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Adoption of sustainable management practices in oil palm plantations by smallholder farmers in Sumatra, Indonesia

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Abstract

Rapid conversion of forests to oil palm plantations leads to major environmental destructions. Loss of biodiversity, soil erosion and nutrient depletions are the results of major oil palm cultivations. To prevent further environmental destruction by palm oil production, more sustainable management practices were developed. In addition, incentives were introduced to motivate smallholders to apply these sustainable management practices. The latter is very important, since smallholders own the better part of oil palm plantations. However, little is known how smallholders are influenced by these incentives. The aim of this report is to analyse factors that promote the application of two sustainable management practices: Pruning and leaving palm fronds as an additional row on the plot in the Jambi Province in Indonesia. Therefore, a binary logit model is applied to assess sociodemographic and perception variables as well as plot and farm characteristics that influence smallholder's choice in adopting a combination of these two sustainable management practices. Migration, household size, number of plots, age of plot, household distance to plot, and connection to a river were identified to significantly impact smallholder's decision of adopting sustainable management practices. For instance, connection to a river significantly decreases the likelihood of adoption. Thus, this report identifies possible promising incentives for a sustainable palm oil production. However, to understand the impact of these incentives and therefore smallholder's action in more detail, further research is necessary.

1 Introduction

Palm oil is the most demanded vegetable oil in the world, as it has a high yielding potential and a great price advantage compared to other oil crops (FAOSTAT 2017). Over the past 50 years, palm oil cultivation expanded drastically in Indonesia. Thus, large areas of forests were converted into oil palm plantations, causing remarkable environmental threats (HANSEN et al. 2015; FITZHERBERT et al. 2008). For instance, unlike the highly biodiverse forests, oil palm plantations support only a little number of flora and fauna species (FITZHERBERT et al. 2008). In addition, deforestation leads to large-scale nutrient depletion of soil and vegetation. Carbon contents in oil palm plantations are significantly lower than in forests (GUILLAUME et al. 2015). Furthermore, deforestation causes soil erosion, and although this effect is most predominant directly after land clearing, mature plantations also face soil erosion, along with nutrient loss through harvest and its resulting loss of biomass (DISLICH et al. 2016).

To counteract the effects of soil erosion and nutrient depletion by oil palm cultivation conservation practices have been developed. One approach is organic mulching, since oil palms produce large amounts of biomass. Oil palm residues, such as empty fruit bunches or oil palm fronds, are returned to the plantation to conserve soil and water. This way, essential plant nutrients are released to the soil during their decomposition (MORADI et al. 2015). A similar idea is pruning of oil palms and leaving palm fronds on the plot, where responsible pruning also, increases oil palm yield (CORLEY and TINKER 2016). The latter is important as a great share of oil palm plantations are being managed by smallholder farmers who have not reached their full production potential (INDONESIAN SUSTAINABLE PALM OIL COMMISSION 2012). Therefore, practices to increase yields are desirable in order to lower the pressure on future forest degradation.

Since a combination of management approaches has a positive economic and ecological impact sustainable management practices need to be promoted. However, as of today, only little focus has been spent on reasons why smallholder farmers adopt certain management practices. Therefore, this study aims to outline and analyse determinants that influence farmers' decisions to adopt sustainable management practices. In particular this study focuses on two sustainable management practices: (1) pruning and (2) leaving palm fronds as an additional row on the plot. First, the development of oil palm cultivation, regarding its expansion, environmental and social concerns regarding the latter, and sustainable management practices are introduced. Second, determinants of sustainable management practices of smallholder farmers in the Jambi Province of Indonesia are analysed by using a binary logit model.

2 Literature background

2.1 Palm oil cultivation

Two species of oil palms are acknowledged today, the American *Elaeis oleifera* (Cortes, 1897), and the African *Elaeis guineensis* (Jacquin, 1763), which can be almost exclusively found in Asia (CORLEY and TINKER 2016). On this account, the present report uses the word oil palm for the species *E. guineensis*. The following chapter will describe the oil palm, *E. guineensis,* in general, its major expansion, and the environmental concerns that came along with it. Oil palms are predominantly found in tropical regions, as the optimal growth temperature varies between 24 to 28°C and bright sunshine should average 5 h/day throughout the year (or solar radiation of 16 to 17 MJ/m²/day) (CARR 2011). Also, a mean annual rainfall of 3500 mm was found to optimally support oil palm growth in Indonesia and Malaysia (CORLEY and TINKER 2016).

Besides the mentioned characteristics, slow crystallization properties, structural hardness, and a tendency for recrystallization make palm oil and its fractions and components a suitable crop for many food and non-food products. (LAI et al. 2015; EUROPEAN PALM OIL ALLIANCE 2016). Furthermore, palm oil is highly demanded due to its increased economic advantages over other vegetable oils. Soya and sunflower oil, for example, are more expensive and have lower average yields per hectare (Figure 1).

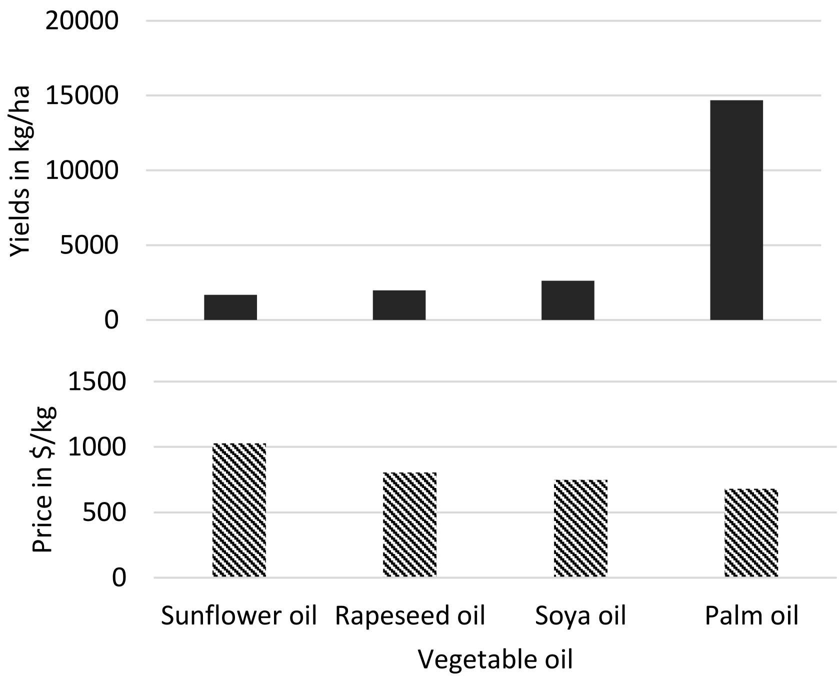

Figure 1: Comparison of vegetable oils in respect to their yielding potential and market price (February 2016)
Source: IMF 2016 & FAOSTAT 2017

2.1.1 The Indonesian oil palm expansion

The first indication of oil palm use can be traced back to more than thousands of years ago. Its major expansion, however, occurred only over the last 50 years (LAI et al. 2015). Some evidence suggests that oil palms originated in Africa. However, in Africa, attempts to commercialize oil palms failed because of political instabilities, internal conflicts, and difficulties in obtaining land and providing infrastructure. In Asia, oil palms were originally grown as ornamental plants. They were, however, found to be highly productive, which led to the first commercial planting in Sumatra and Indonesia in 1911. Still, the first South East Asian oil palm industry was not fully established until 1938. It is suggested that knowledge gaps in large scale extraction methods, as well as uncertainties about palm oil's economic benefits, caused the delay in oil palm commercialization (CORLEY and TINKER 2016).

A significant step towards the commercialization of oil palms was the inclusion of smallholders. Smallholder farmers hold a share of 40% of the national palm oil production in Indonesia, with an ongoing upward trend (INDONESIAN SUSTAINABLE PALM OIL COMMISSION 2012; RSPO 2017). Long-term investments in land and planting materials, access to mills, and little potential of meeting immediate subsistence needs make oil palm cultivation typically difficult for smallholder farmers. However, governments provided finance and infrastructure, which helped smallholder farmers overcome the high entry barriers to the palm oil market. (LAI et al. 2015). Consequentially, a constant increase of smallholder involvement in palm oil production could be witnessed over the past decade. From 2003 to 2011, an increase of 6.55% was reported, whilst over the same time, the share of government estates and private plantations increased by only 0.47% and 4.44% respectively (INDONESIAN SUSTAINABLE PALM OIL COMMISSION 2012; RSPO 2017).

However, the governmental support for oil palms only facilitated the major expansion. It can be said that the most widely accepted and important reason for the oil palm boom was the continuously increasing demand for vegetable oil and biofuels. The global demand for vegetable oil had more than tripled over the past two decades, from 20 million tonnes to 60 million tonnes, and is expected to continue rising. Moreover, the biofuel industry of the European Union had increased its use of palm oil by 365% since 2006. This increase can be linked to government policies promoting the growth of biodiesel (USDA 2017; GERASIMCHUK and KOH 2013).

Indonesia holds a share of nearly 40% of the global palm oil production. In 2006, Indonesia became the world's biggest palm oil producer, replacing the former leader

Malaysia (Figure 2). While the palm oil production in Malaysia was held relatively constant over the past four years, the palm oil production in Indonesia increased by 23%, from 28.5 million tonnes to 35 million tonnes (USDA 2017). Also, the area in which palm oil is grown has increased steadily over the past twenty years (Figure 3), from 2.4 million ha in 1990, to 33 million ha in 2014. As a result, this enormous development has affected concerned areas socially, economically and environmentally.

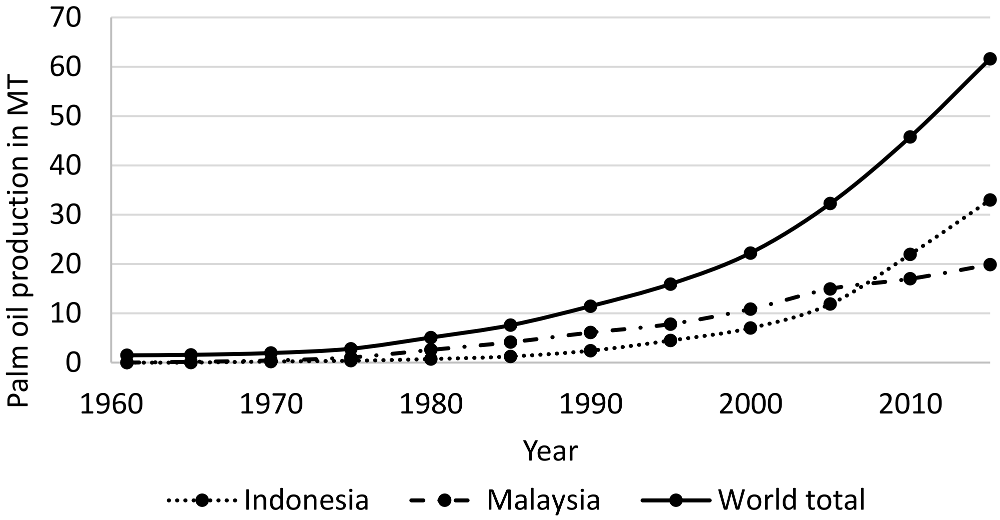

Figure 2: Development of the palm oil production in Malaysia and Indonesia
Source: own representation based on FAO 2016; USDA 2017

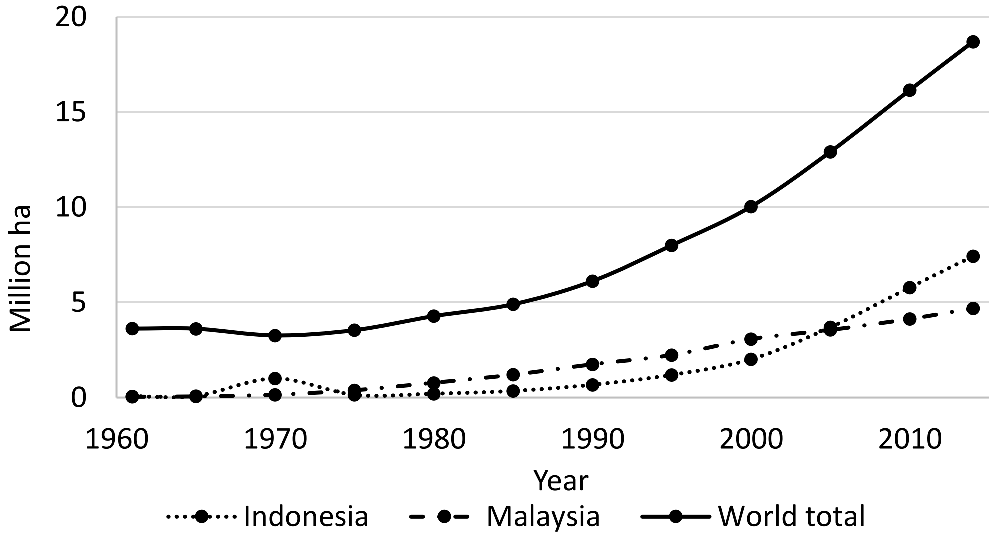

Figure 3: Area under oil palm cultivation
Source: own representation based on FAOSTAT 2017

2.1.2 Environmental impacts

Oil palm expansion has caused major deforestation in Indonesia and Malaysia, as millions of hectares of primary and secondary forests were cleared and converted to plantations. Large areas of primary lowland rainforests in Indonesia provide a habitat to a variety of flora and fauna species, and peatlands have been acknowledged as great carbon reserves (KOH and WILCOVE 2008). The conversion of forests to oil palm plantations, however, reduces ecosystem functioning (DISLICH et al. 2016). As oil palms need light, carbon dioxide, water, and nutrients (CORLEY and TINKER 2016), plantations generally require the removal of all other vegetation. Thus, oil palm plantations are mainly dominated by only one plant species. Also, fauna species are found less frequently in oil palm plantations than in primary forests (DANIELSEN et al. 2009). Accordingly, the cultivation of oil palms has been recognized as a major threat to biodiversity and ecosystem services. An increasing number of publications has addressed these topics over the past century (HANSEN et al. 2015).

A four-year study on mammals in Jambi, Indonesia, revealed that only four species are detected regularly on oil palm sites. This equals only 10% of the total number of species found within the 80 000 ha landscape. The decreasing forest area threatens fauna species, as oil palm plantations do not provide a suitable environment (MADDOX et al. 2007). However, mammals are not the only species that is being affected by oil palm expansion. Significant reduction in taxonomic and functional diversity could also be detected for ants and beetles (EDWARDS et al. 2014). Thus, it can be said that generally, mainly species-poor communities are supported. It can also be seen that in oil palm plantations, flora communities, such as lianas and epiphytic orchids, are found to be completely absent (DANIELSEN et al. 2009).

Furthermore, concerns regarding decreasing water levels in wells during dry periods have been raised. It is assumed that the conversion of rain forests to oil palm plantations has resulted in water scarcity, due to the redistribution of precipitated water by runoff (MERTEN et al. 2016). At the same time, studies have shown that oil palm production can increase flood risks (SUMARGA et al. 2016), which increases the likelihood of soil erosion. Soil loss was found to be 50 times greater in oil palm plantations than in forests, although it varies depending on plantation age and can be minimized by soil conservation practices. However, besides soil erosion, soil fertility is highly impacted by oil palm cultivation. The burning of forests releases large amounts of nutrients, which were previously bound in organic soil matter and vegetation. This can be exemplified through the fact that newly established plantations exhibit a lower capability of water infiltration and therefore, higher surface run-off which then instigates soil erosion (MERTEN et al. 2016). The loss of upper soil layer by erosion accounts for a reduction of carbon contents of up to 60% (GUILLAUME et al. 2015). Also mature plantations face nutrient leaching through the harvest and removal of palm biomass (DISLICH et al. 2016).

Nevertheless, many argue that oil palms have many environmentally favourable attributes when its full life cycle is observed. It is argued that management practices influence the potential of conservation value in oil palm plantations. Accordingly, negative environmental impacts are seen in direct correlation with poor management practices and uncontrolled expansion (SAYER et al. 2012).

To effectively observe the environmental threats caused by oil palm expansion, associated alternative crops such as soybean, rapeseed, or maize must be observed in relation to palm oil's production-ecological sustainability. A comparison of production-ecological sustainability indicators shows that palm oil production in South East Asia offers the highest sustainability, besides sugarcane in Brazil and sorghum in China, where, for its production, land, nitrogen, water, and energy resources are used most efficiently. Simultaneously, pesticide inputs are relatively low in relation to the net energy produced. In regards to the maintenance of soil quality, solitary palm oil was found to be the most sustainable (VRIES et al. 2010). Furthermore, it is proposed that industrial oil palm estates have the power to still support the preservation of forests in riverine areas, on steep slopes, and areas of high conservational value in general, and thus, contribute to saving important biodiversity. Also, smallholder systems can contribute to a more heterogenic landscape, which is thought to increase biodiversity (SAYER et al. 2012).

To conclude the previous section, it can be said that, when looking at palm oil individually, it has led to major environmental damages. Important ecosystems have been destroyed, with most of them beyond repair. However, by looking at palm oil in relation to other oil crops and evaluating its full life cycle, it provides opportunities for environmentally friendly oil production. Life cycle assessments showed that impacts of oil palm production are lower than those of rapeseed or soya production. Still, potentials of oil palm production, in respect to conservational values, need to be put in practice to increase its efficiency and lower the pressure on the environment. Also, socio-economic aspects need to be considered, as stakeholders get affected by oil palm management in several ways.

2.1.3 Socio-economic impacts

Economic advantages of oil palm management are not evenly distributed throughout all stakeholders (OBIDZINSKI et al. 2012). The oil palm boom heavily affected the livelihood of transmigrants, as well as of native villages. Transmigrant villages were part of the transmigration program, within which families from densely populated areas were relocated on a voluntary basis to the less densely populated islands of Sumatra, Kalimantan, and Papua (ELMHIRST 1999). Native villages, on the other hand, were founded by autochthonous people, which are characterized by a more sedentary lifestyle (GATTO et al. 2015). While many stakeholders, such as employees, out-growers, or investing households, highly benefitted in terms of financial gains, other stakeholders were negatively impacted. The native landowners, especially, suffered through the non-recognition of traditional land use rights and losses (OBIDZINSKI et al. 2012). Oil palms are often planted on forest land, logged land, grass, and scrub land for which local farmers hold traditional land rights, thereby withdrawing their opportunities to use the land independently. Also, the possibility of using provided ecosystem services such as forest products is taken (LI 2015). Moreover, although the oil palm development increased the number of jobs, the highest financial gains are mostly obtained by skilled migrants. The local, poor population often receives only little. The oil palm development has proven to hardly evocate multiplier effects (OBIDZINSKI et al. 2014). These differences can be most likely explained by different cultivation patterns. In the Jambi province, for example, a remarkable contrast in oil palm cultivation can be found between native and transmigrant villages. Native villages have generally started to cultivate oil palm later and at a slower pace as they are more likely to be involved in rubber production. The transmigration program, on the other hand, was pivotal to the oil palm expansion, as it was beneficial in many ways for transmigrant families, and also supported, as of today, an unequal development of the native and transmigrant population (GATTO et al. 2015). In this regard, it is also notable that benefits derived through palm oil cultivation often depend on district authorities and smallholder cooperatives. Lack of transparency and unequal benefit sharing drives conflicts throughout the population (RIST et al. 2010). FEINTRENIE et al. (2010) argue that fair partnerships between smallholders and companies are necessary to make palm oil more attractive for smallholder farmers. However, the full livelihood impacts, besides financial gains, of oil palm cultivation are little understood (RIST et al. 2010).

The unequal distribution of benefits obtained from oil palm plantations is, again, associated with government policies. Land-use change and policies favour stakeholders in different ways and typically, local communities are worse off (SUWARNO et al. 2016).

Still, a study in Malaysia revealed that smallholders and migrants, as well as natives, benefitted from oil palm plantations through improved infrastructure. Besides, through the improvement of road networks, communities also acknowledged better access to quality education and medical facilities. Consequentially, better health and living standards were reported (ABAZUE et al. 2015).

To conclude, it is difficult to assess the effect of oil palm cultivation to the society as either positive or negative. Some parts of the population highly benefit, while others pay the costs. Therefore, it is necessary to look at groups individually and assess specific effects. Such controversial effects also highlight the necessity of adequate policy mechanisms that support equal benefit sharing.

2.2 Sustainable management practices

The recognition of environmental problems caused by oil palm cultivation as well as the unevenly distributed economic and social benefits has led to the development of multiple sustainability incentives. The most common definition of sustainability can be found in the Brundtland report: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT 1987). Biodiverse and properly functioning landscapes are essential to provide ecosystem services that benefit human well-being (FOSTER et al. 2011). Sustainable palm oil plantations, however, should not only support ecological functions but rather find a balance between ecological, economic and social aspects. Increasing palm oil yield improves livelihoods, especially of smallholder farmers and simultaneously, existing oil palm plantations can be used more effectively. However, there is no single best management practice that can be applied to all plantations. It is therefore important to evaluate plantations individually. The present report focuses on a combination of two sustainability management practices that aim to improve soil fertility and increase yield. These include pruning and leaving palm fronds as an additional row.

Pruning was identified to increase oil palm yield, but only when performed adequately. Harvesters should prune regularly and prune only those leaves that enable access to ripe fruit bunches. During this process, as little green fronds as possible should be cut, always keeping at least 33 to 40 fronds. Pruning dead leaves only, as well as pruning only two leaves below the bunch, can increase bunch yield by 19.3 t/ha/year (adjusted mean for six years), whilst pruning up to the bunch can lead to yield losses (CORLEY and TINKER 2016). Pruned leaves are used on the plantations to lower erosion and restore nutrients to the soil. Thus, they are either stacked in frond piles in alternate interlines or spread widely. Furthermore, pruned leaves effect soil moisture, pH, total P, exchangeable Na, base saturation and electrical conductivity (TAO et al. 2016). However, no difference in fauna feeding activities between areas with pruned leaves and those without any input or chemical fertilization have been found. This is surprising, as palm fronds are easily decomposable (MORADI et al. 2014). One possible explanation might be the fact that palm fronds were placed on underground vegetation. In addition, carbon stocks were found significantly higher under palm frond piles compared to completely uncovered soil (FRAZÃO et al. 2013). In general, it can be said that returning palm fronds to the plot is important for soil quality, as it limits erosion from raindrops or running water, maintains soil fertility, and improves soil structure (CORLEY and TINKER 2016).

3 Empirical analysis

3.1 Study site

Underlying data of the present thesis was taken from the project CRC 990 Indonesia. The survey was conducted in five different districts in the Jambi Province in Sumatra, Indonesia. The Jambi Province is located in central Sumatra and borders the East coast (Figure 4). In total, Jambi has an area of 53.4 thousand km², of which approximately 13% currently being used for conservation, with a population size of around three million people. The livelihood in Jambi predominantly relies on commodity plantations for rubber, palm oil, cocoa, cloves, etc.. The districts in which the survey was conducted, namely Muaro Jambi, Batang Hari, Sarolangun, Tebo and Bungo, belong to the low and mid lands in the Jambi Province (ERLINDA et al. 2016). The Jambi Province is characterized by a tropical climate with a mean minimum annual temperature of 22 to 24°C and a mean maximum annual temperature of 31 to 33°C (average monthly value of the last 20 years, measured at the official weather station in Jambi, in a height of 25 m). The mean annual rainfall varies around 2200 mm/year. It has yearly dry and wet seasons, with the dry season lasting from May to September. In this time, rainy days per month range from six to nine days. The wet season lasts from October to April and rainy days per month range from eight to fifteen days. The average monthly rainfall in the dry season (114 mm) was 42% of that in the rainy season (270 mm) (WORLD DATA 2017). The dominant crop in Jambi is rubber. In 2012, GATTO et al. (2015) examined land-uses in the mentioned districts. Studies showed that 51% of the area was covered with rubber, while secondary forest accounted for 17%, fallow 15%, oil palm 12%, and other uses 5%, including residential areas and food crops, like paddy, fruit, and vegetables. While the rubber area and land under fallow have remained about the same over the past twenty years, the oil palm area has increased almost tenfold and the forest area has been roughly cut in half. The topography of the Jambi Province is highly characterized by the Batanghari river, which crosses the province from West to East. The Jambi Province is rich in flora and fauna biodiversity, with endangered species such as the Sumatran tiger and Sumatran rhinoceros present (ERLINDA et al. 2016). In the surveyed villages, agriculture holds the largest share of income.

In total, 27 villages with transmigrant households and nine autochthonous villages were selected. Transmigrant villages were randomly selected out of a list, with at least 70% of the households in the transmigrant villages gaining their primary income from oil palm cultivation. Within the autochthonous villages, about 30% of the farmers gained their primary income from oil palm cultivation, as most autochthonous villages are predominantly employed in rubber production, rather than in oil palm cultivation. Within each village, transmigrant and native, approximately 20 households were randomly selected from a list provided by the administration office. Data collection took place from October to December 2016. Because of flooding, one village was not asked before February 2017. A structured questionnaire was used (see appendix A). Interviews were carried out in the local language by twelve enumerators from Jambi University. The survey was a follow-up. The initial survey was carried out in 2015. For some analysis data on plot characteristics were also taken from the baseline survey.

Figure 4: Map of the study area (DRESCHER et al. 2016); modified.
The named areas are the districts where the survey was conducted.

3.2 Variable description

3.2.1 Dependent variable

The main variable of interest is whether farmers apply a combination of sustainable management practices. Farmers were asked if they prune their oil palms and if they leave oil palm fronds as an additional row on their plots. A binary variable was created that combined both management practices. Farmers were then grouped into adopters and non-adopters. Adopters were classed as those who use both practices on at least one of their plots. The analysis was conducted on plot level to check for possible plot characteristics that influence the adoption decision.

3.2.2 Independent variables and hypothesis

Earlier studies revealed the complexity of determinants influencing adoption decisions of sustainable management practices and new technologies (MARTIN et al. 2015; ERNAH and WAIBEL 2016; HE et al. 2007). Therefore, the present study involves socioeconomic and individual perception variables as well as plot characteristics. In total 15 variables are being used as potential explanatories (Table 1).

Sociodemographic variables

Migration (MIGR) implies whether a household is part of a transmigration or an autochthonous village. Migration households are part of the transmigration program and hence, are associated with larger oil palm areas and faster adoption than autochthonous households. In the past, autochthonous households adopted oil palm at a slower pace (GATTO et al. 2015). It is hypothesised that transmigration households have better access to information and, therefore, are more likely to adopt sustainable management practices.

Age (AGE) measures age of the household head in years. Past studies revealed a higher tendency of young people to invest in new technology (NI et al. 2016; MOGES and TAYE 2017). Younger farmers are often hypothesised to be more willing to innovate because of a longer planning horizon (DERESSA et al. 2009). As improvements due to better management practices need some time to pay off, the present study expects younger farmers to be more likely to adopt.

Education (EDUC) measures the education of the household head in years of schooling. Recent studies on adoption determinants exhibit a positive relationship between education and adoption of new management practices (MOGES and TAYE 2017; MANGO et al. 2017). Thus, higher educated farmers are expected to be more likely to adopt sustainable management practices.

Household size (HSIZ) measures the total number of household members. Sustainable management practices are associated with higher labour intensity. Larger families are enabled to accomplish more diverse tasks and are therefore expected to be more likely to adopt sustainable management practices. Household size is hypothesised to increase adoption (JERA and AJAYI 2008). However, it also needs to be noted that large households do not necessary provide more labour. Therefore, the number of household members employed in own agriculture (HWORK) was also used as an explanatory variable. The more household members are employed, the higher the likelihood of adoption.

Gender (SEX) is often reported to play a remarkable role in decision making (DERESSA et al. 2009). In the present study, household heads are mainly male. Often, female household members lack access to information and new technologies (AKUDUGU et al. 2012). Accordingly, the present study suggests that male farmers are more likely to adopt sustainable management practices than female farmers.

Farm characteristics

The total managed rubber area (RUBB) was used as a determinant of sustainable management adoption. Rubber is the dominant crop in the Jambi Province (GATTO et al. 2015). Rubber outcome is reported to highly depend on labour availability, as labour input increases tapping frequency and thus, leads to higher outputs (SCHWARZE et al. 2015). Therefore, households managing large rubber areas are expected to be less likely to adopt new management practices on oil palm areas.

Also, it is measured if farmers received extension services or trainings (EXTE) on soil management. Results of MOGES and TAYE (2017) and ADEOTI (2009) reported agricultural advice to increase the likelihood of adoption. This is also hypothesised in the present study.

Moreover, the number of plots is analysed (NOPL). MANGO et al. (2017) reported that the likelihood of adoption increased with direct correlation to an increasing number of plots. This can be explained by the fact that an increase in plot number increases the risk of loss of harvest due to poor management practices and thus, farmers are encouraged to adopt conservation technologies. Also, a higher number of plots is associated with greater wealth. Therefore, the present study hypothesises an increasing likelihood of sustainable management adoption with an increasing number of plots.

Oil palm perception

Farmers were asked on their opinion on how oil palms influence water quality and availability. Their perception was measured using a five point Likert scale, with the following gradations: 1 = decreases very much, 2 = decreases slightly, 3 = no change, 4 = increases slightly, 5 = increases very much.

Water availability plays an important role for oil palm plantations. Insufficient water evocates yield losses. However, the effect of water stress is difficult to determine as different oil palm stages require different amounts of water (CARR 2011). In any case, villagers in the Jambi Province, Indonesia, displayed concerns about decreasing water levels in wells during dry periods (MERTEN et al. 2016). Therefore, the present study hypothesises that farmers who view oil palm plantations as negatively impacting water availability, are more likely to implement sustainable management practices. Similarly, this is assumed for water quality. Both variables were grouped into one called water-influence (WATER) and the mean was determined.

Plot characteristics

The regression analysis is conducted on plot level, as farmers might not adopt sustainable management practices on all their plots similarly. In this regard, plot size (SIZPL) measures the size of the plots in ha. According to KASSIE et al. (2013), farmers are more likely to adopt water and soil conservation practices on larger plots. Farmers managing larger plots are expected to be wealthier and therefore, more likely to adopt. Similarly, this is hypothesised for sustainable management practices on oil palm plots in the present study.

Furthermore, age of the plots (AGEPL) is used as an explanatory variable. Oil palms need some time to fully develop, as palm fronds reach their maximum growth rate after six years (VERHEYE 2010). As the present study analysis pruning, palm age is expected to have a positive influence on sustainable management adoption.

The distance between a plot and the house (HDIST) is expected to negatively impact the adoption decision. An increase in distance increases time and energy of reaching and managing the plot. This goes in line with findings by MOGES and TAYE (2017).

Another two plot variables used in the model are steepness (STEEP) of the plot and connection to a river (RIVER). The Steepness of a plot is associated with a higher visible erosion (MOGES and TAYE 2017). Thus, smallholder farmers are expected to be more likely to adopt sustainable management practices on steeper plots. Similarly, this can be expected for plots that are crossed by or border a river.

Table 1: Explanatory variables for the adoption of pruning and leaving palm fronds as an additional row

Variables	Description	Expected sign
Sociodemographic Variables		
MIGR	1 if household migrated to the village, 0 otherwise	+
AGE	Age in years of household head	-
EDUC	Number of years schooling of the household head	+
HSIZ	Number of household members	+
HWORK	Number of household members that are employed in own agriculture	+
SEX	1 if farmer is male, 2 if farmer is female	-
Farm characteristics		
RUBB	Total managed rubber tree area in ha	-
EXTE	1 if farmer received extension service or training on soil management, 0 otherwise	+
NOPL	Number of plots per household	+
Opinion of oil palm influences on …		
… WATER	Quality and availability: 1 = decreases very much, 2 = decreases slightly, 3 = no change, 4 = increases slightly, 5 = increases very much	+
Plot characteristics		
SIZPL	Plot size in ha	-
AGEPL	Age of plot measured in years	+
HDIST	Plot distance to the house in km	-
STEEP	Steepness of the plot, measure categorical: 1 = 0°, 2 = 10°, 3 = 20°, 4 = 30°, 5 = 45° and 6 = more than 45°	+
RIVER	1 if plot borders or is crossed by a river, 0 otherwise	+

To ascertain that there are no relationships among the independent variables, a correlation matrix was used. In the following the matrix is displayed (Table 2).

Table 2: Correlation coefficients of the independent variables (grey shaded correlations are high)

	MIGR	AGE	EDUC	HSIZ	HWOR	SEX	RUBB	EXTE	NOPL	WATER	SIZPL	AGEP	HDIST	STEEP	RIVER
MIGR	1.000														
AGE	0.075	1.000													
EDUC	-0.024	-0.332	1.000												
HSIZ	-0.056	-0.111	0.024	1.000											
HWORK	-0.074	0.225	-0.217	0.129	1.000										
SEX	-0.034	-0.002	-0.028	-0.032	-0.063	1.000									
RUBB	-0.279	-0.059	0.111	-0.007	0.020	0.002	1.000								
EXTE	-0.091	-0.032	0.034	0.092	-0.031	0.009	-0.017	1.000							
NOPL	0.137	-0.036	0.140	-0.127	-0.036	-0.033	0.133	-0.066	1.000						
WATER	-0.221	-0.023	-0.115	0.019	0.006	-0.046	0.033	0.015	-0.071	1.000					
SIZPL	-0.164	-0.028	0.073	0.046	0.009	-0.023	0.088	-0.020	0.087	0.064	1.000				
AGEPL	0.359	0.118	-0.029	-0.078	-0.056	0.011	-0.163	-0.072	0.101	-0.087	-0.023	1.000			
HDIST	0.034	-0.017	-0.024	-0.007	-0.028	-0.014	-0.033	-0.042	-0.001	-0.029	0.179	-0.126	1.000		
STEEP	0.107	-0.008	-0.030	-0.034	-0.012	0.035	-0.032	-0.065	-0.041	-0.094	0.048	0.098	0.080	1.000	
RIVER	-0.083	-0.010	0.027	0.048	-0.008	0.019	0.061	-0.031	-0.002	0.023	0.146	-0.095	0.152	0.113	1.000

3.3 Binary logit model

Smallholder farmers were asked whether they adopt certain sustainable management practices or not. The aim of the present study is to investigate underlying factors that influence their adoption decision. A common approach, where the probability of a dichotomous outcome (e.g. adoption or non-adoption) is put in relation to various explanatory variables, is the binary logit model. This approach has been used in many earlier adoption studies (e.g. MARIANO et al. 2012; ADEOGUN et al. 2008; DERESSA et al. 2009). Farmers are represented by the dummy variable:

$$y_i = \begin{cases} 1 & if\ farmer\ adopts\ certain\ management\ practices \\ 0 & if\ farmer\ does\ not\ adopt\ certain\ management\ practices \end{cases}$$

The probabilities of adoption and non-adoption are expressed as a logistic regression model:

$$Probability\ of\ adoption = P(Y_i = 1) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki})}} = \frac{e^{(\beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki})}}{1 + e^{(\beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki})}}$$

$$Probability\ of\ non - adoption = P(Y_i = 0) = 1 - P(Y_i = 1) = \frac{1}{1 + e^{(\beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki})}}$$

$$\frac{P(y_i = 1)}{P(y_i = 0)} = \frac{P_i}{1 - P_i} = e^{(\beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki})}$$

In the following the logarithmic transformation of the probability of adoption is displayed:

$$ln\left[\frac{P_i}{1 - P_i}\right] = \beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki}$$

P is the probability of observing a positive outcome, i denotes the i-th observation in the sample β_0 is the intercept term and β_1, β_2, …, β_k are the coefficients associated with each explanatory variable X_1, X_2, …, X_k. Marginal effects were used to display the predictions of the model. They show the effect of a one-unit change in X_i when all other factors are held constant.

$$\frac{\Delta P_i}{\Delta X_i}_{\ all\ other\ x\ held\ constant} = \frac{\partial P_i}{\partial X_i}$$

4 Results

4.1 Farmer categorization

Farmers are categorized into two absorbing states, adopters and non-adopters. In total, 764 farmers are considered, from which 530 (~ 70%) prune their oil palms and leave palm fronds as an additional row on their plots. Selected variables, such as plot and household characteristics are presented in Table 3.

Sociodemographic variables do not differ significantly between adopters and non-adopters. For instance, adopters and non-adopters have on average the same number of household members employed in agriculture (1.14). It is unexpected that adopters are not significantly older or higher educated than non-adopters.

In terms of farm characteristics, adopters are shown to manage more rubber area, to more often receive extension services or trainings on soil management, and to own more plots. Statistics show that adopters, on average, manage 3.26 ha of rubber and own on average 2.5 plots compared to 1.58 ha of rubber managed and 1.15 plots owned by non-adopters. All three differences are significant at a 1% level.

Results also show that three out of five plot characteristics are found to significantly differ between adopters and non-adopters, with adopters cultivating older oil palms on their plots (16.6 years) compared to non-adopters (14.27 years), the distance between the house and the plots is on average being 2.53 km larger of non-adopters, and adopters having a river crossing or bordering their plots more often. All three findings are significant at the 1% level. Finally, adopters and non-adopters do not differ in their perception of oil palm influences on water.

Table 3: Descriptive statistics of the variables for sustainable management practice adoption (pruning and leaving palm fronds as an additional row)

	Sample (n = 764)		**Adopters (n = 530)**		**Non-Adopters (n = 234)**		
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	p-value
Sociodemographic Variables							
MIGR	0.75	0.43	0.74	0.44	0.76	0.43	0.5334
AGE	50.22	10.83	50.3	11.03	50.05	10.39	0.7701
EDUC (years)	7.8	3.58	7.71	3.59	8.01	3.55	0.2749
HSIZ	3.83	1.5	3.79	1.46	3.92	1.6	0.2343
HWORK	1.14	0.5	1.14	0.52	1.14	0.46	0.9210
SEX (1 = male, 2 = female)	1.01	0.11	1.00	0.09	1.02	0.144	0.1029
Farm characteristics							
RUBB*** (ha)	2.86	3.67	3.26	3.67	1.98	1.58	0.0084
EXTE***	0.09	0.30	0.12	0.32	0.05	0.23	0.0068
NOPL***	2.38	1.5	2.5	1.62	2.1	1.15	0.0006
Oil palm perception (Quality and availability: 1 = decreases very much, 2 = decreases slightly, 3 = no change, 4 = increases slightly, 5 = increases very much)							
WATER	2.19	0.8	2.19	0.81	2.18	0.79	0.8068
	Sample size (n = 1829)		**Adopters (n = 1092)**		**Non-adopters (n = 737)**		
Plot characteristics							
SIZPL (ha)	2.12	1.98	2.14	1.98	2.09	1.97	0.5769
AGEPL***	15.67	7.72	16.6	6.87	14.27	8.66	0.0000
HDIST*** (km)	5.06	11.14	3.94	9.23	6.47	13.03	0.0034
STEEP (1 = 0°, 2 = 10°, 3 = 20°, 4 = 30°, 5 = 45° and 6 = more than 45°)	2.11	1.26	2.07	1.24	2.18	1.28	0.1018
RIVER***(1 = yes, 0 = no)	0.20	0.40	0.18	0.39	0.24	0.43	0.0055

Note: Paired t-test: * reports significance at the 1% level**

4.2 Results of the model

In Table 4, the results of the logistic model are displayed. The chi-squared test statistic is significant at the 1% level, which implies the joint significance of the adoption model. To assess how well the model fits, a classification analysis was conducted. In total, 63.97% of the observations are correctly predicted by the logit model. It needs to be noted that the model explains only little variance (Pseudo R^2 = 0.051). As it is likely that farmers are being influenced in their decision to adopt by neighbouring farmers, it is assumed that there is a correlation between farmers from the same village. Therefore, clustered standard errors are calculated. The correlation matrix (Table 2), displayed relatively high correlations of migration. Migration was still included in the model as both, the Akaike information criterion and the Bayesian information criterion, are slightly smaller, with migration as an independent variable. Also, the coefficients of the remaining independent variables changed only slightly. This as well accounts for the high correlations among age, working household members and education.

Two household characteristics are significant at the 10% level in the decision to adopt pruning and leave palm fronds as an additional row on the plots. Living in an autochthonous village has a positive impact on adoption, whilst household size negatively impacts the adoption decision. Age, education, gender and number of household members employed in agriculture are contrary to the hypothesis and are therefore not significant.

Only one farm characteristic is significant in the decision to adopt sustainable management practices at the 5% level. As hypothesised, number of plots correlates positively with adoption. However, rubber cultivation and attendance in training or extension services do not significantly impact the adoption decision. Also, the perception of oil palm's impacts on water does not have a significant impact on the decision whether a farmer uses the analysed management practices.

Finally, three out of five plot characteristics correlate positively with adoption. The plot age is highly significant at the 1% level. Farmers who manage older plots are more likely to adopt pruning and leave palm fronds as an additional row. As expected, household distance correlates negatively with the decision to adopt. The further plots are away from the house, the less likely farmers are to use the analysed management practices. Surprisingly, farmers who have a river crossing or bordering their plot are less likely to adopt with a significance level of 10%.

Table 4: Parameter estimates of the binary logistic regression model for factors influencing adoption of pruning and leaving palm fronds as an additional row on plot level in Jambi Province of Sumatra

Variable	Marginal effects	Clustered standard error	p-value
MIGR*	0.1021	0.057	0.075
AGE	0.0006	0.001	0.664
EDUC	-0.0026	0.005	0.582
HSIZ*	-0.0209	0.012	0.090
HWORK	0.0287	0.034	0.396
SEX	-0.2068	0.159	0.193
RUBB	0.0109	0.007	0.144
EXTE	0.0670	0.068	0.325
NOPL**	0.0262	0.013	0.038
WATER	0.0290	0.030	0.342
SIZPL	0.0091	0.009	0.287
AGEPL***	0.0102	0.003	0.000
HDIST***	-0.0050	0.002	0.004
STEEP	-0.0130	0.012	0.264
RIVER*	-0.0565	0.032	0.073

Number of observations = 1646
Wald chi^2 (15) = 165.47
Prob > chi^2 = 0.000
Pseudo R^2 = 0.0510
Log pseudolikelihood = -1047.5577
Overall percentage of right predictions = 63.97%
* Significance at 10%
** Significance at 5%
*** Significance at 1%

5 Discussion

Oil palm cultivation has caused dramatic environmental damages. The present study analyses factors that influence smallholder farmers decision to adopt sustainable management practices and outlines incentives to promote more sustainable behaviour.

In terms of the role of migration the present findings suggest that households that migrated to the Jambi Province are less likely to adopt sustainable management practices. The negative association between migration and adoption is surprising. Conventionally, one would expect that farmers living in transmigration villages have a higher likelihood of adoption as they are often better trained on oil palm management and have better access to information (GATTO et al. 2015). One possible explanation is that native farmers might have a stronger emotional relationship to the location and environment, because of their more sedentary lifestyle (see chapter 2.1.3). Therefore, they appreciate the environment more, and thus, have a higher tendency to adapt conservation practices. However, this implies that farmers are aware of the positive impacts due to adopting the management practices, which was not analysed in the present study. To fully understand the impact of native and transmigrant backgrounds on the adoption of sustainable management practices future research is necessary.

Household size decreases the likelihood of sustainable management adoption. This is unexpected as it contradicts recent studies that found that a higher household size is associated with higher labour availability and thus, higher likelihood of adoption (MARIANO et al. 2012). The negative correlation observed in this study might be due to higher household investments, for example food, which discourages adoption. This goes in line with findings by ADEOTI (2009), who investigated factors influencing the adoption of irrigation technology. Furthermore, the number of household members that are employed in agriculture is not significant at all. This implies that labour availability is not a concern in regards to the adoption of sustainable management practices. This result is consistent with that of MUROVHI et al. (2011), who reported a positive but non-significant effect of labour availability on the adoption of leaf-litter biomass technology. However, other studies show that the number of working household members has a significant positive effect on the adoption of new technologies (e.g. ODENDO et al. 2009). The difference might be explained by the fact that the analysed management practices in the present study are not as labour intensive as the ones studied before. According to SCHWARZE et al. (2015), oil palm management in general is only little labour demanding. Adoption of the analysed management practices will not change this fact.

The distance between the plot and residence is an important variable which negatively affects the probability of using sustainable management practices. This is reasonable as plots that are further away are more time and energy consuming. Plots in close distance to the residency are more likely to be regularly visited and managed. This result reflects MOGES and TAYE (2017), who reported a decreasing likelihood of adoption of soil and water conservation techniques with increasing distance from the residence area.

Education and age do not influence the decision to adopt pruning and leaving palm fronds as an additional row on the plot, which contradicts the hypothesis that elderly and more educated farmers are more likely to adopt. This implies that the analysed management practices are not difficult to learn and, therefore, do not exclude uneducated or elderly farmers. They neither require a huge know-how and thus, do not exclude young unexperienced farmers. This result is in contrast with that of MANGO et al. (2017), who reported that a household head's age significantly influences the likelihood of adoption of soil and water conservation practices.

Also, gender does not significantly impact the adoption decision. This indicates that female farmers are not excluded from adoption because of lack in access to information. In the study area, however, mainly male farmers are responsible for oil palm management. At this point, no further statement can be made about the role of gender in the adoption decision. Further research is necessary.

It is found, from this study, that the likelihood of using sustainable management practices increases as number of plots increases. This might be explained by the fact that farmers who own more plots are less risk exposed, and thus are willing to adopt to new non-conservative methods, such as sustainable management practices. This result is consistent with that of MANGO et al. (2017), who reported that an additional piece of land used by the household increases the odds of the adoption of conservation practices.

Plot size increases the likelihood of adoption but on a non-significant level. This implies that the analysed management practices are not too time consuming or expensive to keep farmers from applying them on larger plots. According to KASSIE et al. (2013), plot size significantly increases the likelihood of adoption of soil and water conservation techniques. This indicates that site-specific characteristics play an important role in determining adoption decisions.

It was also found that farmers receiving extension services on soil management were found to be more likely to adopt sustainable management practices, however, unlike recent studies (ADEOTI 2009; MOGES and TAYE 2017), on a non-significant level. One possible explanation is that pruning and leaving palm fronds on the plot are not difficult to adopt and hence, do not essentially require training. It also suggests that farmers might see benefits of adopting independent of soil conservation, and that the analysed management practices are already of common knowledge to many farmers.

Sustainable management practices are less likely to be adopted on plots that are next to or divided by a river. This finding was unexpected, since it was assumed that, since river areas have a high exposure to erosion, farmers would be more likely to adopt on these plots. However, the decrease in likelihood of adoption in river areas could be explained by the fact that rivers might act as barriers to reach the plot and thus increases the effective distance between plot and household, which was discussed in the previous paragraph. This is consistent with the fact that steeper plots decrease the likelihood of adoption, although at a non-significant level. Management of steeper

plots are also more complicated, and thus, time and energy consuming. Moreover, farmers managing plots in close distance to rivers might be less exposed to water scarcity and are thus, not aware of the importance of conservation practices.
As expected, the likelihood of adoption increases with oil palm age. Pruning is only required on palm fronds that enable access to ripe fruit bunches (see chapter 1.3). The number of leaves produced increases with age and only decreases in the last years of the life span (VERHEYE 2010).

The study aims to identify the determinants underlying the decision of smallholder farmers to adopt sustainable management practices. It has shown that a wide range of different aspects, such as social, household specific and site-specific factors significantly influence adoption. All of these aspects have to be addressed for agricultural practices to be successful.
Further analysis should include adoption rates over time. A panel data set could give more comprehensive information about adoption decisions. This is important as the present analysis showed the significance of time related variables like plot age, and to some extent, household size. The present study could not find perception variables to influence adoption decision. However, attitudes are an essential indicator of personal actions. Thus, it is necessary to conduct further research in this direction. It is also important to enhance farmers' knowledge on soil management practices. A wider knowledge can increase adoption and thus, should be applied more widely. This could be vital to increase farmers awareness of oil palm's impact on soil and water. Moreover, a forward study should include propensity score matching to examine causal links between adopters and non-adopters. The present study cannot exclude the fact that observed differences between adopters and non-adopters can be traced back to general differences rather than the adoption or non-adoption of sustainable management practices. It also, does not allow statements on whether farmers are aware of the sustainability impact of their action and can therefore not exclude the assumption that the management practices were adopted for different reasons.

6 Conclusion

In the present thesis factors are investigated that influence smallholder farmer's decision making to adopt sustainable management practices in the Jambi Province of Sumatra. Data was used from a survey of randomly selected transmigration and autochthonous villages.

The data reveal considerable influence of household and plot specific characteristics on the adoption decision. The main determinants include plot age, distance of oil palm plots to the residence, household size, number of plots and migration. These findings can be used to tailor to the needs of smallholders and address specific target groups. This will not only help to promote conservation practices, but also increase palm oil production. The latter is important on a global level, as oil palm has better environmental characteristics than alternative crops and rapidly increases in importance.

Therefore, policy incentives should take these findings into account. In particular, advanced infrastructure should be promoted to increase adoption rates on plots that are further away from a residence. Facilitated access to plots will encourage farmers to manage and maintain their oil palms more regularly. More responsible pruning leads to higher palm oil production. Thereby, pressure of forest conversion to oil palm plantations is lowered. In addition, findings of the study reveal that the analysed management practices are easy to adopt. They don't require extension services or high education. Therefore, it is important to raise smallholder farmers awareness on the value of conservation and to disseminate the importance of sustainable management practices.

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Appendix

A Questionnaire (Selected questions, that are relevant for the analysis)

CRC 990 Indonesia

Follow-up Survey-2016

This is a research project carried out jointly by the University of Göttingen in Germany, the University of Jambi and Bogor Agricultural University. We wish to learn more about the environmental conditions in Jambi Province and about the decisions that farmers make on their farms and in their communities. The survey is conducted in **5** different Districts, and your village and household was selected to be part of the study. If you agree to participate in the interview, your responses will be treated confidentially and used strictly for research purpose. The questions covered in this questionnaire are about you, your family members, farming activities, physical assets and resource management. If you have any doubts about the interview, you are free to ask questions at any time. It is important to note that there are no “right” or “wrong” answers. It is your most honest response that will help us to understand your opinion. The interview will take no longer than 2 hours. Your household number will be used for identification in the study, and therefore your name will not be used.

Section 1 - Introduction and consent

1.1 Household Identification

1. Date of Visit:	2. a) Time start: b) Time end:
3. District:	4. Village:
5. Dusun (name or number):	6. RT or Unit (number):
7. GPS Coordinates: ____________________S; __________________E;_________________Alt	
8. Household ID:	
8. Respondent (Full name):	
9. Is the respondent HH head? Yes / No	
10. If not; relation to the household head: a) HH head’s full name:	
11. Mobile phone numbers: a) Primary: b) Secondary:	
12. Distance from the household’s dwelling to the nearest market/trading center (km):	
13. Interviewer name:	
14. Supervisor name:	

15. Date questionnaire was checked by supervisor (dd-mm-yyyy):

2.3 Which crops are you or any member of your household currently **cultivating**? Please include crops that you grow on your own land, but also crops that you manage on rented or share-cropped land.

Crop	Total managed (Ha)
2. Rubber Plantation *(Less than 10 other trees per ha than rubber)*	

3.2 For the following questions, we are interested in all those oil palm plots that are **managed by yourself or a member of your household**, no matter whether the oil palms are grown on your own land or land that you rented from somebody else to grow oil palms.

How many oil palm plots are managed by your household? ☐

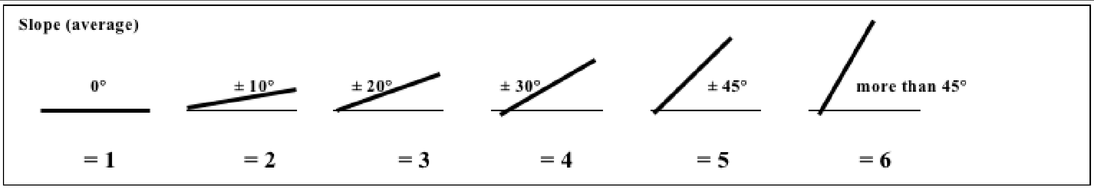
3.3 Please indicate for each of these plots managed by yourself or a member of your household…

	Plot 1	**Plot 2**	**Plot 3**
1. Size of the plot in hectares			
2. Year Planting			

3.7. How far is the plot from …
(in kilometers!) *Write 0 if it is within 500 meters, or n.a. if Not available*

	New plot: ____________	New plot: ___________	New plot: _________
1. …your house?			

	New plot:_________	New plot:_______	New plot:_____
3.8 Is there a river bordering the plot or running through the plot?	Yes/No	Yes/No	Yes/No
3.10 a. How steep is the plot on average? (see figure below)			



3.24 We would like to ask you now, how growing oil palm influences your land and your family, from your point of view. Please give us your honest opinion that is based on your personal experience.

If I grow oil palm…	**Decreases very much**	**Decreases slightly**	**No change**	**Increases slightly**	**Increases very much**
3. … water availability					
4. … water quality					

3.19 During the last 12 months, did you perform (manual) weeding or leaf pruning? Yes/No
If no, continue with question 3.20. If yes, fill out the following table, remember to complete first the information for Plot 1, and then continue with Plot 2.

	Plot 1	Plot 2	Plot 3
	Cutting leaves off the palms	**Cutting leaves off the palms**	**Cutting leaves off the palms**
	Yes/No	**Yes/No**	**Yes/No**

3.20 During the past 12 months have you…			
3. …left the palm leaves as an additional row on your plantation?	**Yes/No**	**Yes/No**	**Yes/No**

7.1 Could you tell me whether during the past 12 months you have receive extension or training about…

	Received extension?	*If yes*, who provided this extension service? {Code A}	How many times did you receive this service during the past 12 months?

10.1 In the following, I will ask you some questions about the history and characteristics of your family.

4. Total number of household members who were staying with you in the house during the past 12 months:	

10.2 For each of these_________ persons, can you please give me their names (first name is sufficient).

Enumerator: write the names into the first column; remember that the first row is for the household head.

I am now going to ask you some additional questions for each household member. Let us start with the household head.

HH Member ID	**Name**	**Age**	**Sex 1=male 2=female**	**Years of education**	**Main occupation in the last 12 months? {Code C}**	
					Primary	**Secondary**
1						

Statutory Declaration

I declare that I have developed and written the enclosed Master's Thesis myself, and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked. The Master's Thesis was not used in the same or in a similar version to achieve an academic grading or is being published elsewhere.

X	X
Date	Johanna Meinecke