perceptions of ecosystem functions provided by native trees in oil palm are positive. This can also be seen by the distribution across the full sample and per group in Figure 3-4, where we could observe that on average farmers assigned to the treatments have higher positive perceptions that those in the control group.[17]

We use the exploratory factor analysis to summarize all the statements in one latent factor. Through this, we assemble the statements that share a common variance into one variable. Since the statements were measured on a 5-point Likert scale, we use the Polychoric correlation. In addition, due to the large set of statements we define the loading with a Varimax rotation and retain factors with an eigenvalue greater than 1 (Yong & Pearce, 2013). Six statements did not load significantly on the factor. Internal validity was checked with help of the Kaiser-Meyer-Olkin indicator, which measures sampling adequacy (KMO=0.85) and Cronbach's alpha (α=0.8205). Values above 0.70 in both indicators are acceptable.

[17] Mean differences for each statement between control and treatment groups can be observed in Table 3-7 in Appendix 2.

Table 3-3 Perceptions of the provision of ecosystem functions from tree planting in oil palm in the follow-up

Planting native multi-purpose trees on and along my oil palm plantation …	(1) Mean	(2) Item used for Factor analysis
Regulation: *Maintenance of essential ecological processes*		
1. …increases soil fertility	3.56 (0.09)	Y
2. …decreases soil erosion	4.17 (0.06)	Y
3... increase temperature in the plantation	4.38 (0.05)	Y
4. …decreases water availability	2.11 (0.11)	Y
5. …increases water quality	4.15 (0.06)	Y
Habitat: *Providing suitable living space for wild plants and animals*		
6. …increases bird diversity	4.30 (0.05)	
7. …increases insect diversity	4.02 (0.06)	
8. …decreases the likelihood of pests and diseases in oil palm	3.46 (0.07)	Y
9. …leads to nutrient competition between trees and oil palms	3.86 (0.08)	
10. …takes too much space	3.49 (0.08)	
Information: *Providing opportunities for cognitive development*	3.52 (0.13)	Y
11. …makes my plantation more beautiful	3.52 (0.13)	Y
Provisioning: *Provision of natural resources*		
12. …increases the availability of nutritious food for my family…	3.96 (0.08)	Y
13. …is an important source of timber.	4.09 (0.10)	Y
14. …increases my income.	3.60 (0.12)	Y
15. …decreases the stability of my income	3.23 (0.08)	
16. …increases the well-being of my family	3.64 (0.12)	Y
17… increase the time that I can spend on doing other things…	3.36 (0.06)	
Total factor	4.46 (1.21)	
KMO		0.857
Cronbach’s alpha		0.820

Note: Standard deviation in parenthesis. Statements measured on a scale of 5-point Likert scale of agreement. Min-Max value for the total factor: (1.170 – 6.065).

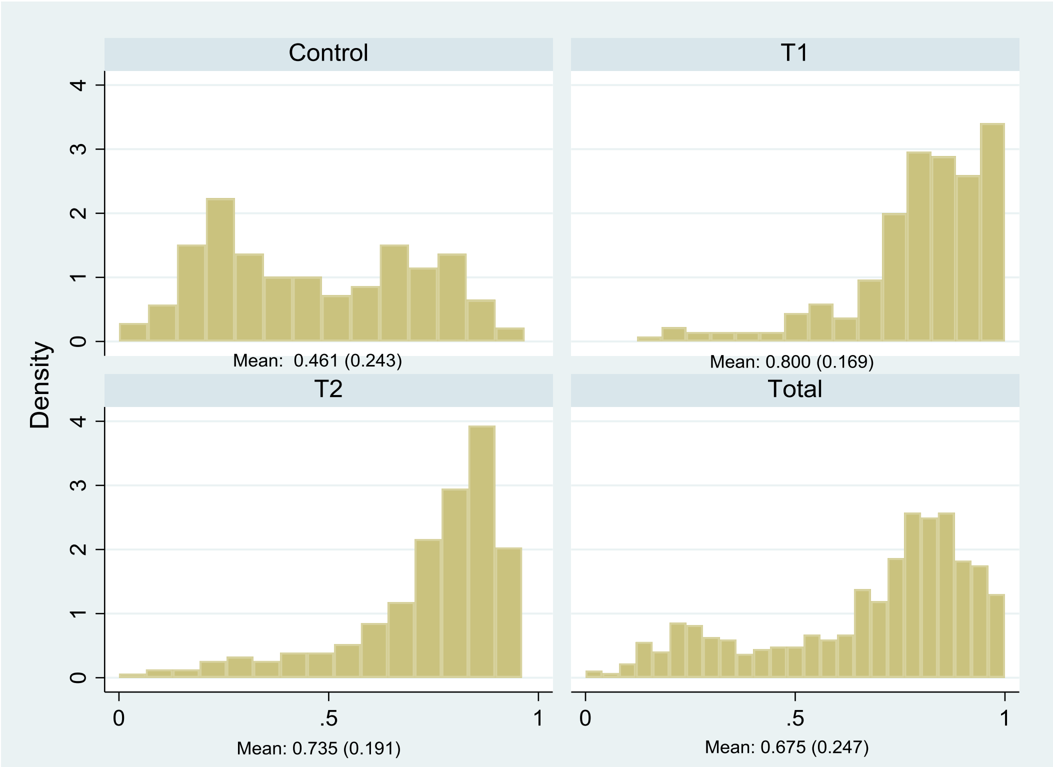

Figure 3-4 Perceptions score towards ecosystem functions by trees in oil palm

Note: The graph shows the density of the distribution of the total score of perceptions by treatment group. Below each quadrant is the corresponding mean and standard deviation in parenthesis. Sample size: 670

3.4.5 Intention to plant

The intention to plant trees is elicit by subjective expectations. A subjective expectation is the belief a person has on the probability that an event will occur in the future (Manski 2004). Conventionally, subjective probabilities have been drawn by Likert scales, open-ended questions, or binary questions (yes/no). However, these approaches are less information than estimating probabilities with the visuals aid (Delavande et al., 2010; Manski, 1990; Ray & Bhattacharya, 2004). We use beans as visual aid to capture the intention that farmers will plant trees in oil palm. For the question, farmers were given 20 beans to represent their subjective expectations. At first, we explain that the amount of beans they take will represent the likelihood that a future event will happen (Delavande & Kohler 2009). Then, we asked for their intention to plant.[18] We count and wrote down the number of beans taken by the

[18] The question asked to farmers was: "How likely do you think it is that in the next 12 months you will plant native trees within your oil palm plantation?".

farmer and, for the analysis we multiply the number by 0.05 to represent probabilities. We ensured that farmers understood the concepts of probabilities with training questions.

Figure 3-5 shows the mean distribution of the probability that farmers will plant trees in their oil palm plantations from the full sample and for each group. We observe that, on the average, farmers assigned to the treatment groups stated a higher intention to plant than farmers assigned to the control group.

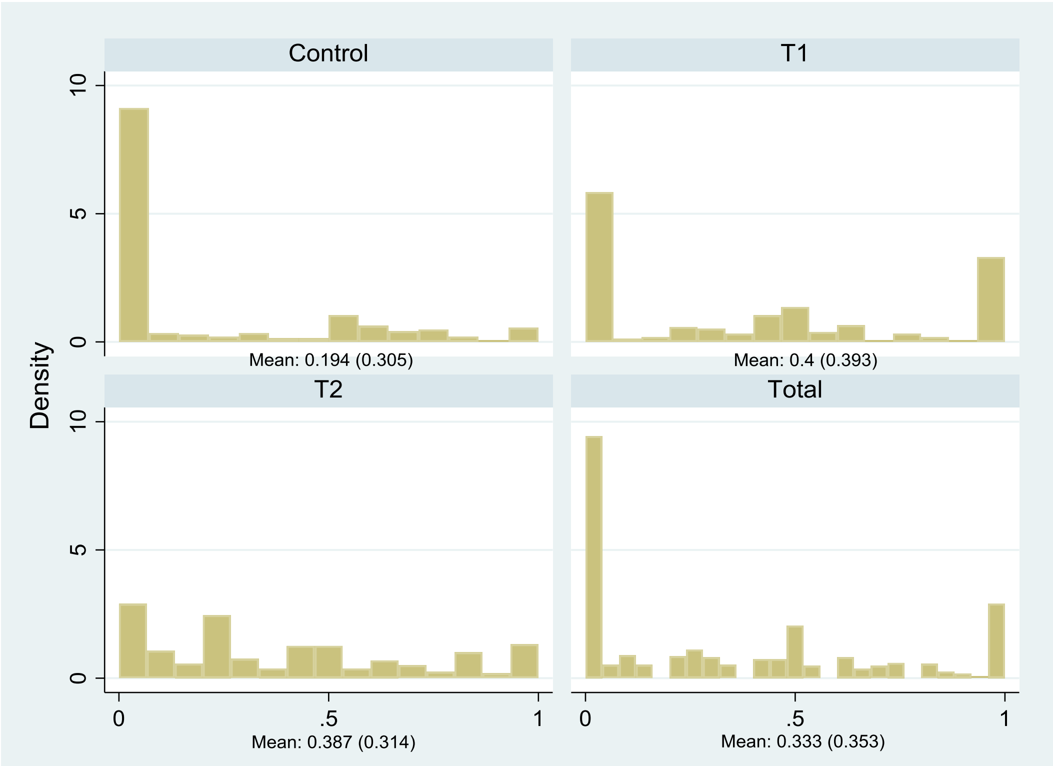

Figure 3-5 Intention to plant trees in oil palm
Note: Distribution of the subjective belief that farmer will plant trees in oil palm. Below each quadrant is the corresponding mean and standard deviation in parenthesis. Sample size: 670

3.5 Results

3.5.1 How tree planting can be promoted among smallholder oil palm farmers?

Table 3-4 reports the Intent-to-treat estimates. We observe that assignment to T1 on average increases the perception factor by 0.34 points, and assignment to T2 by 0.27 points in comparison to the control group. Intent-to-treat estimates further reveal that farmers' subjective probability that they will plant trees is 20 percentage points higher in both, T1 and T2, compared to the control group. Our findings are in line with earlier, non-experimental, studies emphasizing that informational interventions succeed in increasing the knowledge of an individual and creating awareness about a specific topic (De Martino, Kondylis, Pagiola, & Zwager, 2016; Zelenski et al., 2015). Our findings also suggest that information given through videos and illustrations seems effective to change intrinsic factors. This is consistent with other studies that employ similar methods to deliver information (Abrahamse et al., 2005; Bernard, Makhija, Orkin, Taffesse, & Spielman, 2016; Chandon et al., 2005). Yet, it is often mentioned that perceptions and intentions are difficult to measure and are subject to social desirability that could lead to over/under reporting (Clayton, 2012; Robert Gifford & Nilsson, 2014; Podsakoff, MacKenzie, Lee, & Podsakoff, 2003), even it is found that social desirability is only weakly correlated with environmental attitudes and not related to pro-environmental behavior (Milfont, 2009). To minimize potential bias in our results, we took care of the phrasing and design of the scales prior the data collection. In addition we explained to our respondents the importance of their honest answer, as it was done in other studies (Meijer et al., 2015).[19]

Column 3 of Table 3-4 shows marginal effects at means of the interventions on actual tree planting decision. We observe that farmers assigned to T1 are on average 7 percentage points more likely to plant trees in their oil palm plantations in comparison to the control group. Farmers assigned to T2 are 42 percentage points more likely to plant trees in their oil palm plantations compared to the control group. While both interventions have a significant and positive effect, the effect of T2 is significantly

[19] We adapt the scale to the local context and gave an explanation to the farmers to clarify any concept.

larger than that of T1, indicating that a change of behavior can be expected only when the circumstances under which adoption decisions are made are changed (Abrahamse et al., 2005; Steg & Vlek, 2009). This favors the idea that information in combination with structural changes are crucial to influence a behavioral change (Abrahamse et al., 2005; Bamberg, 2003; Campos et al., 2017; Steg & Vlek, 2009).

Based on these findings, we can conclude that farmers in T1 face some important barriers when it comes to the actual adoption decision, preventing them to put their intentions into practice. Another explanation is, particularly in large-scale environments such as, landscapes that are dominated by oil palm monoculture, farmers may feel that their actions will not have any contribution to the overall environmental restoration and therefore will not pursue any effort (Schmuck et al., 2003). However, some studies suggest that when individuals have high intrinsic motivations, these will be strong drivers of adoption (De Groot & Steg, 2010; Kollmuss & Agyeman, 2002; Van der Werff et al., 2013). This leads us to explore the mediating effect of perceptions and intention on actual adoption.

Table 3-4 Intent-to-Treat effects

	(1) Perceptions	(2) Intention to plant	(3) Actual tree planting
T1	0.333*** (0.028)	0.203*** (0.046)	0.070*** (0.024)
T2	0.275*** (0.028)	0.200*** (0.040)	0.421*** (0.030)
Control variables[1]	Y	Y	Y
Observations	670	670	670
R^2	0.362	0.117	
Pseudo R^2			0.236

Note: Each column is a separated weighted regression. Columns 1 and 2 show the estimated coefficient of an OLS regression. Column 3 shows marginal effects from a logit regression. Standard errors are cluster-corrected at village level, shown in parenthesis. Results for the full regressions are in Table 3.9 in Appendix 2.

[1]Control variables include household characteristics and stratification variables.

3.5.2 Do perceptions and intentions mediate the effect of the interventions on actual adoption?

As postulated in our theoretical framework in Section 3.2, we hypothesize that perceptions and intentions mediate the effect of the informational and structural intervention to explain actual behavior. We assume that both interventions will shape perceptions, then those farmers who perceived tree planting positively, would be more likely to increase their intention to plant, and then in turn would adopt tree planting in oil pam. We examine this relation through a path analysis depicted in Figure 3-6. Our focus is on estimating equation 2.2 in Section 3.4.2.[20]

In the upper part of Figure 3-6 we observe that assignment to T1, has a positive and significant mediating effect, when controlling for perceptions and intentions. This means that the indirect effect of T1 ($\beta_{indirect\ T1\rightarrow a}$=0.045***) runs through perceptions, to influence intention and then is translated into higher probability of adoption compared to the control group. However, since the direct effect ($c' = 0.135$) independent of the mediators, is insignificant we conclude that the effect of information provision is fully explained by an increase of perceptions, and an increase of intentions. A possible explanation for this result is that farmers whose positive perceptions and intentions are higher, the perceived cost, in terms or time and effort, discourage adoption, in particular since saplings were not given (Kollmuss & Agyeman, 2002). Similar findings are shown in Brauw et al. (2015), whose study explores the mediating effect of nutritional knowledge on adoption rates of orange-fleshed sweet potato. The researchers find that an increase of knowledge has a limited importance for adoption. Also shown by Bamberg & Moser (2007), information provision can influence adoption choices through perceptions and intentions. Thus, perceptions and intentions are an important intermediate step in the adoption process when only information is provided (Meijer et al., 2014).

When we look at the mediating effect of T2 on actual adoption, shown in the lower part of Figure 3-6 we observe that assignment to T2 has a positive and significant effect, when mediated by perceptions and intentions ($\beta_{indirect\ T2\rightarrow a}$ = 0.038***). The direct effect of T2 on actual adoption (${c'}_{T2}$ = 0.577***) is positive and significant, indicating that the combination of information with delivery of saplings increases the likelihood of adoption, even when the mediators are held constant. As shown by other studies, when subjective beliefs and perceptions are considered, while changing the

[20] Table 3-5 provides a summary of the estimates for the path analysis. It displays the causal direct and indirect effects of the treatments to perceptions, to intention and actual adoption.

context where decisions are made, the likelihood to adopt increases (JBolderdijk et al., 2012; Corral-Verdugo, 1997; de Leeuw, Valois, Ajzen, & Schmidt, 2015; Steg & Vlek, 2009). An alternative explanation is that farmers assigned to T2 perceive that they have control over their decisions, given that they received seedlings, and therefore adopt accordingly (Ajzen, 1991). As hypothesized, perceptions and intentions mediate the effect of both treatments. However, while we observe that the causal effect of T1 is fully mediated through a change in perceptions and intentions, the effect of T2 is only partially explained. Our path analysis shows that the additional effect of overcoming barriers is crucial for adoption of tree planting.

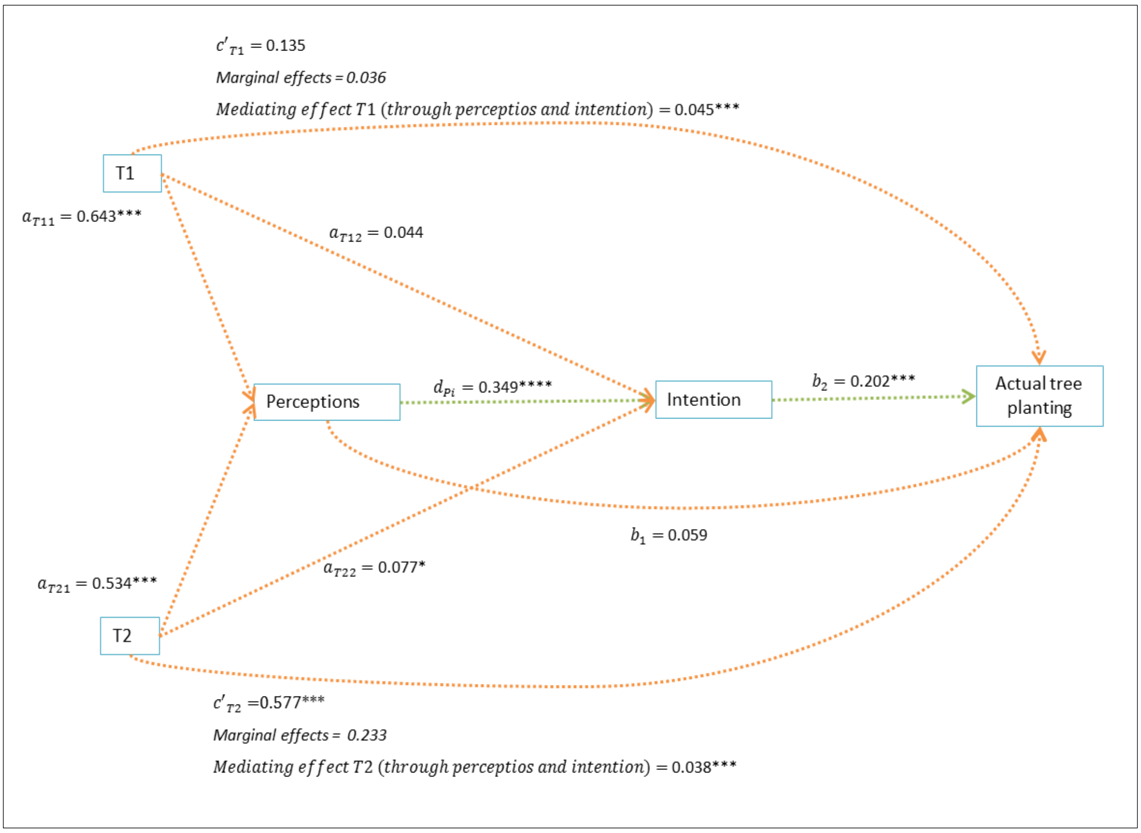

Figure 3-6 Results of a mediation analysis

Note: N=670. Estimates for each path are given in standardized form. Full estimations are Table 3.10 in Appendix 2. We control for additional baseline covariates as a robustness check. The regression coefficients are next to their respective path. Effects of T1 are shown in the upper part of the diagram, while effects of T2 are shown in the lower part. The model was performed with a Maximum Likelihood Robust (MLR) estimator in Mplus. Since the mediators are continuous variables those regressions can be interpret as in an OLS regression. The regression coefficient for actual behavior can be interpreted as in a Logit regression. Model fit: Loglikelihood user model (H0): -320.477, Akaike (AIC): 688.955, Bayesian (BIC): 797.130, Sample-size adjusted Bayesian: 720.928

Table 3-5 Summary information for the causal effects of the interventions in a serial multiple mediator model

	Consequent											
		(1)				(2)				(3)		
		Perceptions				Intention				Actual tree planting		
Antecedent		Coeff.	SE	Pvalue		Coeff.	SE	Pvalue		Coeff.	SE	Pvalue
T1	a_{T11}	0.643	0.037	0.000	a_{T12}	0.044	0.053	0.406	c'_{T1}	0.135	0.095	0.154
T2	a_{T21}	0.534	0.041	0.000	a_{T22}	0.077	0.046	0.092	c'_{T2}	0.577	0.073	0.000
Perceptions		-	-	-	d_{pi}	0.349	0.040	0.000	b_1	0.059	0.065	0.363
Intention		-	-	-		-	-	-	b_2	0.202	0.049	0.000
Constant												
		R^2 =0.364				R^2 =0.147				R^2 =0.372		

Note: Estimates are given in standardized form (see Figure 3-3).

3.6 Conclusion

The current study addresses the question of how the adoption of native trees can be promoted among small-scale oil palm farmers in Sumatra. In particular, we investigate the effects of informational and structural interventions on farmers' perceptions, intentions and actual adoption of native trees. Two key contributions are made with this study: 1) we provide experimental evidence on two environmental policies for the adoption of tree planting in oil palm; 2) we explore the causal effects of the interventions, mediating effect by perceptions and intentions, on actual planting. We show that information provision positively influences the underlying mechanisms of adoption. Yet, the joint delivery of information and a change in the structural constraints is a key element to increase actual adoption. The free distribution of seedlings in combination with information had a strong positive effect on the adoption of a biodiversity-enhancing approach. Our study has shown that information campaigns can influence farmers through modifying their perceptions and intention. For environmental programs it is important to identify the bottlenecks: if farmers have negative perceptions of a technology and/or no intention to adopt, information campaigns can be effective. But if there are other barriers, it is important to identify these in order to tailor the intervention to the specific situation.

3.7 Appendix 2

Table 3-6 Baseline characteristics and mean difference between treatment and control groups

	(1) Total	(2) Control	(3) T1	(4) T2	(5) C=T1	(6) C=T2	(7) T1=T2	(8) C=T1	(9) C=T2	(10) T1=T2
Household head characteristics										
Age of HH head	49. 52 (0.59)	49.14 (1.02)	49.62 (0.77)	49.79 (1.23)	0.708	0.687	0.909	0.946	0.838	0.677
Years of education HH Head	7.53 (0.16)	7.67 (0.21)	7.42 (0.32)	7.49 (0.26)	0.510	0.604	0.850	0.802	0.211	0.897
=1 if access to environmental education past 12m	0.076 (0.02)	0.052 (0.02)	0.084 (0.02)	0.092 (0.04)	0.325	0.380	0.870	0.999	0.983	1.000
=1 if female	0.02 (0.004)	0.03 (0.010)	0.01 (0.008)	0.01 (0.006)	0.141	0.203	0.706	1.000	1.000	1.000
Perception of trees in OP	2.15 (0.044)	2.03 (0.044)	2.28 (0.068)	2.13 (0.09)	0.004***	0.335	0.175	0.013**	0.235	0.215
Household charactersitics										
Household size (nr of persons)	3.96 (0.06)	3.93 (0.11)	3.83 (0.09)	4.13 (0.11)	0.502	0.209	0.047**	0.937	0.591	0.086**
Value of assets (in 1,000 IDR)	49,745.24 (16749.47)	32,778.05 (3473.89)	84,134.21 (48120.35)	32,011.06 (3661.573	0.295	0.880	0.288	0.875	0.987	0.927
=1 if other crops are cultivated	0.28 (0.04)	0.29 (0.07)	0.26(0.07)	0.29 (0.08)	0.732	0.997	0.754	0.998	1.000	0.998
Total land owned (ha)	5.69 (0.29)	5.68 (0.38)	5.81 (0.62)	5.58 (0.48)	0.863	0.865	0.771	0.253	0.184	0.504
=1 if homegarden	0.91 (0.03)	0.833 (0.08)	0.91 (0.03)	0.96 (0.01)	0.324	0.113	0.139	0.262	0.016**	0.919
Farms' oil palm characteristics										
Total hectare oil palm managed	4.47 (0.24)	4.42 (0.23)	4.63 (0.62)	4.29 (0.27)	0.750	0.714	0.616	0.404	0.169	0.319
Share of plots with systematic certificate	0.684 (0.05)	0.695 (0.09)	0.661 (0.06)	0.698 (0.09)	0.752	0.983	0.741	0.841	1.000	0.622
Plot age	14.83 (0.74)	15.52 (1.16)	14.40 (6.26)	14.59 (1.48)	0.501	0.626	0.920	0.014**	0.020**	0.649
Mean number of trees per hectare in OP	3.43 (0.95)	5.07 (2.57)	2.62 (0.60)	2.63 (0.90)	0.360	0.377	0.992	1.000	0.924	0.756
=1 Trees planted in OP	0.01 (0.00)	0.003 (0.003)	0.007 (0.005)	0.01 (0.006)	0.554	0.279	0.619	1.000	1.000	1.000
=1 Trees cut in OP	0.034 (0.01)	0.033 (0.01)	0.06 (0.01)	0.01 (0.01)	0.169	0.127	0.004***	1.000	1.000	0.918
Actual tree planting Endline										
=1 Trees planted in OP (Endline)	0.20 (0.032)	0.04 (0.016)	0.10 (0.027)	0.43 (0.031)	0.072*	0.000***	0.000***	0.770	0.000***	0.000***
N	817	270	274	273						

Columns (1) to (4) show mean estimates and corresponding standard errors. Columns (5) to (7) report p-values for a test of mean difference based on a linear regression model.
Columns (8) to (10) report p-values for Kolmogorov–Smirnov test (K–S test).
Stars refer to * 0.10 ** 0.05 and *** 0.01 significance level.
Standard errors are cluster-corrected at village level, shown in parenthesis.

Table 3-7 Perceptions of the provision of ecosystem functions from tree planting in oil palm in the follow-up

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Item used for the Factor Baseline	Item used for the Factor Follow-up
Planting native multi-purpose trees on and along my oil palm plantation …	N 744	Total	Control (n= 240)	Information ($T1$) (n=245)	Structural ($T2$) (n= 253)	T1-C	T2-C	T2-T1		
Regulation										
1. …increases soil fertility	744	3.56 (0.09)	2.89 (0.140)	3.78 (0.12)	3.91 (0.05)	0.00***	0.00***	0.339	Y	Y
2. …decreases soil erosion	744	4.17 (0.06)	3.99 (0.15)	4.37 (0.10)	4.12 (0.09)	0.018**	0.380	0.086*		Y
3... increase temperature in the plantation.	744	4.38 (0.05)	4.17 (0.04)	4.71 (0.05)	4.23 (0.04)	0.00***	0.369	0.00***		Y
4. …decreases water availability	744	2.11 (0.11)	2.93 (0.15)	1.55 (0.10)	1.94 (0.11)	0.00***	0.00***	0.02**	Y	Y
5. …increases water quality	744	4.15 (0.06)	3.98 (0.07)	4.50 (0.06)	3.97 (0.11)	0.00***	0.92	0.00***		Y
Habitat										
6. …increases bird diversity	742	4.30 (0.05)	4.36 (0.06)	4.50 (0.06)	4.05 (0.06)	0.143	0.00***	0.00***		
7. …increases insect diversity	743	4.02 (0.06)	4.04 (0.06)	4.32 (0.06)	3.70 (0.09)	0.00***	0.00***	0.00***		
8. …decreases the likelihood of pests and diseases in oil palm	742	3.46 (0.07)	3.05 (0.06)	3.63 (0.10)	3.66 (0.09)	0.00***	0.00***	0.00***	Y	Y
9. …leads to nutrient competition between trees and oil palms	744	3.86 (0.08)	4.27 (0.08)	4.07 (0.07)	3.31 (0.07)	0.09*	0.00***	0.00***	Y	
10. …takes too much space	744	3.49 (0.08)	3.95 (0.03)	3.64 (0.05)	2.96 (0.12)	0.00***	0.00***	0.00***	Y	
Information										
11. …makes my plantation more beautiful	743	3.52 (0.13)	2.50 (0.18)	3.96 (0.10)	3.96 (0.12)	0.00***	0.00***	0.95	Y	Y
Provisioning										
12. …increases the availability of nutritious food for my family	743	3.96 (0.08)	3.29 (0.13)	4.38 (0.04)	4.13 (0.06)	0.00***	0.00***	0.04**		Y
13. …is an important source of timber	744	4.09 (0.10)	3.29 (0.15)	4.57 (0.06)	4.30 (0.06)	0.00***	0.00***	0.00***		Y
14. …increases my income	743	3.60 (0.12)	2.60 (0.10)	4.18 (0.04)	3.88 (0.09)	0.00***	0.00***	0.00***	Y	Y
15. …decreases the stability of my income	744	3.23 (0.08)	2.82 (0.08)	3.77 (0.09)	3.06 (0.08)	0.00***	0.04**	0.00***		
16. …increases the well-being of my family	744	3.64 (0.12)	2.66 (0.11)	4.22 (0.06)	3.92 (0.09)	0.00***	0.00***	0.01**	Y	y
17… increase the time that I can spend on doing other things	744	3.36 (0.06)	2.98 (0.10)	3.64 (0.07)	3.43 (0.06)	0.00***	0.00***	0.05*		
Total factor	740	4.46 (1.21)	3.40 (0.13)	5.08 (0.05)	4.76 (0.08)	0.00***	0.00***	0.00***		
KMO									0.733	0.857
Cronbach's alpha									0.6763	0.820

Note: Columns (2) to (5) show mean estimates and corresponding standard errors. Columns (6) to (8) report p-values for a test of mean difference based on a linear regression model. Standard errors are cluster-corrected at village level, shown in parenthesis. 5-point Likert scale employed, where 5 states strongly agree. Statements were adapted from Meijer et al. (2015) to the context of oil palm. The classification of ecosystem functions was based on Dislich et al. (2016). Standard deviation in parenthesis Min-Max value for the total factor: (1.170 – 6.065) *p < 0.1 **p < 0.05, *** p < 0.01

Table 3-8 Determinants for selection into endline to construct the inverse probability weights

	(1) Selection	(2) selection
T1	0.360*** (0.132)	0.349*** (0.126)
T2	0.514*** (0.132)	0.466*** (0.124)
Years of education	0.008 (0.012)	0.002 (0.014)
Total hectare oil palm owned	-0.009 (0.008)	-0.010 (0.008)
=1 if homegarden	0.342**(0.143)	0.414***(0.141)
=1 if farmer planted trees last 12 months	-0.533 (0.495)	-0.676 (0.518)
=1 if received environmental education	-0.0005 (0.219)	-0.040 (0.218)
=1 if autochtonous village	0.221 (0.156)	0.242 (0.165)
=1 if oil palm share > 73.5% in the village	-0.044 (0.119)	-0.026 (0.130)
=1 if access to seeds in the village	0.113 (0.145)	0.133 (0.150)
Age of the hosuehold		0.070**(0.035)
Age of the household (sqr)		-0.0007**(0.0003)
=1 if female		-0.749**(0.362)
Number of hh members at home past 12 months		0.0068(0.040)
=1 if other crops are cultivated		-0.054 (0.135)
=1 if trees were cut last 12 months		0.209 (0.238)
Year of planting		0.002 (0.009)
Mean estimate for 11 assistants[1]		-1.66 (2.45)
Constant	0.254 (0.197)	-5.767 (18.43)
Observations	817	817
Pseudo R^2	0.044	0.065

Note: Standard errors are cluster-corrected at village level, shown in parenthesis.
[1]From the 11 assistants none were statistically significant different
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3-9 Intent-to-Treat effects

	(1) Actual tree planting	(2) Perceptions	(3) Intention to plant
T1	1.332*** (0.485)	0.333*** (0.028)	0.203***(0.046)
T2	3.466*** (0.458)	0.275*** (0.028)	0.200*** (0.040)
Access to seedlings	-0.222 (0.240)	0.050** (0.019)	0.002 (0.046)
Autochtonous	-0.293 (0.318)	0.026 (0.022)	0.085*(0.045)
Share of oil palm	-0.421***(0.152)	0.039 (0.024)	0.086**(0.033)
Age	-0.038 (0.074)	0.0006 (0.007)	0.017** (0.008)
Age (sqr)	0.0002 (0.000)	-6.13e-08 (0.000)	-0.0001** (0.000)
Years of education	0.059* (0.035)	0.002 (0.002)	0.008**(0.003)
Number of hh members at home past 12m	0.055 (0.067)	0.005 (0.005)	0.002 (0.007)
=1 if farmer has a homegarden	-1.511***(0.450)	-0.009 (0.0197)	-0.059 (0.055)
=1 if farmers has trees in oil palm plantation	0.167 (0.294)	0.041**(0.020)	0.102***(0.027)
=1 if farmer has cut trees in the past 12 months	-0.110 (0.932)	-0.0110 (0.038)	-0.015 (0.071)
Perceptions on tree benefits-baseline	0.083 (0.116)	0.018**(0.008)	0.025* (0.014)
Constant	-1.382 (1.990)	0.282 (0.197)	-0.415**(0.196)
Observations	670	670	670
R^2		0.362	0.117
Pseudo R^2	0.236		

Note: Each column is a separated weighted regression. Columns 1 and 2 show the estimated coefficient of an OLS regression. Column 3 shows marginal effects from a logit regression.
Standard errors are cluster-corrected at village level, shown in parenthesis.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3-10 Path analysis to test perceptions and intention as mediators

		Unstandardized		Standardized		
		(1)	(2)	(3)	(4)	(5)
Perceptions			p-values		p-values	Odds ratio
	T1	0.341 (0.020)	0.000	0.643 (0.037)	0.000	
	T2	0.276 (0.021)	0.000	0.534 (0.041)	0.000	
	Access to seedlings	0.050 (0.019)	0.008	0.087 (0.033)	0.008	
	Autochtonous	0.027(0.023)	0.239	0.047 (0.040)	0.239	
	Share of oil palm	0.040 (0.019)	0.040	0.080 (0.039)	0.040	
	Age	0.001 (0.001)	0.410	0.029 (0.035)	0.410	
	Years of education	0.003 (0.002)	0.251	0.040 (0.035)	0.251	
	Household members	0.005 (0.006)	0.351	0.031 (0.034)	0.351	
	Homegarden	-0.010 (0.028)	0.728	-0.011(0.031)	0.728	
	If trees in oil palm	0.042 (0.018)	0.021	0.076 (0.033)	0.021	
	Perceptions-baseline	0.018 (0.008)	0.025	0.076 (0.034)	0.025	
	=1 if cut trees last 12 m	-0.012 (0.042)	0.776	-0.009 0.032)	0.776	
R-square		0.364		0.364		
Intention						
	Perceptions	0.499 (0.056)	0.000	0.349 (0.040)	0.000	
	T1	0.033 (0.039)	0.406	0.044 (0.053)	0.406	
	T2	0.057 (0.034)	0.092	0.077 (0.046)	0.092	
R-square		0.147		0.147		
Actual adoption						
	Intention	1.307 (0.335)	0.000	0.202 (0.049)	0.000	3.694
	Perceptions	0.548 (0.603)	0.363	0.059 (0.065)	0.363	1.730
	T1	0.651 (0.471)	0.167	0.135 (0.095)	0.154	1.918
	T2	2.761 (0.431)	0.000	0.577 (0.073)	0.000	15.815
R-square		0.360		0.372		
Intercepts						
	Intention	-0.036 (0.029)	0.221	-0.101 (0.083)	0.221	
	Perceptions	0.280 (0.067)	0.000	1.133 (0.278)	0.000	

Thresholds				
OP$1	3.952 (0.507)	0.000	1.726 (0.170)	0.000
Residual Variance				
Intention	0.107 (0.005)	0.000	0.853 (0.023)	0.000
Perceptions	0.039 (0.002)	0.000	0.636 (0.035)	0.000
Direct effect T1	0.651 (0.471)	0.167	0.135 (0.095)	0.154
Indirect effect T1 (through only perceptions)	0.183 (0.202)	0.364	0.038 (0.042)	0.362
Indirect effect T1 (through only intention)	0.043 (0.053)	0.419	0.009 (0.011)	0.418
Indirect effect T1 (through perceptions and intention)	0.218 (0.063)	0.001	0.045 (0.013)	0.000
Total indirect effect T1	0.444 (0.204)	0.030	0.092 (0.011	0.027
Total effect T1	1.095 (0.450)	0.015	0.092 (0.042)	0.027
Direct effect T2	2.761 (0.431)	0.000	0.577 (0.073)	0.000
Indirect effect T2 (through only perceptions)	0.151 (0.167)	0.366	0.032 (0.035)	0.364
Indirect effect T2 (through only intention)	0.074 (0.048)	0.124	0.015 (0.010)	0.120
Indirect effect T2 (through perceptions and intention)	0.180 (0.052)	0.000	0.038 (0.010)	0.000
Total indirect effect T2	0.405 (0.171)	0.018	0.085 (0.035)	0.015
Total effect T2	3.166 (0.419)	0.000	0.661 (0.063)	0.000
Direct effect perceptions	0.548 (0.603)	0.363	0.059 (0.065)	0.912
Indirect effect perceptions (through intention)	0.652 (0.183)	0.000	0.070 (0.019)	0.000
Total indirect effect perceptions	0.652 (0.183)	0.000	0.070 (0.019)	0.000
Total effect perceptions	2.761 (0.431)	0.041	0.129 (0.063)	0.039
N	670			

Note: Results of a weighted structural equation model. Estimator: Maximum Likelihood Robust (ML), the model was performed in Mplus
Loglikelihood user model (H0): -338.722 /Akaike (AIC): 701.445 / Bayesian (BIC): 755.621 / Sample-size adjusted Bayesian (BIC): 715.220
Marginal effects were estimated with the unstandardized estimates from Column 1. We follow the formula: $(u = 1|x = 1) = \frac{1}{1+e^{-L}}$; where $L = Thresholds\ op +\ \beta_{direct\ T1 \rightarrow actual\ adoption}$ for T1 and $Thresholds\ op +\ \beta_{direct\ T2 \rightarrow actual\ doption}$ for T2.

4 General conclusion

4.1 Summary of findings

Conversion of biologically rich areas into intensified agricultural land undermines the capacity of these environments to sustain and maintain vital ecosystem functions. This is particularly the case where the conversion includes the simplification to a monoculture system such as that of oil palm. The process through which an oil palm plantation is established, in combination with its homogenous structure, deteriorates ecosystem functions such as climate, water and soil regulation. At the same time, the cultivation of oil palm represents high economic gains, at the national and household level. This reflects positively on income and food availability among local populations. Recognizing these economic benefits and the ecological loss, there is a need for policies that reconcile these trade-offs. This is particularly urgent in Indonesia, an oil palm and biodiversity hotspot. Indonesia is globally the largest producer of palm oil while experiencing a rapid loss of tropical rainforest and secondary forest. The expansion of oil palm in the country is expected to continue as the national government envisages large investments in the oil palm sector and adoption of the crop is rapidly increasing among smallholder farmers.

Given the role that Indonesian oil palm farmers could have in restoring or maintaining biodiversity, it seems crucial to design policies that foster pro-environmental behaviors by adopting biodiversity-friendly practices in oil palm plantations. Such policies can draw on social-psychological theories, which argue that behavioral change is influenced by cognitive processes that involve intrinsic factors such as perceptions and intentions. An individual will therefore evaluate the perceived cost and benefits of adopting a new behaviour, conditional on these underlying perceptions and intentions. Thus, this dissertation contributes to the understanding of the connection between perceptions, intentions and actual decisions, based on the case of Indonesian oil palm farmers. Specifically, we address four research objectives. First, we analyze the perception of changes in ecosystem functions in oil palm plantations. Second, we explore factors that are correlated to farmers' environmental concerns. Third, we investigate the causal effects of two environmental policies on tree planting behavior. And finally, we explore mediation pathways that explain how the provision of information and the combination of information with delivery of seedlings for free, can increase the adoption of tree planting through changes in the perceptions and intentions a person holds.

In chapter 2 we address the first and second research objective. We provide a descriptive analysis of how smallholders in Indonesia perceive recent changes in ecosystem functions in oil palm. In addition, we explore factors that are correlated with farmers' environmental concern. Oil palm expansion in Indonesia steered differences in farm management among smallholders, leading to heterogeneous effects on the environment. Combined with the heterogeneity in landscapes, this is expected to cause variation in the loss of ecosystem functions in the region. This again, would be expected to reflect in farmers' perceptions of ecosystem losses. Yet, little is known about how farmers perceive ecosystem functions and the extent to which farmers are concerned about the environment. We contribute to this limited amount of literature by employing psychological theories to design a set of 5-point Likert scales that measure perceptions and environmental concern. In the empirical analysis, we use a multivariate probit model to explore physiographic factors that influence the perceived change in soil and water regulation as well as in bird and insect diversity. Using Spearman's rank-order correlation, we link the perceptions of the change in ecosystem functions in oil palm to the level of environmental concern. Finally, we estimate an OLS regression to find relations between household head, household and village characteristics on the one side and the scale of environmental concern on the other side.

Our results show that farmers' perceptions are in line with empirical studies that have reviewed and quantified ecosystem functions in oil palm (Clough et al., 2016; Dislich et al., 2016). We find a pattern among farmers to perceive an increase in provisioning services, and a decrease (or independence) of regulating services over time. The fact that these same perceptions are significantly correlated with the level of environmental concern might indicate that soil and water regulation are aggravating problems in the region. Other factors that we found to be associated with environmental concern are contextual. Farmers living in villages with access to forest tend to be less concerned about the environment. On the contrary, farmers are likely to be more concerned in wealthy villages, in places with a larger share of oil palm, after having experienced a natural shock, and where they have access to a river. At the individual level, we find that an individual develops their concern for the environment according to the extent to which he/she believes they are part of nature. Overall, these findings suggest that while farmers are concerned about the changes in their natural environment, and these indeed shape their perceptions, the perceived increase in provisioning functions of oil palm cultivation may drive farmers' decisions to continue expanding its area. This is line with studies that identified that farmers are responsive to economic opportunities while ecological motives play a minor role in their ecological values (McCarthy et al. 2012; Feintrenie et al. 2010; Feintrenie et al. 2010; Feintrenie & Levang 2011; Feintrenie & Levang 2009; Therville et al. 2012). Although we find that biospheric values influences farmer‘s concern for the environment, as reflected in their connectivity to nature, the extent to which farmers will adopt a pro-environmental behavior is out of the scope of this paper. This leads us to chapter 3 of the dissertation where we test adoption of a biodiversity-friendly practice in oil palm and if perceptions and intentions influence such behavioral changes.

In chapter 3 we address the question how tree planting can be promoted among smallholder farmers and which psychological mechanisms mediate adoption. While there is a vast collection of studies shedding light on the environmental externalities of oil palm cultivation (Cramb & Curry, 2012; Dislich et al., 2016; Fayle et al., 2010; Fitzherbert et al., 2008; Foster et al., 2011; Margono et al., 2012, 2014), only few studies have looked at the effect of policy instruments to induce adoption of environmentally-friendly behavior and the intrinsic factors driving adoption in particular (Cole et al., 2010; Jack et al., 2013; Leimona et al., 2009). We contribute to the existing literature by providing experimental evidence on two environmental policies to encourage tree planting adoption in oil palm. In monoculture oil palm systems, biodiversity enrichment can be achieved by the integration of native trees in the plantation. We build our intervention on studies that show positive ecological effects of such tree planting in oil palm (Gérard et al., 2017; Teuscher et al., 2015, 2016). By designing and implementing a Randomized Controlled Trial (RCT) we infer causal effects of two policy instruments. Our first intervention tries to close knowledge gaps by providing information about tree planting in oil palm. The second intervention additionally tries to overcome missing access for seed material by distributing seedlings for free. We focus on perceptions towards the ecosystem functions of trees in oil palm plantations, the intention to plant, and actual tree planting. Our empirical analysis shows that both interventions have a positive and significant effect on these three outcomes. However, the effect of the combination of information in addition to the free distribution of seedlings has a stronger effect on observed behavior. Furthermore, our findings show that perceptions and intentions fully explain the effect of providing information and partially explain the effect of the combination of information and seedlings delivery on actual adoption. This finding indicates that behavioral factors as well as structural barriers are critical to technology adoption in the given case.

4.2 Policy recommendations

Policy makers should proactively support smallholder farmers to protect the environment. Taking into account the role of smallholders, policies should be designed to enhance biodiversity while not harming the economic interests of the farmers. The findings presented in the previous two chapters provide us with evidence to suggest a set of policy recommendations.

Addressing management practices is a viable way to contribute to the ecological restoration in oil palm. In the third chapter we observed that the additional provision of seedlings in combination with information is key to promote tree planting in oil palm landscapes. Particularly, the diffusion of information with cognitive-empathy messages. Yet, it is important to bear in mind that the cultivation of oil palm in Jambi is unique, and it is necessary to consider the history of its expansion. Most of the oil palm plantations were established by companies. They created homogenous structures and left little space for other crops or trees to be planted on. In focus groups discussion that I conducted, farmers constantly pointed out that companies provided a strong message that trees compete with oil palms for nutrients. Therefore, many farmers are hesitant to plant trees among their oil palms. In addition, some farmers have planted fruit and timber trees in their oil palm plantations but the trees have not survived or they did not bear fruits. This experience was communicated to other farmers and discouraged tree planting.

Given that most of the plantations are already old (some above 20 years) and considering that farmers are likely to replant oil palm, policies that carefully address tree planting need to be implemented soon. Intercropping oil palms with trees at the initial stages may be an opportunity to enhance biodiversity while providing income to farmers (Corley & Tinker, 2016).

Farmers will require additional information to ensure the success of this approach. For example, some villages in our sample are farming on peatland areas. Farmers in these areas require information on the suitability of different trees in this particular type of soil. This requires the scientifically rigorous testing of innovative agroforestry practices that improve biodiversity and incomes at the same time. In order to effectively address possible barriers to tree planting adoption, also access to seedlings needs to be improved. Farmers already raise their own oil palm seedlings. Building on this knowledge, seedlings of other trees could be locally produced, creating additional income in the local economy. Supporting the development of a local market would reduce the long-run dependency on government or NGO services and reduce project cost. In the information and access provision, a special emphasis should be on the economic benefits of trees. Access to such information is key to change perceptions and equip farmers with knowledge to establish and maintain trees in their plantation. Engaging local organizations and villager leaders to provide environmental extension may be a window of opportunity to increase agency among smallholders.

Another promising approach is to increase the heterogeneity of landscapes, specifically by protecting the remaining remnant forest, and to promote agroforestry practices (Azhar et al., 2015; Fitzherbert et al., 2008; Foster et al., 2011). However, institutionalized initiatives, such as the Roundtable on Sustainable Palm Oil (RSPO), have been criticized for lacking efficiency in maintaining biodiversity (Azhar et al., 2015). Given that biodiversity has a prominent role in many SDGs and associated targets (CBD, 2016), policies should be designed to minimize environmental externalities. Biodiversity restoring practices are likewise needed in other impoverished land use systems. Existing fallow or logged areas should be used as biodiversity hubs on top of oil palm plantations. One practice could be the use of ground vegetation. If it consists of nitrogen fixing leguminous plants, this strategy can also improve soil quality (Foster et al., 2011). Thereby, groundcovers can reduce the need for fertilizers and herbicides. In turn this can improve invertebrate richness and improve yields in oil palm (Gérard et al., 2017; Woittiez et al., 2016).

Furthermore, environmental programs should consider perceptions and intentions of target populations in their project design. This is of crucial importance since individuals may hold different perceptions and subjective beliefs, which may largely influence their final choice of behavior (Lusk et al., 2014; Manski, 2017). Especially in the cases where rewards or incentives are no longer present, internalized motivation can sustain pro-environmental behavior (Osbaldiston & Sheldon, 2003).

4.3 Limitations and further research

Some caveats might limit the scope of this dissertation and are worth to mention.

In chapter 2 we rely on cross-sectional data and provide a descriptive analysis. We cannot statistically proof causality and therefore, our assumptions about the processes remain suggestive. Further research that includes a methodology to address self-selection bias and unobserved heterogeneity may shed a light on causalities among the described relations. Another limitation is the environmental scale employed in this study. Most of the environmental scales used to infer perceptions and attitudes are designed with complex framing and mostly oriented to people living in developed countries. While some studies analyze environmental concerns in developing countries, the external validity may not be guaranteed. Further studies that combine different survey instruments and scales will help to improve the measurement of perceptions.

In chapter 3 we have provided experimental evidence of two interventions. While our randomization is balanced and robustness checks support our findings, the implementation of the interventions may limit our results. Farmers' exposure to the informational campaign was limited to a single event. The extent to which our outcomes may have been different if the exposure would be more frequent cannot be assessed. Further experimental studies could test the effect of the intensity of the information exposure. This could be done in a new RCT. The second intervention, the delivery of seedlings for free, allows to only observe adoption effects of one incentive in addition to information. Testing other incentives or rewards to induce pro-environmental behavior will help to design other policy instruments. We purely focus on the decision to adopt without further exploring the adaptability of the seedlings to the ecosystems or the number of trees planted. We deliver the seedlings during the rainy season so that farmers could be able to plant them. However, we did not keep track whether the farmer planted or not or if any irregularity occurred between the implementation of the intervention and the endline. Additional research should be done on the number of trees planted, favoured species and tree survival. This might provide insights into the performance of enrichment tree planting at a small-scale. It might be worth to re-visit the villages and collect the experiences of farmers. Qualitative studies may be helpful to understand the experiences of the farmers who planted trees and their perception of the policy. The informational campaign was weakened by the fact that it was based on just one year of results from the enrichment experiment.[21] During the extension sessions farmers questioned the economic benefits of trees, to which we were not able to respond sufficiently. The recent findings after two years highlight that tree performance among oil palms is positive and that the availability of sun, nutrient and water, due to thinning, have improved oil palm yields. Better data on the performance of this plot can increase the credibility of the information campaign, thereby raising its effectiveness.

Further research on how information is diffused among farmers might shed light on channels to influence a change of perceptions. This is particularly important in Indonesia, where it appears that farmers are largely influenced by each other, while extension services seem not to be successful in the promotion of technologies and the diffusion of information. Similarly, additional research that highlights internal values, ethical convictions, and social norms might help to better understand farmers' motivations for long-term adoption. Based on such research, the media seems to be a promising entry point to change farmers' behavior in the context of Indonesia. The use of mobile phones is a particularly common way for farmers to access information. In our survey we found that in many instances mobile internet access was used to search for management practices. Finally, our study does not analyze gender roles. Only about 2 percent of respondents in our sample are female. This limited observation of the role of women on influencing perceptions or engaging in pro-environmental behavior should be addressed. Future research on this topic needs to consider its gender dimension.

[21] We refer to the experimental plot established by natural scientist under the same research collaborative group.

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6 General appendix

The questionnaires employed to collect the data for this dissertation are presented in the attached CD.

These include:

- Village Survey 2015
- Household Survey 2015
- Post-experimental Survey 2016
- Household Survey 2016

7 Declarations

1. I, hereby, declare that this Ph.D. dissertation has not been presented to any other examining body either in its present or a similar form.

Furthermore, I also affirm that I have not applied for a Ph.D. at any other higher school of education.

Göttingen, …………………………………………..

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(Signature)

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(Name in block capitals)

2. I, hereby, solemnly declare that this dissertation was undertaken independently and without any unauthorized aid.

Göttingen, …………………………………………..

……………………………………………………(Signature)

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