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Ageing smallholders and passive successors in Indonesia's oil palm sector

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Abstract

Smallholders play an important role as producers of cash-crops in developing countries and are often responsible for land clearing and agricultural expansion into pristine environments where productivity is low. Closing yield-gaps of smallholders to industrial plantations as well as diversifying production systems has been identified as a mean to prevent further environmental degradation. At the same time, developing and emerging economies are beginning to struggle with an ageing farmer population, potentially hindering advances in land productivity. In Indonesia, increased income from oil palm cultivation has led to rapid educational attainments within one generation. While this opens job opportunities for children of oil palm smallholders, it inhibits farm succession and thus contributes to ageing among smallholders. Using primary data from a random sample of 417 oil palm smallholders in Indonesia, we investigate trends of farm succession and test, how these moderate possible effects of ageing on plantation investments and outcomes. Our results suggest, that older farmers are associated with lower productivity levels generally and are less likely to replant mature plots. These trends are moderated by succession plans of households. Succession generally moderates negative effects on productivity – indifferent of the successor's involvement. Households with a successor are generally more likely to replant. We argue that these results hint towards strategic decision-making in ageing smallholders and that observed trends of lower productivity and technology adoption in ageing farmer populations are likely a mix of both decreasing ability and strategic decisions by the farmer.

JEL Codes: D110, D910, D150.

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(1) Introduction

Oil palm cultivation in Indonesia is a socio-economic success story. Indonesia is the biggest palm oil producer globally with smallholders responsible for approximately 34% of the total production (Statista 2023, 2022). While oil palm expansion has been associated with many negative environmental consequences (Clough et al. 2016), it has also led to higher incomes, increased spending on education and improved food security among smallholder farmers (Qaim et al. 2020). Following investments of oil palm income into education, many children of oil palm smallholders are now able to pursue careers outside agriculture. This leaves an ageing population of farmers and creates uncertainty for the succession and future management of family plantations. Ageing smallholder farmers are becoming an increasing problem for the sustainability of agriculture across South-East Asia and missing successors are an important driver of this trend (Ren et al. 2023; Rigg et al. 2020). Without a successor, smallholders may choose to decrease spending or stall investments into the plantation (Apipoonyanon et al. 2021; White 2015). This is against the backdrop of predicted increases in the global demand for palm oil (OECD 2023), where closing productivity gaps for smallholders will be crucial to prevent further expansion of total oil palm area (Euler et al. 2016a). Understanding these long-term trends and their effects on farm management today is therefore crucial for policy-makers to prepare policy responses suitable to an ageing population of farmers.

We address this issue by analyzing, how ageing and different succession types among oil palm smallholders affect farm management outcomes in Indonesia. We start by identifying distinct types of (non)succession. We then use these succession types as moderating variables in the relationship of age and farm management outcomes. For short-term outcomes, we focus on fertilizer application and overall productivity of oil palm plots. With regards to long-term effects, we assess replanting behavior of smallholders. Finally, we use qualitative evidence from the region of data collection to substantiate our findings and draw policy recommendations from them.

With our work, we contribute in two main ways to the current literature on ageing in smallholder agriculture of developing and transitioning countries. First, we provide a case-study of an important smallholder population affected by ageing and under pressure of productivity increases (Dalheimer et al. 2022) with Indonesia's smallholder sector. Second, we combine insights on farm succession and long-term strategic decision-making of smallholders (Apipoonyanon et al. 2021; Arends-Kuenning et al. 2021; White 2015) with more recent research trends on ageing (Ren et al. 2023; Jansuwan and Zander 2021; Rigg et al. 2020). Doing

so, we show that negative effects of ageing can be related to decreases in ability or connected to educational attainments but likely also include strategic decision-making on the side of smallholders which depend on long-term plans like farm succession.

Given the cross-sectional nature of our data, we do not aim to establish causal relations between ageing, moderating effects of succession and farm management outcomes. Our aim here is to instead show credible associations between long-term plans of smallholders and current practices, discuss the implications of these findings and thereby provide the ground-work for future research in this arena. We first compute inverse mills ratios (IMRs) from a multinomial logit model to account for selection biases into different types of succession. With these IMRs as controls, we then assess short- and long-term changes in farm management practices. First through moderation analysis to assess effects of succession on productivity directly and indirectly through fertilizer application, and second for replanting behavior of smallholders using a logit model form of moderation analysis.

Our results suggest that older farmers are associated with lower productivity and a lower likelihood to replant mature plots. Succession plans moderate both of these effects. Lower productivities of older smallholders are only true for those households without a successor. Having a successor – even a passive one – moderates this negative effect to a non-existent one. For replanting behavior, active succession effectively moderates this negative trend while succession generally increases the likelihood to replant independent of the smallholders' age. We do not see effects of age on fertilizer applications generally or within different succession types. Qualitative evidence from focus group discussions in the region of our data collection suggests, that current smallholders expect their children to pursue careers outside agriculture while they want to keep on working on the family plantations. Their children on the other hand view plantations as an asset to be kept for a passive income while focusing on different jobs. We identify two major challenges from these shifts in management styles. First, current replanting efforts of the Indonesian government need to take into account that smallholders with a passive successor may prefer managing an ageing plantation with decreasing income over a large investment into an uncertain future and 3-5 years of reduced income after replanting. And second, the sector as a whole will need to adjust to older smallholders without successors and related declines in productivity. Finding interventions to increase productivity among this group is needed to close existing productivity gaps. This will require further research on the pathways of how ageing affects productivity and how these may be mitigated.

The rest of this paper is structured as follows. In chapter (2), we will provide a background on ageing and succession in smallholder agriculture of developing and transitioning economies as well as the Indonesian oil palm sector. Based on this, we develop a theoretical framework for our analysis in chapter (3). Chapter (4) is dedicated to our data and the analytical approach. We present results in chapter (5), discuss the implication of those results in chapter (6) and close the paper with a conclusion in chapter (7).

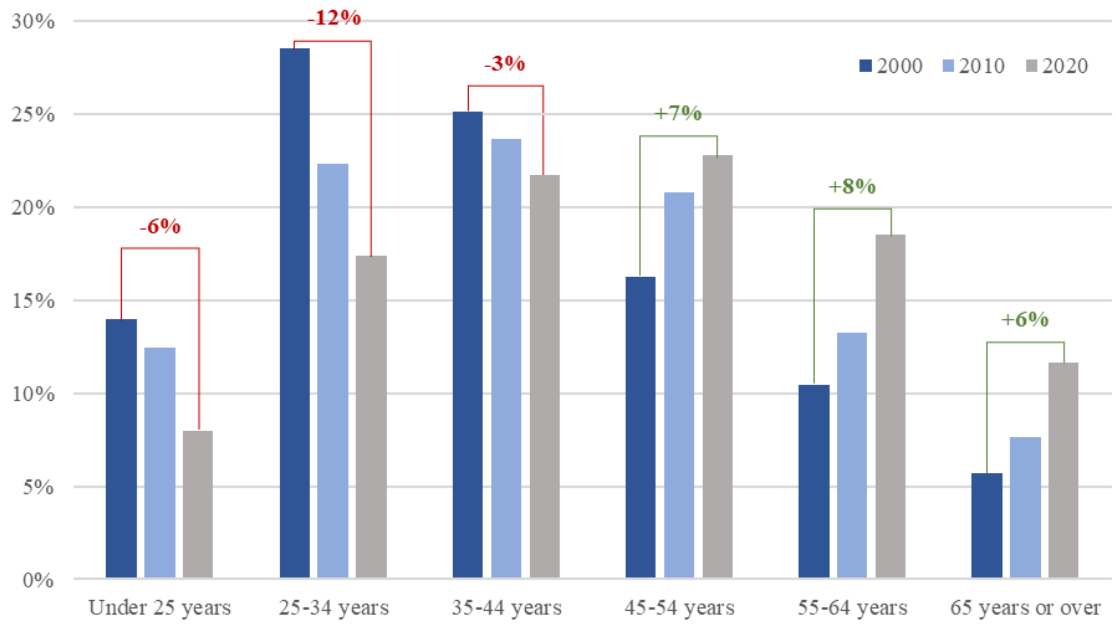
(2) Background

Ageing in smallholder agriculture

Smallholders with less than 2 hectares of land cultivate 24% of all agricultural land globally (Ricciardi et al. 2018). In the global north, economic development from agrarian- to industrial- or service-based economies has been associated with a shift from smallholder-based agriculture to large-scale intensive farming. In many countries of South-East Asia these shifts in the agricultural sector have not happened despite transitioning from agrarian to industrial or service-based economies (Rigg et al. 2020). While both employment and GDP-contribution of the agricultural sector decline, average plantation sizes remain low or even decrease (Lowder et al. 2014). At the same time, the average age of farmers increases (Rigg et al. 2020).

In Indonesia, employment in agriculture has dropped from 44% at the turn of the century to 29% in 2021 while the value added of agriculture to total GDP has declined slowly from 15% in 2000 to 13% in 2021 (World Bank 2023). Average farm sizes have decreased from 1.0 to 0.8 hectares per agricultural household between 2013 and 2023 while the average age of agricultural household heads has increased from 50.8 years to 52.5 years in the same time-span (BPS 2013, 2023a). The same trend can be observed in overall agricultural employment. The share of people occupied primarily with agriculture aged 45 or older increased from 32% in 2000 to 53% in 2020, while the share of those younger than 45 years declined from 68% to 47% (see figure 1; (BPS 2001, 2012, 2023c)).

Figure 1
Employment in agriculture by age cohort in Indonesia 2000-2020; Sources: BPS 2001, 2012, 2023c



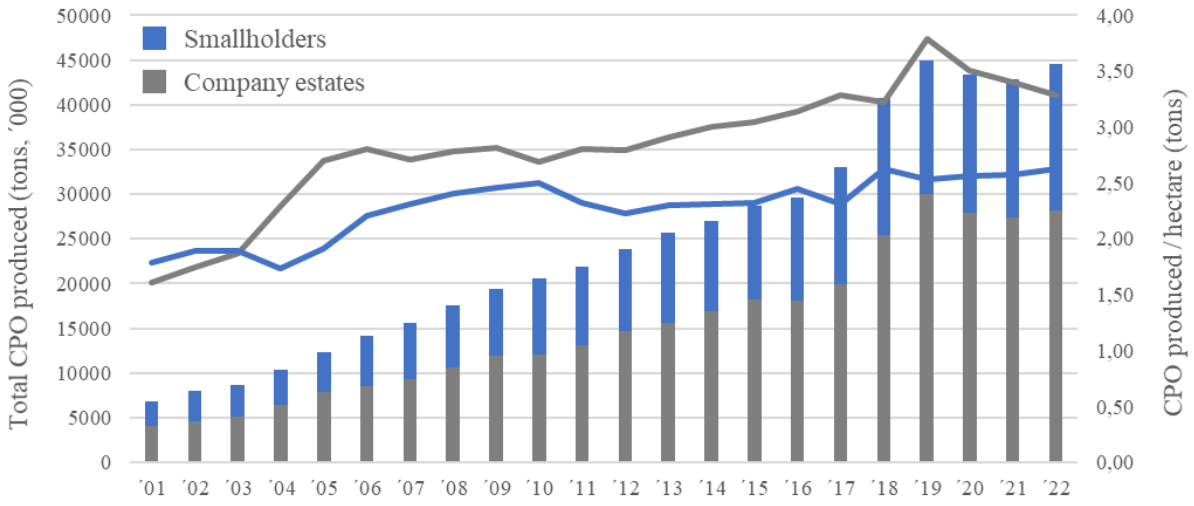
Ageing farmers have been associated with a lower likelihood to adopt new technologies (Huang et al. 2020), a reduction of agricultural inputs (Satola 2019) and a lower productivity generally (Ren et al. 2023). Recent estimates from China attribute a reduction of 5% in agricultural outputs to ageing of the farmer population between 1990 and 2019 (Ren et al. 2023). In Thailand, ageing farmers transition to less labor-intensive crops, reduce their cultivated land through leasing or leave farming altogether (Jansuwan and Zander 2021). The main issue associated with ageing in a smallholder population seems to relate to the productivity of farms. While many studies discuss the implications for farm-income and thus livelihood standards in rural areas (Rigg et al. 2020), the problem arising from declines in productivity in the Indonesian oil palm sector are likely not socio-economic but environmental.

The Indonesian oil palm sector

Oil palm cultivation in Indonesia started under Dutch colonial rule but boomed only during the 1980s and 1990s when the Indonesian government instigated a transmigration program to bring farmers from overpopulated parts of the country like Java to Sumatra (Gatto et al. 2015). Back then, companies established new plantations in a nucleus-estate-scheme around existing company plots (Euler et al. 2016b). Over time, other migrants followed and established plantations as well as locals who would mainly farm jungle rubber and other crops until then (Gatto et al. 2015). Adopting oil palm increased smallholder's income and thereby dietary quality, food consumption and other household welfare indicators like spending on children's education (Qaim et al. 2020). The main benefit of oil palm is its' high returns on labor. Oil palm

requires higher initial investments but less labor to maintain and remains productive for 25-30 years (Euler et al. 2017; Corley and Tinker 2016). However, the expansion of oil palm cultivation in Indonesia has also been associated with environmental degradation, reduced ecosystem functioning and declines in biodiversity (Qaim et al. 2020). Contrary to the overall trend in Indonesian agriculture, average farm sizes of oil palm smallholders have increased from 2.05 hectares in 2011 to 2.34 hectares in 2021 (BPS 2013, 2023a). Average farmer ages are not reported in official statistics for the oil palm sector. However, in Jambi province – a hotspot of oil palm cultivation and the region of our data collection – the average age of farmers increased from 46.3 to 49.1 years between 2013 and 2023 (BPS 2023a). Total production of crude palm oil (CPO) has been increasing steadily over the past decade but flat-lined around 45 million tons since 2019 (see figure 2). While smallholders cultivate more than 40% of the total oil palm area in Indonesia, they only produce 35% of total CPO (BPS 2023b). This is due to a lower productivity of smallholders compared to company-managed estates (see figure 2).

Figure 2
Total Production and Productivity per Hectare of Smallholders and Company-Estates in Indonesia between 2001 and 2022; Source:



The productivity of smallholder plantations and yield gaps to company-managed estates have been at the center of attention for much research in the Indonesian oil palm sector when assessing drivers of expansion into pristine environments (Euler et al. 2016a; Jelsma et al. 2017; Kubitza et al. 2018; Dalheimer et al. 2022). The main concern here is that predicted increases in the global demand for palm oil will have to be met through further expansion of total oil palm area and thus further environmental degradation, if production from the existing plantation area is not increased substantially in the smallholder sector.

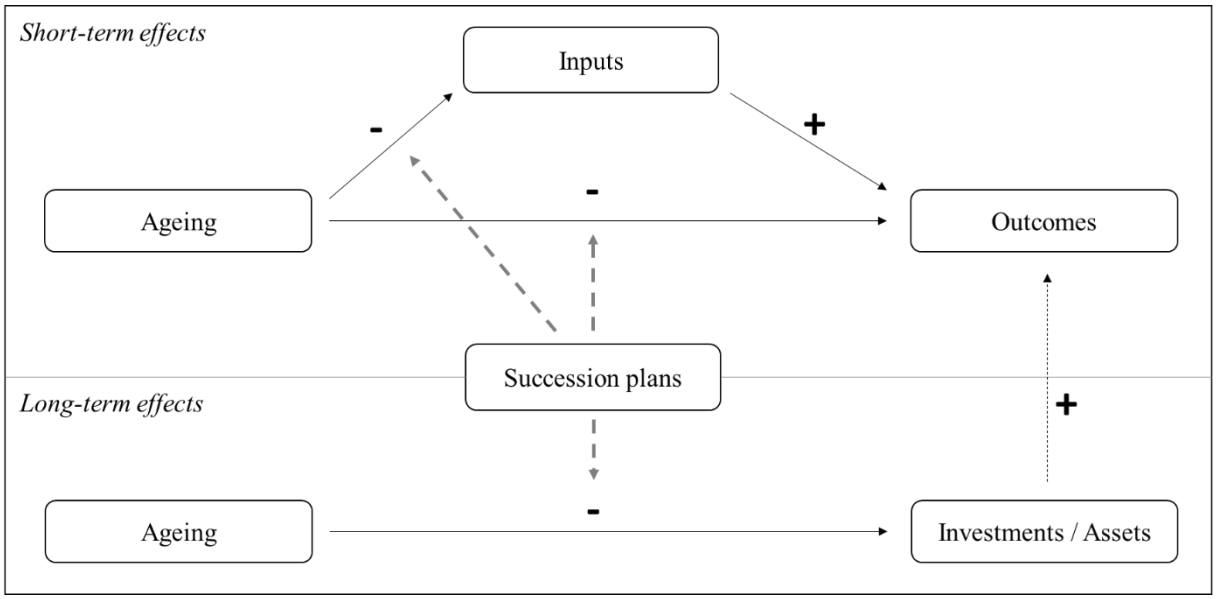
Ageing and succession

Ageing describes the process of smallholders growing older individually and on average as a group. While individual ageing is a natural process, ageing of a smallholder population only occurs if older smallholders do not exit farming and younger farmers are not entering farming anymore (Rigg et al. 2020). Ageing and succession in smallholder agriculture are two interlinked but slightly different symptoms of the same process. Succession or the failure thereof is a precursor of ageing. A successor is a key component in transferring farmland to the next generation and thus of younger farmers entering the sector (Jansuwan and Zander 2021). But even when farmland is not transferred to the next generation, older farmers could still sell their land to younger farmers outside the family and thus prevent an ageing of the smallholder population in general. Only if they have reason to hold on to their lands or fewer young people enter farming, will the population of farmers age overall. However, if farmers struggle to find successors, one can assume that this is due to a shortage of young people motivated to enter farming generally. So, while farmer's succession plans may not reflect the current stage of ageing in a population they can be interpreted as an early symptom – especially if farmers without successors are not planning to sell their land when they grow older.

More importantly, succession plans of smallholders may incur some of the negative effects associated with ageing. Existing research on farm transfers and succession is largely based on developed countries, where succession of family farms, drivers of trends and associated consequences have been widely researched (see Suess-Reyes and Fuetsch (2016) for an overview). Some studies have assessed succession trends in transitioning countries like Brazil (Arends-Kuenning et al. 2021) or China (Zou et al. 2018), but succession trends in the Global South remain thoroughly under-researched. Evidence generated in the Global North suggests, that farmers without a successor may choose to divest from their plantations and adapt more passive farm management practices or even abandon farm land (Sottomayor et al. 2011; Wheeler et al. 2012). These strategic choices likely affect the overall productivity of farms as well. If smallholders decide not to invest into new technology but instead liquidate assets, output from the farm could decline as well. In a population where many ageing farmers have no successor, these strategic decisions may be attributed to ageing if succession plans are not taken into account. This is why we believe that studies investigating trends of ageing should take long-term plans of smallholders regarding farm succession into account.

(3) Theoretical framework

Figure 3
Theoretical framework



Our theoretical framework (see figure 3) loosely based on the livelihood strategy framework, initially developed by Winters et al. (2001) and then adapted by other such as Nielsen et al. (2013) or Kühling et al. (2022). Here, households hold assets, which they use for activities to produce certain outcomes. These outcomes are then utilized for consumption or invested into activities and assets. In our model, we do not differentiate between activities and outcomes anymore. Instead, we integrate ageing as a variable affect outcomes, inputs and investments / assets.

In this framework, ageing can affect outcomes through three pathways. The first is a direct link of ageing on farm outcomes. Here, the hypothesis is that smallholders, as they grow older, loose some of their physical and cognitive ability to perform on the same level as their younger peers. They become less likely to adapt new farm management practices or adopt technology, thus reducing their farm outcomes or productivity. The second pathway is through reduced inputs. As smallholders near their retirement age, they may choose to decrease spending on inputs in order to save money for retirement and may use less of their own labor, compared to younger peers. The third pathway is through investments into farm assets. Instead of investing into the plantation, ageing farmers may stall investment or even disinvest / liquidate assets in order to finance retirement.

We now integrate succession plans as a possible moderator of these effects and ask, if and how effects of ageing on inputs, outcomes and investments might be different depending on the

smallholder's succession plans. The most obvious moderation may be a successor who is actively involved in the daily operation of the farm together with her or his parent. In this set-up any loss of physical or cognitive ability on the parental side could easily be substituted by the successor. The same is true for lower inputs in own labor. And spending on inputs such as fertilizer as well as investments into the plantation may be more appealing for the parent generation, if they know that the next generation will profit from this investment.

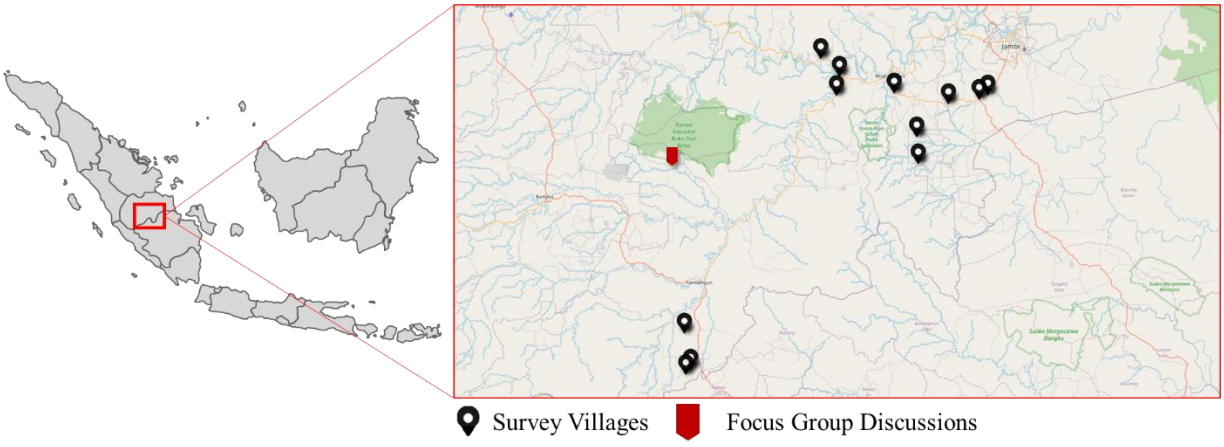
(4) Data & Descriptive Statistics

Data Collection

Our quantitative data was collected in June and July 2022 in the Jambi Province of Sumatra, Indonesia. We revisited a total of 368 households which were part of a survey in 2019 already. The data collection covered 12 randomly selected villages in three oil palm cultivation districts: Muaro Jambi, Batanghari and Sarolangun[1]. Of the original 408 households, 40 could not be revisited, as they had either moved away or were not available for interviews. We did not replace households which could not be revisited. The interviews were conducted by research assistants from the University of Jambi.

We further conducted two focus group discussions with oil palm smallholders in October 2023 in one village (Pematang Kabau) which was not part of the quantitative data collection but in the same region as the villages surveyed (see figure 5).

Figure 4
Map of surveyed villages in Jambi Province on Sumatra, Indonesia (created with OpenStreetMap.org)



[1] See Brenneis et al. (2023) for more details on household selection and randomization for the data collection in 2019 which preceded this survey.

After data cleaning, outliers in reported productivity levels of oil palm plots or applied fertilizer amounts were excluded from the analysis[2].

Ageing & succession plans of smallholders

Given that this study is based on cross-sectional data, we cannot observe the effects of individual ageing on our outcomes of interest. Instead, we aim to assess differences between older smallholders in our sample and their younger counterparts regarding farm management and how these may be mediated or moderated by succession plans.

Succession in general is a process rather than a distinct event, where responsibility of the family business is handed over to a successor over time. Passing down legal titles or the position of a manager in companies could be regarded as a specific point of succession and is often used in company-related succession research (see e.g. Bennedsen et al. 2007). However, this logic rarely applies to the context of farming in developing countries. Here, farming is often not registered as a business and land-titles may not exist or also cover family housing. They are only passed down as inheritance when the parent generation passes away. Succession can therefore not be observed through an objective indicator but rather needs to be assessed using questions on succession plans, the involvement of the successor on the farm and details on the appointed successor. For our analysis, we distinguish three different ways of succession:

(1) **Active succession** means that the household could name a successor and this person is actively working on the family plantation.

(2) **Passive succession** means that the household could name a successor, but this person is not involved in any activities on the family plantation.

(3) **No succession** means that the household head could not name a successor.

It is important for us to distinguish between active and passive succession, as many farmers plan for one of their children to succeed them in farming but those children may be living in cities and work in jobs outside agriculture. In these situations, the children may choose to keep the family plantation but only manage it from afar rather than working actively on it. This is a different trajectory compared to a successor working actively on the family plantation and important to differentiate in our analysis.

Table 2 shows the stated succession plans of the smallholders in our sample. Across all households, 80% of smallholders either plan for their oldest son to succeed (39%) them or don't

[2] See Appendix 1 for details on outliers and their exclusion as well as an overview of descriptive statistics

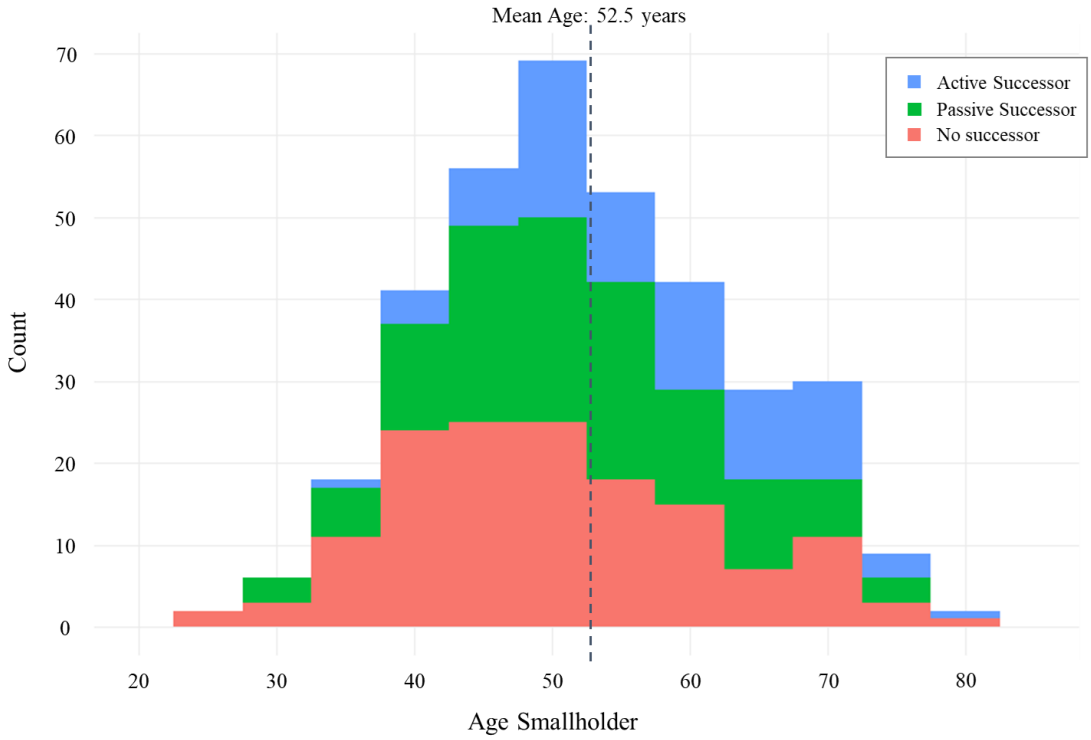
know (yet) who will succeed them (41%). Regarding the involvement of named successors, only 23% of households have an active successor, whereas 36% have a passive successor and 41% do not have a successor. As these figures also include households with young children where succession may not play any role yet, we check for only those households with adult children or no children at all. Here, 28% of smallholders have an active successor, 36% have a passive successor and 36% have no successor. So, while the age of children does affect succession plans of smallholders, the high number of households with either a passive or no successor cannot be explained by a large share of farmers with young children.

Table 1
Succession plans of smallholders; household-level data

	All households		Only with adult children	
Who will manage the farm after you?	N	%	N	%
My oldest son	145	39,4	102	42,5
One of my other children	71	19,3	50	20,8
Someone other than my children	3	0,1	2	0,1
I don't know	149	40,5	86	35,8
Total	**368**	**100**	**240**	**100**
Involvement of successor	N	%	N	%
Active Successor	86	23,4	68	28,3
Passive Successor	133	36,1	86	35,8
No Successor	149	40,5	86	35,8
Total	**368**	**100**	**240**	**100**

To further assess the interplay of age and succession plans, we plot succession plans over the age of successors in our sample and provide the results in figure 5. These confirm that especially active succession only appears to happen for smallholder households aged 40 and above but the shares between active, passive and no succession households remain relatively stable for households over the age of 50.

Figure 5
Age of smallholders & succession plans; household-level data



Fertilizer application and productivity of smallholder plots

The average productivity of smallholder oil palm plantations in Indonesia consistently falls short of both maximum obtainable yields as well as those obtained by company-managed plantations (Euler et al. 2016a; Dalheimer et al. 2022; BPS 2023b). Fertilizer applications in terms of total amounts, timing and placement have been identified as a key lever to close productivity gaps (Woittiez et al. 2017; van Noordwijk et al. 2017). Given the recent increases in global fertilizer prices, smallholders globally have been reported to reduce applied fertilizer rates as a response (World Bank Blogs 2023). Table 3 displays average fertilizer application rates (all fertilizer) in our sample as well as land productivity measured as tons of fresh-fruit bunches produced per hectare per year. We distinguish these figures by succession types of the related households as well as age quantiles in our sample. We use plot-level data as smallholders often cultivate multiple small plots of different ages or sizes. Using a Tukey test, we find statistically significant differences in fertilizer application. Both active and passive succession households appear to be more efficient compared to non-succession households. They apply 138kg and 127kg less fertilizer per hectare. We find no significant difference in means of productivity between succession types. Age quantiles display differences between the youngest

and oldest farmers (bottom vs. top 25%) of 75kg per hectare per year as well as between the 3rd and 4th quantile. We find no significant difference in mean productivity here either3.

Table 2
*Fertilizer application and productivity of smallholders; Plot-level data; Significance of mean differences obtained through ANOVA & Tukey HSD test; *p<0.1, **p<0.05. ***p<0.01*

		Fertilizer Application (kg / hectare / year)		Productivity (tons / hectare / year)	
Succession plans	N	Mean	Std. Dev.	Mean	Std. Dev
Active Successor	178	429 ┐***	303	13.2	8.9
Passive Successor	258	418 ┐***	262	12.1	7.3
No Successor	292	556 ┘	309	12.2	8.1
Age Quantiles	N	Mean	Std. Dev.	Mean	Std. Dev
< 44 years (1st Quant.)	185	508 ┐*	315	13.4	8.3
45-51 years (2nd Quant.)	178	453	275	11.7	7.5
52-60 years (3rd Quant.)	186	508 ┐*	286	12.5	7.6
> 60 years (4th Quant.)	179	434 ┘	310	11.9	8.7
Total Sample	**728**	**476**	**299**	**12.4**	**8.0**

Replanting of oil palm

The productive lifecycle of oil palm spans 25-30 years before the economic productivity starts to decrease[4]. This is mainly due to the height of the palm reaching more than 10 meters, making harvesting more difficult, as well as a reduced production of fruit-bunches (Corley and Tinker 2016). In Indonesia, different sources estimate that 30-50% of all smallholder oil palm plantations will require replanting within this decade (Petri et al. 2023). Replanting oil palm poses a challenge to smallholders, as it requires finances, knowledge and inputs, but it also offers an opportunity to redesign plantations, incorporate new seedlings or more biodiverse layouts (Nurfatriani et al. 2019; Qaim et al. 2020). Given that oil palms remain unproductive for 3-5 years after replanting, the investment incorporates not only the removing of old stems and establishment of the new plantation but also the missing income from productive oil palm during the first years after replanting.

Table 4 displays the replanting plans of smallholders in our sample, disaggregated by their succession type and age quantile. Smallholders in our sample were asked which of their plots they had replanted in the past 5 years (if any) and which they were planning to replant in the

[3] See appendix 2 for mean differences between all groups including 95% confidence intervals
[4] See appendix 3 for a visualization of the age-productivity relation in our sample as well as descriptive visualizations of age and farm outcomes

next 5 (if any). We use plot-level data here to account for the fact that smallholders may have replanted or plan to replant multiple plots in the time-frame we are interested in. For the past 5 years, 5% of all plots were replanted by smallholders. We observe a large difference between succession types – 10% of all plots belonging to active succession households and 7% of those belonging to passive succession households have been replanted while only 1% of those plots connected to households without succession plans. The difference between active and no succession households as well as the one between passive and no succession households is statistically significant at a 95% confidence level, using a Tukey test. For future replanting plans, only the difference of plots planned to be replanted by active succession households (16%) compared to passive (7%) and no succession (5%) households is statistically significant. Regarding age quantiles, it appears that older farmers are generally more likely to either own plots where replanting is planned or has already happened. While farmers in the top 25% age quantile are most likely to own plots which were replanted, those age 52-60 years are most likely to own plots where replanting is planned for the upcoming 5 years.

Table 3
*Replanting of smallholders; Plot-level data; Significance of mean differences obtained through ANOVA & Tukey HSD test; *p<0.1, **p<0.05. ***p<0.01*

		Replanted in past 5 years		Replant in next 5 years	
Succession plans	N	Mean	Std. Dev.	Mean	Std. Dev
Active Successor	180	0.10 ***	0.30	0.15 **	0.36
Passive Successor	259	0.07 ***	0.25	0.08	0.27
No Successor	307	0.01	0.10	0.05 ***	0.22
Age Quantile	N	Mean	Std. Dev.	Mean	Std. Dev
<44 years	185	0.05	0.23	0.06	0.24
44-51 years	178	0.07	0.25	0.07 **	0.25
52-60 years	186	0.02 **	0.13	0.15 * **	0.35
>60 years	179	0.08	0.27	0.07	0.26
Total Sample	**746**	**0.05**	**0.23**	**0.09**	**0.28**

(5) Methodology

Our goal in this analysis is to assess the effect of age on short- and long-term management outcomes (fertilizer usage, productivity & replanting behavior), as well as the moderating effect of succession types in this relation. To account for selection bias into succession types, we first run a selection model with potential predictors of succession types. We then calculate the

inverse mills ratio (IMR) based on this selection model and use it as a control in our estimations of the effect of succession types on farm management. For fertilizer application and productivity, we use a conditional process analysis to assess both direct and indirect effects of age on productivity and include succession types as a moderator. For replanting, we use a standard Logit moderation model.

Selection into succession types

In the first part of our analysis, we focus on determining factors for succession types of households. The goal of this analysis is to calculate the probabilities of a household to end up in its' respective succession type and thereby control for a potential selection bias when assessing the effects of succession types on farm management outcomes.

As our main dependent variable is a categorical indicator ranging from 1 to 3 (1 = no succession, 2 = passive succession, 3 = active succession), we employ a multinomial logit model for this first step. We follow studies such as Arends-Kuenning et al. (2021) to focus on household characteristics which are likely exogenous to succession plans when selecting independent variables in this step. One such exogenous variable identified as a relevant predictor of succession is related to the gender of the children of a household (Arends-Kuenning et al. 2021). As oil palm cultivation is largely male-dominated, we assume that not having a male child reduces the probability of having a successor. We therefore assign a dummy variable which measures, if at least one child of a household is male. We further control for those households with at least one adult child as well as the total number of children per household.

The next set of indicators is related to the education of the household head. Our assumption here is that higher levels of parental education translate into higher educational achievements of children and therefore a lower chance of an (active) succession, as higher educational achievements provide more opportunities for employment outside agriculture. As we cannot include the educational achievements of children due to endogeneity problems, we use parental education as an exogenous proxy.

We further control for some household-level characteristics like the age of the household head and the household's migration history. We also include two variables to measure the remoteness of the household's location. The first is the household's distance from the (regional) capital Jambi City and the second is the distance to the nearest cellular tower[5].

[5] We use the OpenCellid database to find the closest cellular tower to the households GPS location for this calculation.

On the farm-level we include a dummy, indicating whether or not the smallholder has an official land title for his main plot.

Our multinomial Logit model therefore has the following specification:

$$(1)\ \log\left(\frac{P(Y_i=j)}{P(Y_i=K)}\right) = \beta_{0j} + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_n X_{ni}$$

Where $P(Y_i = j)$ is the probability of household i belonging to succession type j and $P(Y_i = K)$ is the probability of household i belonging to the reference category K. β_{0j} is the intercept for succession type j and $\beta_1 \ldots \beta_n$ are coefficients for our predictors $X_1 \ldots X_n$ as outlined above.

We obtain the inverse mills ratio (IMR) as follows:

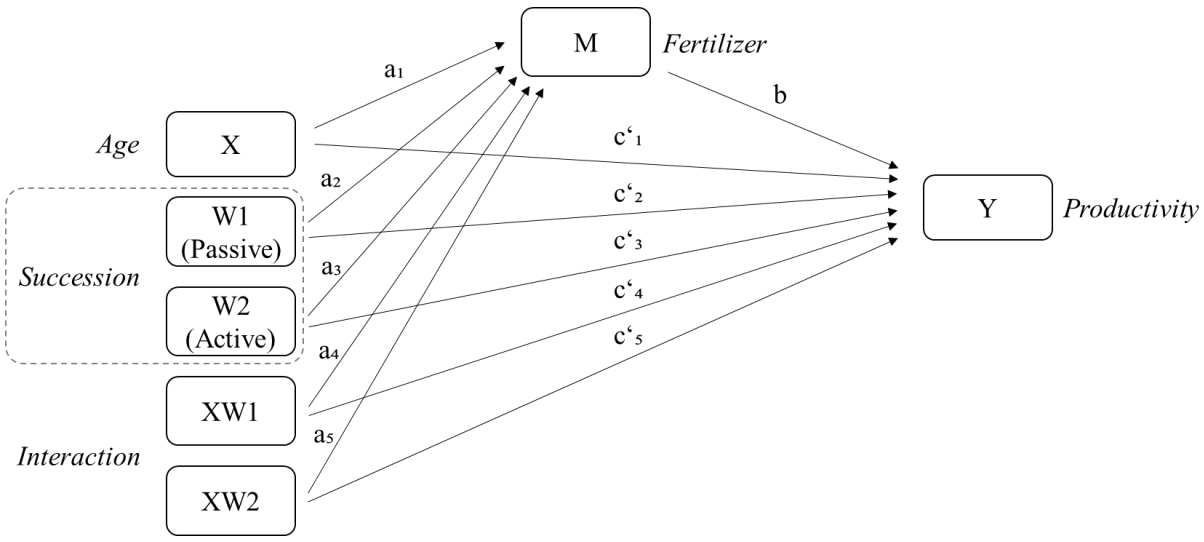
$$(2)\ IMR_j = \frac{\varnothing(\beta_{0j}+\beta_1 X_{1i}+\beta_2 X_{2i}+\cdots+\beta_n X_{ni})}{1-\Phi(\beta_{0j}+\beta_1 X_{1i}+\beta_2 X_{2i}+\cdots+\beta_n X_{ni})}$$

Where $\varnothing(\cdot)$ is the probability density function and $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution.

Effect of succession on productivity and fertilizer usage

The second step of our analysis is dedicated to the effects of succession types on fertilizer application and land productivity. As is evident from our descriptive analysis, succession types seem to affect both fertilizer application as well as land productivity. As fertilizer usage is likely a predictor of productivity, we use a conditional process model, where fertilizer application acts as a mediator between age and productivity, as well as succession types as moderators (see figure 6).

Figure 6
Statistical diagram for a conditional process analysis based on Hayes (2022)



We estimate these effects using two linear models, following Hayes (2022):

(3) $M = i_M + a_1X + a_2W_1 + a_3W_2 + a_4XW_1 + a_5XW_2 + e_M$

(4) $Y = i_Y + bM + c'_1X + c'_2W_1 + c'_3W_2 + c'_4XW_1 + c'_5XW_2 + e_Y$

(5) $\theta_{X\rightarrow M} = a_1 + a_4W_1 + a_5W_2$

(6) $\theta_{X\rightarrow Y} = c'_1 + c'_4W_1 + c'_5W_2$

Where X is the age of the smallholders., M is fertilizer application (kg per hectare & year) and Y is land productivity measured as tons of fresh-fruit-bunches (FFB) per hectare per year. i_M and i_Y are intercepts, $e_M$and e_Y are error terms, a_1 and a_2 are the regression coefficients for our respective succession types W_1 (Passive) and W_2 (Active) on fertilizer application. a_4 and a_5 are regression coefficients for our interaction terms of succession type and age. b is the regression coefficient for fertilizer application on land productivity. c'_1, c'_2 and c'_3 are the respective regression coefficients for age and our succession types on productivity.c'_4 and c'_5 are regression coefficients for our interaction terms of succession type and age. $\theta_{X\rightarrow M}$ is the conditional effect of X (age) on M (fertilizer) and $\theta_{X\rightarrow Y}$ the conditional effect of age on productivity.

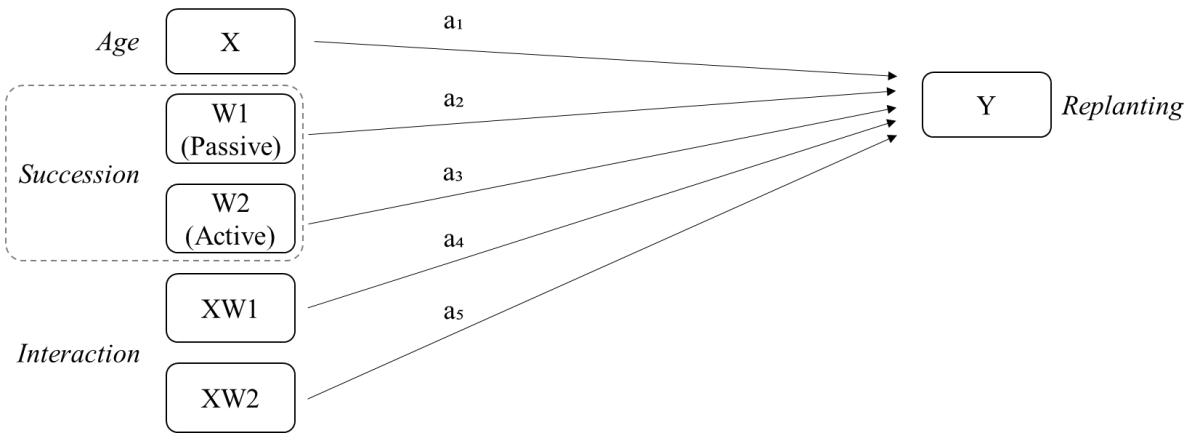
We further add a vector of plot- and household-level controls to the two linear models including the IMR obtained before. We use bootstrapping to calculate standard errors and thus confidence intervals of our effects.

Effect of succession types on replanting decision

We assess replanting behavior using a logit moderation model, where the age of a smallholder is our main predictor, replanting behavior is the outcome and succession is the moderator (see figure 9).

Figure 7

Statistical diagram for a moderation analysis based on Hayes (2022)



We estimate the effects using a logit model of the following specification:

(7) $\log\left(\frac{P(Y=1)}{1-P(Y=1)}\right) = i_Y + a_1X + a_2W_1 + a_3W_2 + a_4XW_1 + a_5XW_2$

(8) $\theta_{X\to Y} = a_1 + a_4W_1 + a_5W_2$

Where Y is a dichotomous variable taking the value 1, if a smallholder has either replanted the respective plot in the past 5 years or is planning to replant the plot in the next 5. The regression coefficients can be interpreted as before but will indicate log likelihoods in this model. In one analysis, we restrict the sample to plots aged 25 years or older. In this setting, Y=1 only reflects those plots, planning to be replanted in the next 5 years.

$\theta_{X\to Y}$ is the conditional effect of age on the likelihood to engage in replanting.

Focus group discussions

We conducted two focus group discussions to discuss our quantitative findings with smallholders from the region of our data collection and collect narratives around succession, generational transfers of plantations and ageing in the oil palm sector. The first focus group discussion was targeted at oil palm smallholders, their succession planning as well as their investment behavior regarding fertilizers and replanting. We invited all smallholders from the village to join this discussion. 24 oil palm owning smallholders followed our invitation to join this discussion. The second discussion was designed for adult children of oil palm smallholders or young smallholders. Here, we wanted to understand their motivations to enter or leave oil palm cultivation as an occupation. For this meeting, the local youth organization extended invitations to anyone interested. A total of 12 young adults joined us of which all were connected to oil palm cultivation either through their parent's plantation, their own plantation or through their work as daily laborers on plantations.

All meetings were recorded and transcribed by local assistants. We analyze this qualitative data for narratives among both groups as well as potential explanations of the effects we find.

(6) Results

Selection into succession types

The main results of our multinomial logistic regression as laid out in equation (1) of our framework are presented in table 4. They confirm findings from studies such as Arends-Kuenning et al. (2021) that having a male child seems to affect succession types. In our sample, those households with a male child are 2.06 times more likely to also have an active successor compared to no succession households. As expected, those housheolds with adult children are also more likely to have a passive (1.83 times) or active successor (2.58 times) compared to no succession households, as those with younger children are less likely to plan for succession yet. Interestingly, the total number of children is negatively associated with the likelihood of having a passive successor. More remote households are also less likely to have a passive successor and those households which were part of the transmigration program are 1.49 times more likely to have a passive successor and 1.27 times more likely to have an active successor. As mentioned before, we use the results of this model to calculate the inverse mills ratio (IMR) of households belonging to one type of succession to account for selection bias in the next steps of our analysis as described in equation (2) of our methodological framework.

Table 4
Multinomial logit model results; household-level data

Dependent Variable:	***Passive Succession***	***Active Succession***
Any Male child	0.74	2.06***
	(0.21)	(0.10)
Any Adult child	1.83***	2.58***
	(0.19)	(0.10)
Number of Children	0.79*	0.80
	(0.13)	(0.13)
Education Household Head	0.94	0.80
	(0.14)	(0.17)
Age of Household Head	1.08***	1.18***
	(0.03)	(0.03)
Age of Household Head Sqrd.	0.99	0.99***
	(0.00)	(0.00)
Distance to Regional Capital	0.76**	0.85
	(0.11)	(0.11)
Distance to closest Cellular Tower	0.99	1.01
	(0.00)	(0.00)
Official Land title	1.02	1.03
	(0.07)	(0.08)
Transmigration Program	1.49***	1.27***
	(0.08)	(0.06)

Constant	*0.22***	*0.00****
	(0.01)	*(0.00)*
Observations	368	368
Controls	YES	YES

Note: *p<0.1; **p<0.05; ***p<0.01; Displayed coefficients are relative risk ratios

Conditional process analysis

We start this part of our results by presenting the regression model as outlined in equation (3) of our methodological framework. In our first model, we regress fertilizer application on the age of smallholders and in the second model, we include succession types of households as well as their interaction terms with smallholder age (see Table 5).

Generally, we see no significant effect of age on fertilizer applications. This is true for both model specifications. The interaction terms with succession types are not statistically significant either. However, passive succession households use about 93kg less fertilizer per hectare on average compared to non succession households – independent of the age of the smallholder. The plot age and land title are both relevant predictors on the plot-level whereas farm assets held by the household, cooperative memberships as well as the distance of the household to the regional capital Jambi are significant predictors on the household level. We also see that including succession types and their interactions improves the model fit slightly from a R^2 value of 0.14 to 0.16.

Table 5
Results for conditional process model following equation (3); Plot-level data

Dep. Variable:	***Fertilizer (kg / hectare / year)***					
	Without moderation			With moderation		
	Coefficient (SE)	LCI	UCI	Coefficient (SE)	LCI	UCI
Age Farmer	-0.34 (1.20)	-2.65	2.05	-0.28 (1.91)	-4.06	3.52
Passive Succession	-	-	-	**-93.33 (24.44)**	**-142.32**	**-43.91**
Active Succession	-	-	-	-32.50 (-30.21)	-179.57	124.43
Age * Passive Succession	-	-	-	-0.77 (2.48)	-5.64	4.10
Age * Active Succession	-	-	-	0.84 (2.74)	-4.52	6.34
Plot Size	-1.90 (5.30)	-12.58	8.47	-0.97 (5.21)	-11.36	9.19
Plot Age	**10.99 (4.22)**	**2.82**	**19.24**	**11.31 (4.21)**	**3.25**	**19.49**

Plot Age Squared	-0.24 (0.13)	-0.50	0.01	**-0.25 (0.13)**	**-0.51**	**-0.01**
Land title	**85.84 (18.02)**	**51.12**	**121.47**	**82.68 (18.55)**	**46.48**	**118.87**
Assets Farm	**35.59 (7.42)**	**21.11**	**50.26**	**28.42 (7.49)**	**13.88**	**43.15**
Education Farmer	16.90 (11.49)	-5.20	39.75	17.46 (11.16)	-3.94	39.59
Cooperative Member	**116.37 (23.09)**	**71.07**	**160.66**	**105.42 (23.52)**	**58.77**	**150.60**
Migration Program	8.21 (29.49)	-49.71	66.72	21.29 (29.95)	-37.96	80.39
Bank Account	27.70 (20.94)	-12.82	68.49	23.18 (21.57)	-18.76	65.57
Distance to regional capital	**0.83 (0.34)**	**0.19**	**1.51**	**0.81 (0.35)**	**0.14**	**1.51**
Inverse mills ratio	-84.35 (71.71)	-223.77	57.43	-140.66 (203.71)	-547.80	247.75
Constant	*-131.93 (107.03)*	*-341.24*	*79.37*	*-34.34 (106.46)*	*-242.95*	*175.34*
Observations	727			727		
R^2	0.14			0.16		

Note: Bootstrapped standard errors; LCI = lower confidence interval; UCI = upper confidence interval; Confidence intervals at 95%

Next, we regress land productivity as tons of fresh-fruit-bunches harvest per hectare per year on the age of smallholders. In the first model specification, we do not include succession types but introduce them in the second specification including their interactions with smallholder age (see table 5)

While not quite significant at a 95% confidence level, the age of smallholders is likely associated negatively to land productivity in the first model specification, as is evident from the confidence intervals obtained through bootstrapped standard errors. When we introduce succession types and their interaction terms with smallholder age, the negative effect becomes even more pronounced, while neither the succession dummies nor their interaction terms with age are statistically significant. Contrary to other studies (see e.g. Ren et al. (2023)), we see no effect of educational attainments on productivity. Only bank account ownership has a relevant negative effect on productivity in our model specification on the farmer-level.

On the plot-level, fertilizer application rates are positively associated with productivity, plot size shows a negative association and plot age has a non-linear but significant association, as expected. Farm assets are positively associated with productivity on the household level.

Table 6
Results for conditional process model following equation (4); Plot-level data

Dep. Variable:	***Land Productivity (tons / hectare / year)***					
	Without moderation			With moderation		
	Coefficient (SE)	LCI	UCI	Coefficient (SE)	LCI	UCI
Age Farmer	-0.04 (0.03)	-0.09	0.01	**-0.07 (0.04)**	**-0.15**	**0.00**
Passive Succession	-	-	-	0.61 (0.60)	-0.57	1.78
Active Succession	-	-	-	0.27 (1.73)	-3.06	3.67
Age * Passive Succession	-	-	-	0.07 (0.05)	-0.03	0.18
Age * Active Succession	-	-	-	0.04 (0.07)	-0.11	0.18
Fertilizer	**0.003 (0.001)**	**0.001**	**0.005**	**0.003 (0.001)**	**0.001**	**0.005**
Plot Size	**-0.33 (0.10)**	**-0.51**	**-0.12**	**-0.32 (0.10)**	**-0.52**	**-0.12**
Plot Age	**1.71 (0.09)**	**1.54**	**1.88**	**1.71 (0.09)**	**1.53**	**1.88**
Plot Age Squared	**-0.04 (0.003)**	**-0.05**	**-0.04**	**-0.04 (0.003)**	**-0.05**	**-0.04**
Land title	0.30 (0.52)	-0.70	1.33	0.31 (0.52)	-0.69	1.34
Assets Farm	**0.78 (0.16)**	**0.47**	**1.10**	**0.81 (0.16)**	**0.50**	**1.14**
Education Farmer	-0.23 (0.23)	-0.71	0.20	-0.23 (0.24)	-0.71	0.22
Cooperative Member	0.47 (0.54)	-0.58	1.56	0.53 (0.56)	-0.56	1.64
Migration Program	-1.05 (0.66)	-2.34	0.25	-1.13 (0.68)	-2.46	0.21
Bank Account	**-2.37 (0.52)**	**-3.37**	**-1.36**	**-2.31 (0.52)**	**-3.30**	**-1.29**
Distance to regional capital	-0.01 (0.01)	-0.02	0.00	-0.01 (0.01)	-0.02	0.01
Inverse mills ratio	**4.47 (1.77)**	**1.09**	**7.96**	4.67 (4.57)	-4.31	13.58
Constant	*-2.29 (2.23)*	*-6.69*	*2.12*	*-5.21 (2.45)*	*-10.05*	*-0.40*
Observations	727			727		
R^2	0.38			0.39		

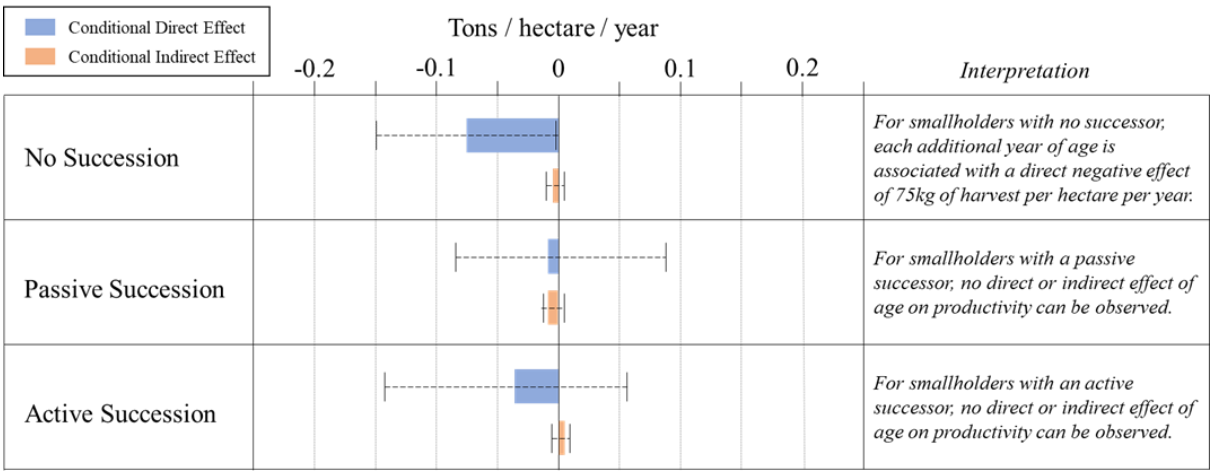
Note: Bootstrapped standard errors; LCI = lower confidence interval; UCI = upper confidence interval; Confidence intervals at 95%

Following these results, we now calculate conditional direct and indirect effects of age on productivity moderated by succession types, as outlined in equations (5) and (6). The results are visualized in figure 8.

These results suggest, that for households without a successor, increasing age of smallholders is associated with a decline of productivity at 75kg of harvest per year and hectare for each year of age. A confidence interval at the 95% level remains strictly negative using bootstrapped standard errors. The same effect is not true for households with a passive or active successor, where the age of the smallholder has no significant effect on productivity.

As was evident from the regression results, no effect of age on fertilizer usage, and thus indirectly on productivity, can be observed in our sample. This is true across households, indifferent of their succession plans.

Figure 8
Conditional effects of age on productivity; Plot-level data



Note: Displayed figures are coefficients; brackets display lower and upper 95% confidence intervals with bootstrapped standard errors

Effects of succession on replanting decisions

Finally, we present the results of our Logit model estimating the effect of age on replanting behavior of smallholders. Again, we first estimate the model without succession plans or their interaction terms with smallholder age and then introduce them in the second model specification (see Table 7). Replanting behavior in this estimation is a dummy variable taking the value 1, if a plot was either replanted in the past 5 years or is planned to be replanted in the next 5 years and 0 else.

Generally, we do not observe an effect of age on replanting behavior of smallholders. The respective coefficients are negative but the confidence intervals obtained from bootstrapped standard errors do not allow to reject the hypothesis that they may be 0 or positive. However, when we introduce succession types and their interaction terms into the model, the coefficient

for passive succession households is positive and statistically significantly different from 0 at a 95% confidence level. Active succession is also positive and the effect even stronger but not quite significant at the 95% level. Because we centered the age of farmers around the mean for our estimations, these coefficients can be interpreted in a meaningful way. Here, they estimate the difference in log-odds of plots being replanted (in the past or future) in passive (or active) succession households versus non-succession households at the mean age of smallholders (~51 years). Log-odds of 1.54 therefore equate to plots being 4.66 times ($e^{1.54}$) more likely to be replanted in passive succession households compared to non-succession households for smallholders at the mean of the age distribution.

Table 7
Logit model results for replanting decisions

Dependent Var.:	***Plot was replanted or will be replanted***					
	Without moderation			With moderation		
	Coefficient (SE)	LCI	UCI	Coefficient (SE)	LCI	UCI
Age Farmer	-0.01 (0.02)	-0.05	0.02	-0.02 (0.03)	-0.08	0.04
Passive Successor	-	-	-	**1.54 (0.48)**	**0.81**	**2.69**
Active Successor	-	-	-	1.83 (1.02)	-0.04	3.90
Age * Passive Successor	-	-	-	0.0004 (0.04)	-0.08	0.07
Age * Active Successor	-	-	-	0.02 (0.04)	-0.06	0.09
Plot size	0.07 (0.11)	-0.18	0.27	0.08 (0.11)	-0.16	0.31
Plot age	**-0.57 (0.07)**	**-0.75**	**-0.48**	**-0.62 (0.08)**	**-0.83**	**-0.53**
Plot age sqrd.	**0.02 (0.002)**	**0.02**	**0.03**	**0.02 (0.003)**	**0.02**	**0.03**
Land title	-0.36 (0.35)	-1.15	0.22	-0.37 (0.45)	-1.48	0.32
Education Farmer	0.08 (0.14)	-0.20	0.36	0.07 (0.16)	-0.26	0.38
Assets Farm	-0.01 (0.12)	-0.24	0.22	0.07 (0.13)	-0.19	0.31
Cooperative member	-0.33 (0.36)	-1.06	0.35	-0.37 (0.38)	-1.17	0.31
Migration program	-0.17 (0.35)	-0.86	0.50	-0.22 (0.36)	-0.96	0.46
Bank account	**-1.31 (0.35)**	**-2.08**	**-0.72**	**-1.25 (0.36)**	**-2.02**	**-0.66**

Distance to capital	**0.01 (0.005)**	**0.001**	**0.02**	**0.01 (0.005)**	**0.002**	**0.02**
IMR	1.57 (0.90)	-0.11	3.41	-0.89 (2.76)	-6.21	4.63
Observations	727			727		
Log Likelihood	-177.76			-125.95		

Notes: Coefficients are log-odds; Bootstrapped standard errors; LCI = Lower Confidence Interval; UCI = Upper Confidence Interval; CI at 95% confidence; IMR = Inverse Mills Ratio from selection equation; *p<0.1, **p<0.05, ***p<0.01

We probe for conditional effects following equation (8) again but do not find any significant or meaningful moderation effects of succession types on the age-replanting relation.

To substantiate our findings, we also estimate this model only for future replanting plans and limit the sample to those plots which require replanting within the next 5 years or are already overdue – i.e., plots aged 20 years or older. The results are displayed in table 8.

Here, we observe a negative association of smallholder age with the likelihood to plan replanting plots which are aged 20 years or older. This is true for both model specifications. Dummy variables for succession types as well as their interaction terms do not have a significant effect on the likelihood to plan replanting.

Table 8
Probit model results for future replanting plans

Dependent Var.:	***Plot will be replanted in the next 5 years***					
	Without moderation			With moderation		
	Coefficient (SE)	LCI	UCI	Coefficient (SE)	LCI	UCI
Age Farmer	**-0.08 (0.04)**	**-0.18**	**-0.02**	**-0.09 (0.35)**	**-0.31**	**-0.01**
Passive Successor	-	-	-	0.84 (2.99)	-0.60	3.81
Active Successor	-	-	-	2.36 (16.49)	-0.86	9.83
Age * Passive Successor	-	-	-	-0.02 (0.52)	-0.23	0.22
Age * Active Successor	-	-	-	0.03 (0.41)	-0.22	0.27
Plot size	0.06 (0.20)	-0.39	0.42	0.08 (0.92)	-0.45	0.55
Plot age	**0.50 (0.15)**	**0.36**	**0.95**	**0.53 (2.79)**	**0.40**	**1.42**
Land title	-0.90 (3.08)	-8.92	0.56	-0.83 (10.60)	-16.62	0.98

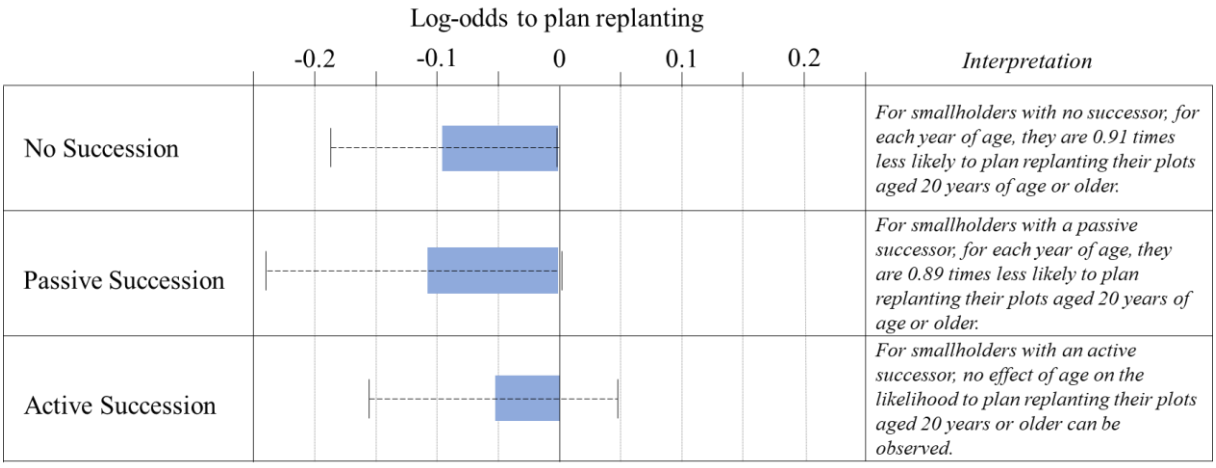
Education Farmer	-0.07 (0.34)	-0.74	0.65	-0.11 (1.09)	-1.20	0.74
Assets Farm	0.12 (0.22)	-0.29	0.60	0.17 (0.88)	-0.29	0.83
Cooperative member	2.29 (7.69)	-0.25	25.44	2.53 (24.53)	-0.45	31.66
Migration program	0.44 (0.61)	-0.66	1.74	0.38 (4.72)	-1.12	2.54
Bank account	**-2.14 (0.69)**	**-3.99**	**-1.30**	-2.03 (6.65)	-5.20	-1.19
Distance to capital	**0.04 (0.04)**	**0.02**	**0.19**	**0.04 (0.32)**	**0.01**	**0.24**
IMR	1.28 (2.05)	-1.75	6.36	-4.14 (23.14)	-20.22	6.22
Observations	186			186		
Log Likelihood	-66.76			-64.62		

Notes: Coefficients are log-odds; bootstrapped standard errors; LCI = Lower Confidence Interval; UCI = Upper Confidence Interval; CI at 95% confidence; IMR = Inverse Mills Ratio from selection equation;
*p<0.1, **p<0.05, ***p<0.01

For this model specification, we find significant moderation effects of succession types on age-replanting relations. The results following equation (8) are displayed in Figure 9 below.

The conditional effect estimations show, that the negative relation between age and the log-odds to plan replanting plots aged 20 years or older is only true for non-succession and passive succession households. While the effect for passive succession households is not quite significant at a 95% level, the obtained confidence intervals make it appear likely that there is a negative effect. This is not true for active succession households.

Figure 9
Conditional effects of age on replanting decisions; plot-level data



Narratives from focus group discussions

Oil palm smallholders from the village of Pematang Kabau are very aware of the demographic changes in their sector. According to them, many young people move to the cities and those staying are no longer motivated to become full-time farmers. While some of the participants seemed upset about this, they also frequently mentioned the importance of their children's education in order to find good jobs or bring back their newly gained knowledge to the village or family plantation. Contrary to the data in our sample, none of the participants mentioned that they do not have a successor at all. However, on the other end, only one participant had a successor working actively on the farm with him. For all other participants, children were either engaged in other occupations or not motivated to work on the family plantation at all. The general lack of interest from their children seems to affect the transfer of knowledge between generations. One farmer mentioned that everything you need to know about oil palm farming can now be found on YouTube - so it would be a waste of time to teach his children. Aligned with this narrative of youth disengaging from farming, smallholders agreed that they rarely, if ever, include their adult children in any decisions regarding the family plantation. Contrary to this missing motivation of transferring knowledge to their children, two smallholders mentioned that if the next generation does not actively engage in farming anymore, the productivity of smallholder plots will probably decrease. They underlined the importance of their children using their education to improve the productivity of the oil palm plantation.

Confronted with the question of ageing in oil palm, many farmers agreed that it is a physically taxing job. One even went so far to say that one was lucky to live past 60 years of age in this village. If this claim was directly related to oil palm cultivation or a more general statement about the health status of villagers could not be determined.

When asked if they would consider selling their plantation at any point, all farmers present strongly declined. To them, their oil palm plantation provides a relatively stable, good income. Instead, they argued that they would rather buy more land for oil palm cultivation but said that none is available anymore. However, they did agree that selling some parts of your plantation to finance extraordinary expenses such as a child's education or health emergencies is relatively common.

When confronted with descriptive statistics on yields and fertilizer usage of different smallholder groups from our sample, some participants mentioned that those households without a successor may choose to outsource more tasks to daily laborers. According to their experience, these laborers may either apply too much fertilizer or, in some cases report higher

figures to the plantation owner, apply a normal amount and sell the leftover fertilizer to make an additional income.

Replanting is a very salient topic among the smallholders in Pematang Kabau and some smallholders have either replanted recently or are planning to replant in the near future. Access to the government program subsidizing the replanting process seems an important requirement for everyone. Problems in accessing subsidies due to missing land titles seem to be of lesser importance here, as most smallholders that participated in the workshop are transmigrants which received official land titles for their plots. When asked about the necessity to replant and how it is affected by long-term plans, most farmers agreed that they would replant when it becomes necessary from a farm management perspective. However, those which had already replanted did report that when deciding to do so, they thought of their children and how they will profit from the plantation for the next 20-30 years. This would explain positive effects of succession types on the likelihood to replant generally.

The narrative of ageing smallholders managing the plantation by themselves without involvement of their children is mirrored by stories from young farmers or young adults from farming families. As this meeting only included young adults who had decided to live in Pematang Kabau, rather than moving to Jambi City, Jakarta or another metropolitan hub in Indonesia, these narratives miss the perspective of those leaving their home towns. However, despite them deciding to stay and mostly engage in oil palm cultivation themselves, they still painted a future of being an oil palm “manager” rather than a farmer. For them, oil palm provides a decent passive income without requiring much work from their side, as most manual labor can be outsourced to daily laborers. When discussing the involvement of parents in decision-making on family plantations, they agreed that most decisions are still taken by their parents. Even those owning their own land reported some interference from their parents regarding decisions on the plantation. So instead of working on the plantation full-time, many aim to become civil servants or start other businesses. This underlines another narrative from the first focus group discussion, where oil palm smallholders argued that the village needs “entrepreneurs” who use their education for new business purposes. When asked why they would decide to stay in a remote village, if oil palm can be managed from afar mostly, they highlighted the advantages of living in rural areas where the cost of living is much lower, crime is almost non-existent and social structures are strong. Despite these advantages, they did also share stories of friends or siblings who decided to move to the city because employment outside agriculture is very limited in Pematang Kabau.

(7) Discussion

Our findings provide an interesting case study of how ageing and succession could affect the oil palm sector in Indonesia and adds a new perspective to current research on agricultural transitions in South-East Asia and ageing of smallholders in developing economies generally. First, we show that oil palm smallholders in Indonesia are ageing. This is already happening and trends of succession captured by our survey hint at a long-term trend, as many smallholders in our sample have no or passive successors to their plantation. These findings are in line with others from countries across South-East Asia as well as the Indonesian agricultural sector generally. Second, our results suggest a change of management styles across the Indonesian smallholder oil palm sector. Passive succession households make up more than a third of our sample. In these households, children are often engaged in occupations outside agriculture but aim to keep the plantation as an asset rather than a full-time job. Third, we find evidence that older smallholders are associated with lower levels of productivity. These findings support evidence from other countries where ageing smallholders have been linked to declining productivity. By introducing succession plans into our model, we now show that this negative association may only be true for households without a successor. This is an important finding, as it allows to distinguish effects of ageing on decision making from those related to declining ability. Furthermore, we show that households with a successor are more likely to replant their plantations generally and that older farmers are less likely to replant their older plots if they do not have a successor. While these findings agree with evidence from other developing our transitioning economies, we find no clear effect of ageing on farm investments such as fertilizer applications or replanting behavior generally.

Research on ageing and succession in smallholder agriculture has been largely separated until now. Succession in family farming has been at the center of much attention in economies of the Global North for more than four decades as well as a few studies starting to assess these trends in developing and transitioning economies in recent years. In these studies, drivers of succession as well as associated strategic choices of smallholders affected by (non-) succession are assessed. Most studies agree, that farmers without a successor are more likely to disinvest from their farm or plantation compared to those with a successor. They have also been associated with decreasing their farm size generally, leasing out land and substituting their own labor with hired workers. With all of these strategic choices, land productivity is predicted to decline. On the other side, studies assessing ageing of smallholder populations look at individual effects of age on certain farm outcomes. Here, evidence supports some of the

aforementioned findings from succession research that older smallholders manage smaller plots and are less likely to adopt technology. They also find that older smallholders are less educated which decreases productivity and that age is directly linked to lower levels of productivity, hinting at a lower ability of older smallholders generally or at a decrease in ability through ageing. With our study, we now show that the two approaches should be combined in order to disentangle individual age-related effects and strategic choices. Our results suggest, that while age is negatively associated with productivity, this is not true for households with any type of successor. If the age-productivity relation was solely based on lower individual ability of older smallholders, having a passive successor should not moderate this negative effect. Declining cognitive of physical abilities of smallholders provide an intuitive reason for lower levels of productivity but these may just as well be related to strategic choices of ageing smallholders or, most likely, a mix of both.

Using succession plans of smallholders as a moderating variable in the age-outcome relation provides a straight-forward approach to disentangle strategic choices from age-inherent effects. However, our study is limited by the cross-sectional nature of our data as well as the indicators available to us. Ultimately, capturing age-related declines in ability will require repeated observations over a longer timeframe and/or specific measurements of physical and cognitive skill which could proxy agricultural ability. This will also allow to estimate the shifting effects of education, potential interplays with technology adoption and their joint effects on productivity. Furthermore, longitudinal data will provide a more accurate picture of actual succession plans. While we can capture current succession plans of smallholders at the time of the survey, these plans may change over time and even where succession plans did not reflect it, a child, spouse of a child or other relative may choose to move back to their home village and take over the farm. With repeated observations over longer time-frames, shifts in management responsibilities, changes in successor involvement and farm transfers can be observed directly. We still believe that eliciting stated plans of smallholders for the future of their plantation is an important measurement, as it provides a relevant insight into their long-term planning and thus a dimension of strategic decision-making.

Including the perspective of successors, which we proxied through focus group discussions with successors of family plantations and young farmers from a village in Jambi Province, Sumatra, will furthermore allow to observe changing styles in oil palm management. For the Indonesian oil palm sector, passive succession households are a new category of smallholders to consider. For these plantations, children of current oil palm smallholders will be responsible but are not involved in the daily management. While current smallholders with passive

successors are more willing to invest into replanting compared to those households without a successor, they will likely undergo changes when the current generation of smallholders transfer plantations to these passive successors. When plantations become assets for the next generation and returns are not strictly required to make a living, decisions are likely different from those of a full-time smallholder. This is evident from the interviews we conducted in our sampling region. Many children of oil palm smallholders want to be "managers" of plantations instead of being considered "farmers". They usually have a different main occupation in mind and treat oil palm farming as a passive income. So, while these new "managers" may also be more open to adapt technological innovations for their land, their decision-making is likely very different from their full-time farmer parents. Our qualitative findings also suggest, that knowledge on how to manage oil palm plantations may be lost in these households, as passive successors are less engaged in farming overall and parents see little value in teaching them about the plantation. Additionally, these households will also be affected by age-related declines in ability, if current smallholders decide to work on the family plantation for as long as possible while their children engage in other activities.

Understanding and differentiating effects of age and long-term plans like succession on farm management outcomes is important to design effect policy responses in the future. Different countries and agricultural sectors likely exhibit different physical and mental strains over time on smallholders. Trends of urbanization and youth-migration and thus successions of family plantations are specific to location, sector and country. Where lower levels of productivity among ageing smallholders are driven by strategic choices based on long-term plans like succession, policy makers can incentivize farm investments for affected age cohorts. This is especially evident when considering our results regarding the replanting behavior of smallholders. Those without a successor are generally less likely to replant, especially if they are older and manage plots which require replanting soon. From a strategic perspective this makes perfect sense. Investing a significant amount of capital into an uncertain future may well be less appealing than managing a plantation where productivity is slowly declining. Replanting is already delayed across the Indonesian oil palm smallholder sector. If subsidies are not adjusted to make replanting cheaper and support smallholders through unproductive years, many older smallholders without a successor may choose to let their palms overmature further. Declines in productivity related to physical or cognitive ability, on the other hand, would require interventions to make technology more accessible to ageing smallholders, to ensure high-quality labor supply in smallholders' agriculture and to design extension services in a way which does not leave physically or cognitively inhibited smallholders behind.

All of these effects provide a basis for concern regarding the future productivity of the Indonesian oil palm sector. In a decade of ageing smallholders, passive successors and few young farmers entering the sector, addressing yield gaps of smallholders to company-managed estates may prove more difficult than ever. Policy makers will need to pay special attention to older smallholders when designing subsidies or extension programs to improve productivity or replant ageing plantations. Passive successors may be less engaged in traditional smallholder networks and extension services need to take this into account. Cooperatives and youth organizations could provide a platform to engage with successors early on and incentivize them engaging in the sector from afar. Local daily labor supply will likely become even more relevant for the sector as less smallholders will actively work on their plantation. Improving work conditions for these laborers could therefore be crucial for the future of the sector.

Finally, it is important to note that none of these trends will likely have negative socio-economic consequences for smallholder households. When children move into more lucrative occupations outside farming, parents will benefit as well. The risk instead is an environmental one. If productivity in the Indonesian smallholder oil palm sector does not improve or even declines, rising global demands for vegetable oils will have to be met by newly established plantations in Indonesia or elsewhere – likely at the cost of the environment.

(8) Conclusion

The oil palm boom in Indonesia has brought many socio-economic benefits to smallholder farmers. Three decades after the rapid expansion of oil palm plantations across Jambi, a generational shift among smallholders is starting to take hold. As the current generation of farmers ages, they struggle with replanting and productivity while their children move to the cities for jobs outside agriculture or engage in other activities outside oil palm cultivation in their home villages. This leaves many smallholders without a successor or with a passive one. As oil palm plantations provide a stable income without requiring active involvement of the successors, they instead aim to manage plantations as assets rather than selling them while engaging in other full-time occupations. Meanwhile, current smallholders are left to work alone on the family plantation and change their investment decisions according to these long-term plans. This has relevant consequences for the overall productivity of the sector. If trends of ageing in smallholder agriculture observed across South-East Asia also take hold in the Indonesian smallholder oil palm sector, this could further dampen outlooks on overall productivity. Policy makers need to be aware of these generational shifts in management and adapt extension services and subsidies for the sector accordingly.

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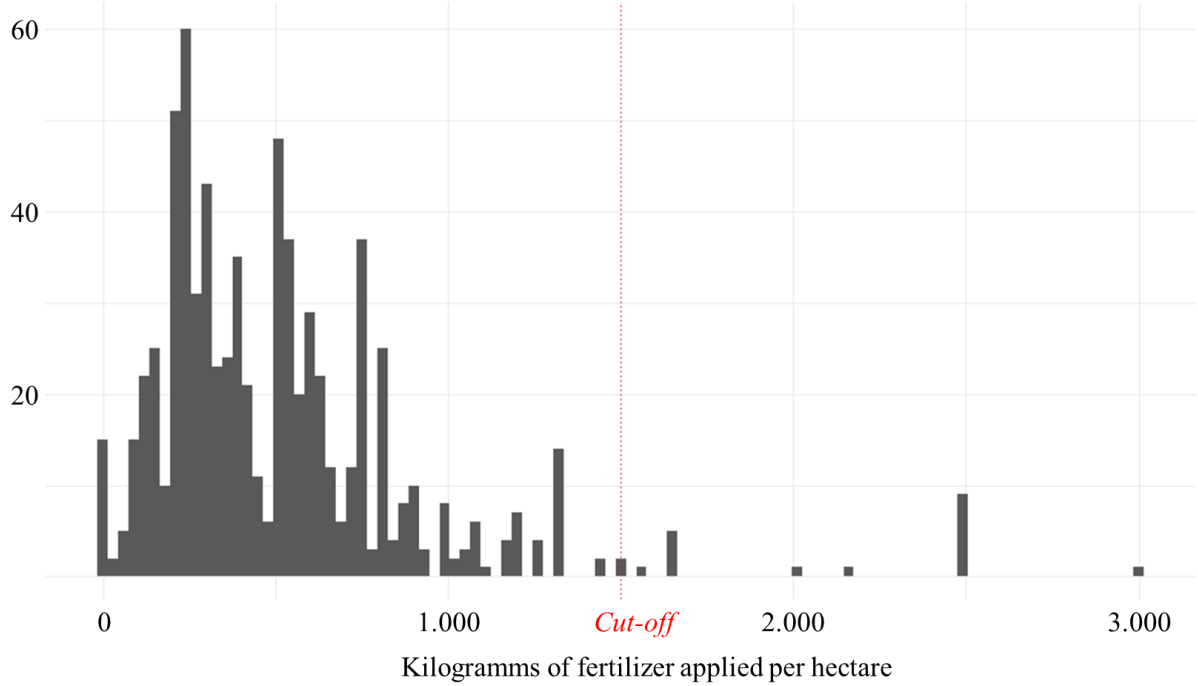
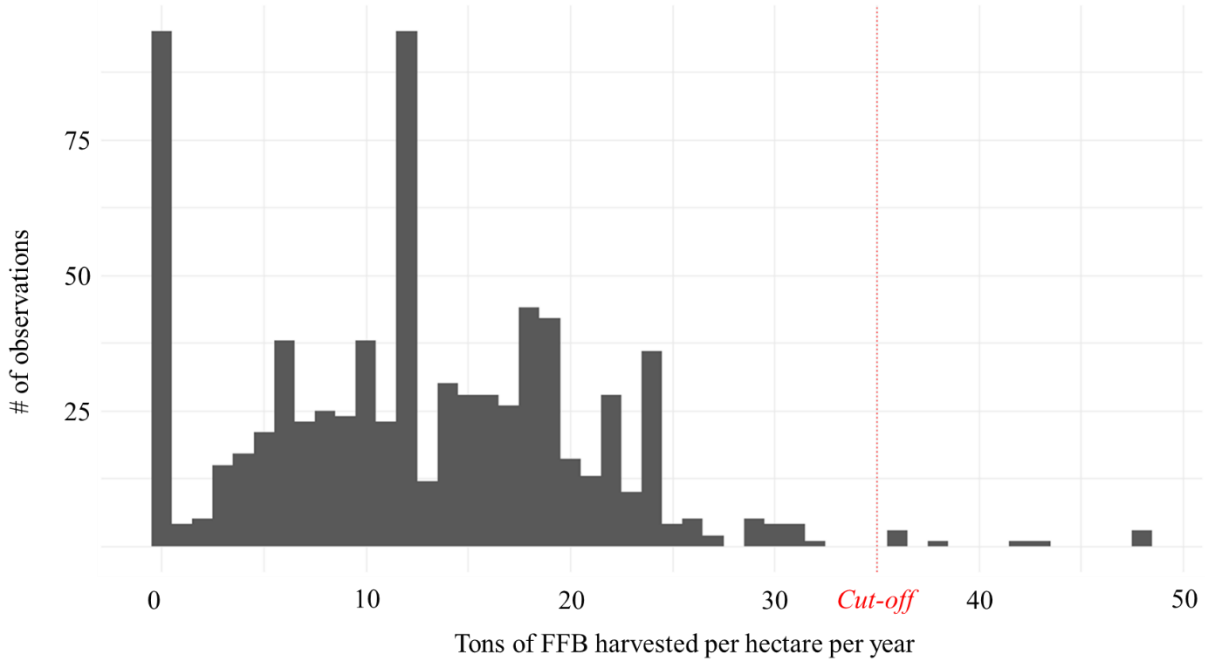
Appendix 1 – Exclusion of outliers & sample statistics

Figure 10
Histogram of fertilizer application per hectare per year; plot-level data



Number of observations excluded: 18

Figure 11
Histogram of land productivity per hectare per year; plot-level data



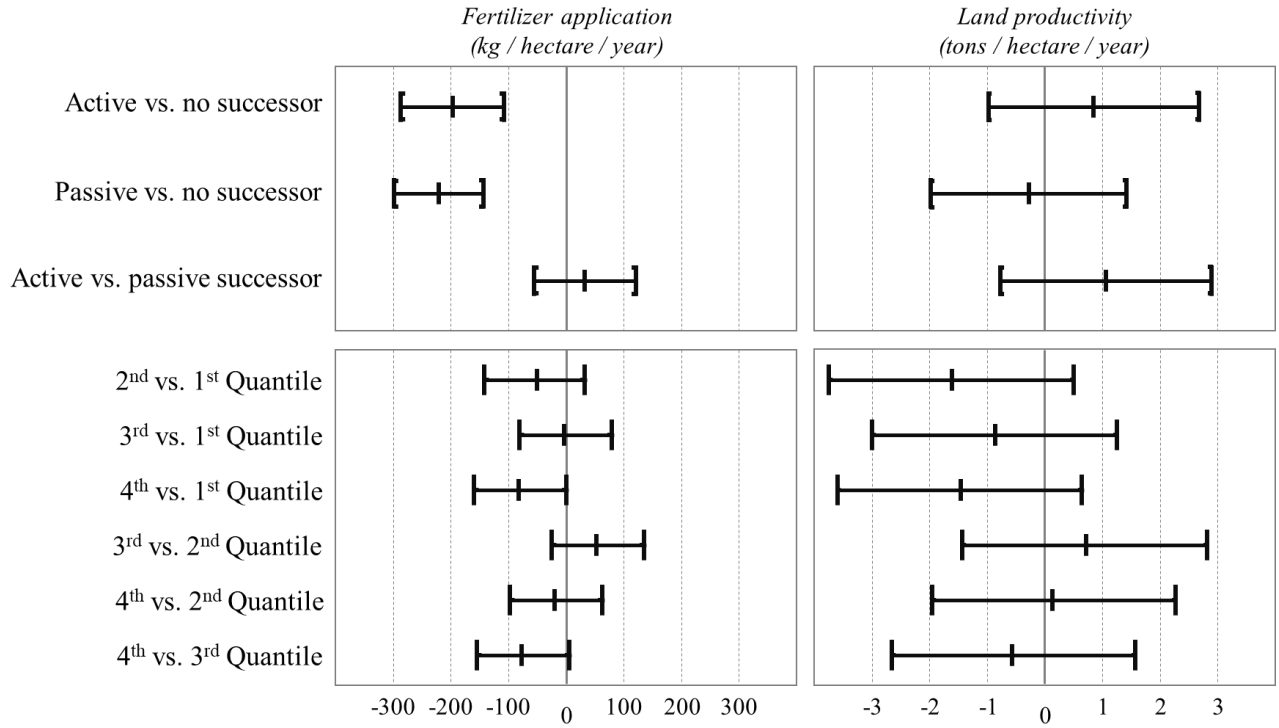
Number of observations excluded: 9
Remaining number of observations after exclusions: 728

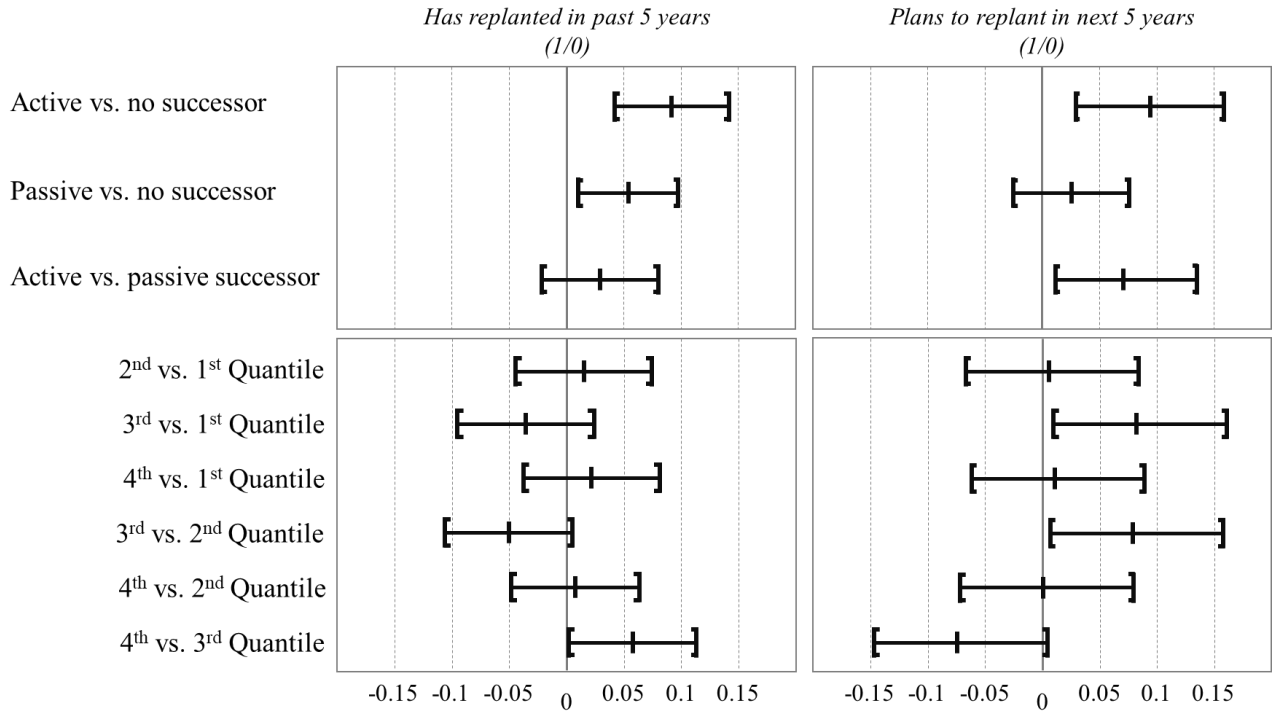
Table 9
Descriptive statistics of sample

Summary of all variables		N	Mean	Std. Dev.
Household				
Household size	Number of people in household	368	3.875	1.460
Children	Number of children of HH Head	368	2.647	1.266
Male child	Household head has male child (dummy)	368	0.753	0.432
Adult child	Household head has an adult child (dummy)	368	0.652	0.477
Transm. Program	Part of the transmigration program (dummy)	368	0.236	0.425
Asset Score House	Number of assets from housing list	368	9.367	2.428
Household head				
Age Head	Age of household head (years)	368	52.571	11.172
Education Head	Highest degree obtained (1-5)	368	1.851	1.073
Cooperative member	Member in an oil palm cooperative (dummy)	368	0.601	0.490
Bank account	Household head owns bank account (dummy)			
Farm				
Size plantation	Total size of oil palm plantation	368	4.780	4.920
Asset Score Farm	Number of assets from farming list	368	5.709	1.527
Land	Total size of land owned (hectare)	368	6.895	8.041
Plots				
Oil palm age	Years since plot was planted	728	13.66	8.90
Plot size	Average size of oil palm plot (hectare)	728	2.36	2.06
Official land title	Plot has an official land title (dummy)	728	0.79	0.41

Appendix 2 – Mean differences in outcome variables

Figure 12 & 12
Tukey HSD test results of mean differences incl. 95% confidence interval; Plot-level data





Appendix 3 – Additional figures

Figure 13
Land productivity over age of plots

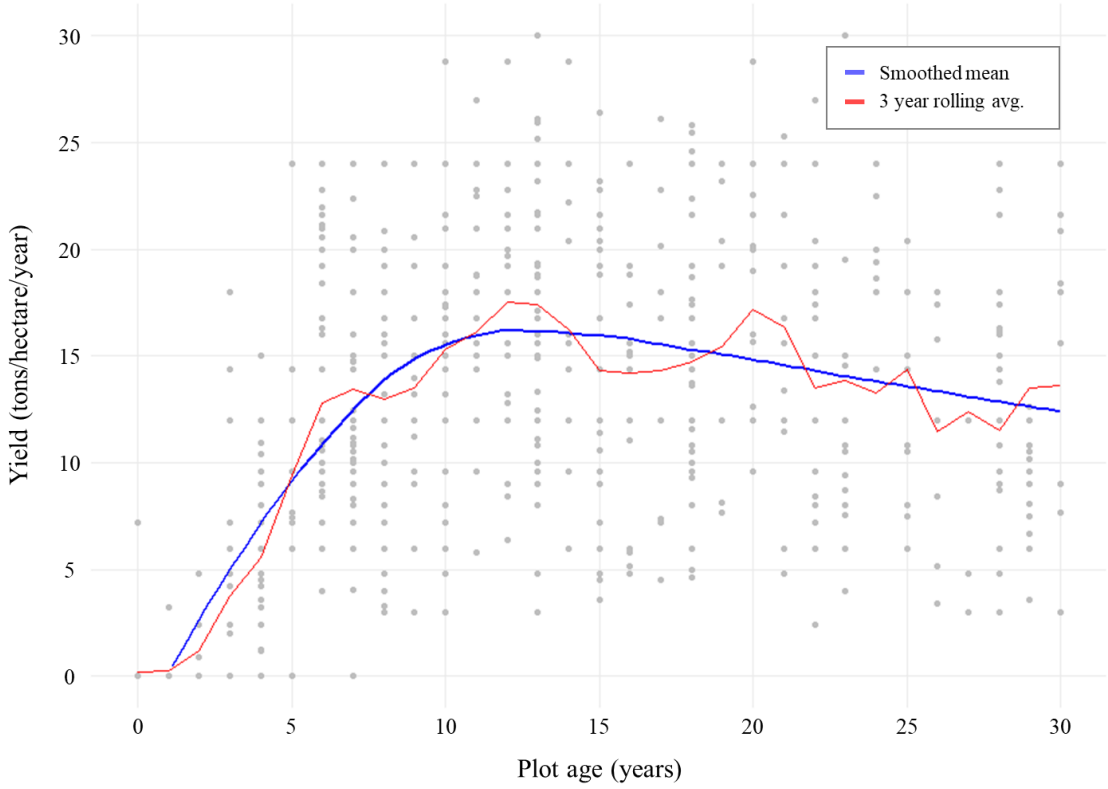


Figure 14
Difference in productivity from plot-age mean over age of smallholders by succession type

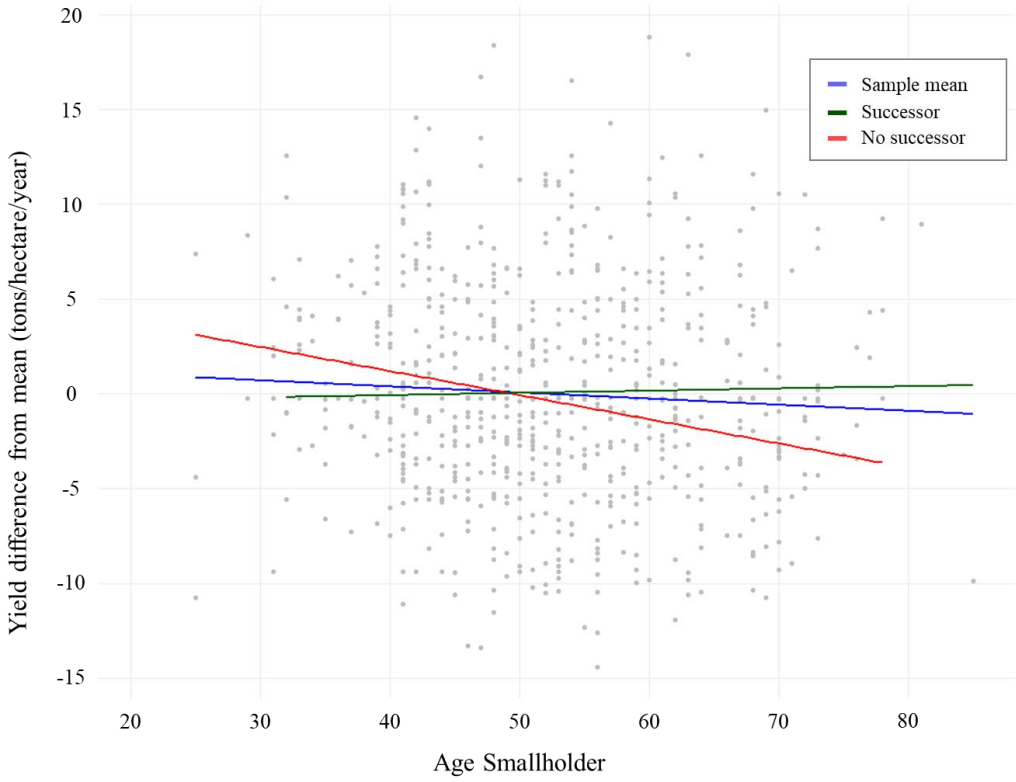


Figure 15
Fertilizer application levels over age of smallholders by succession type

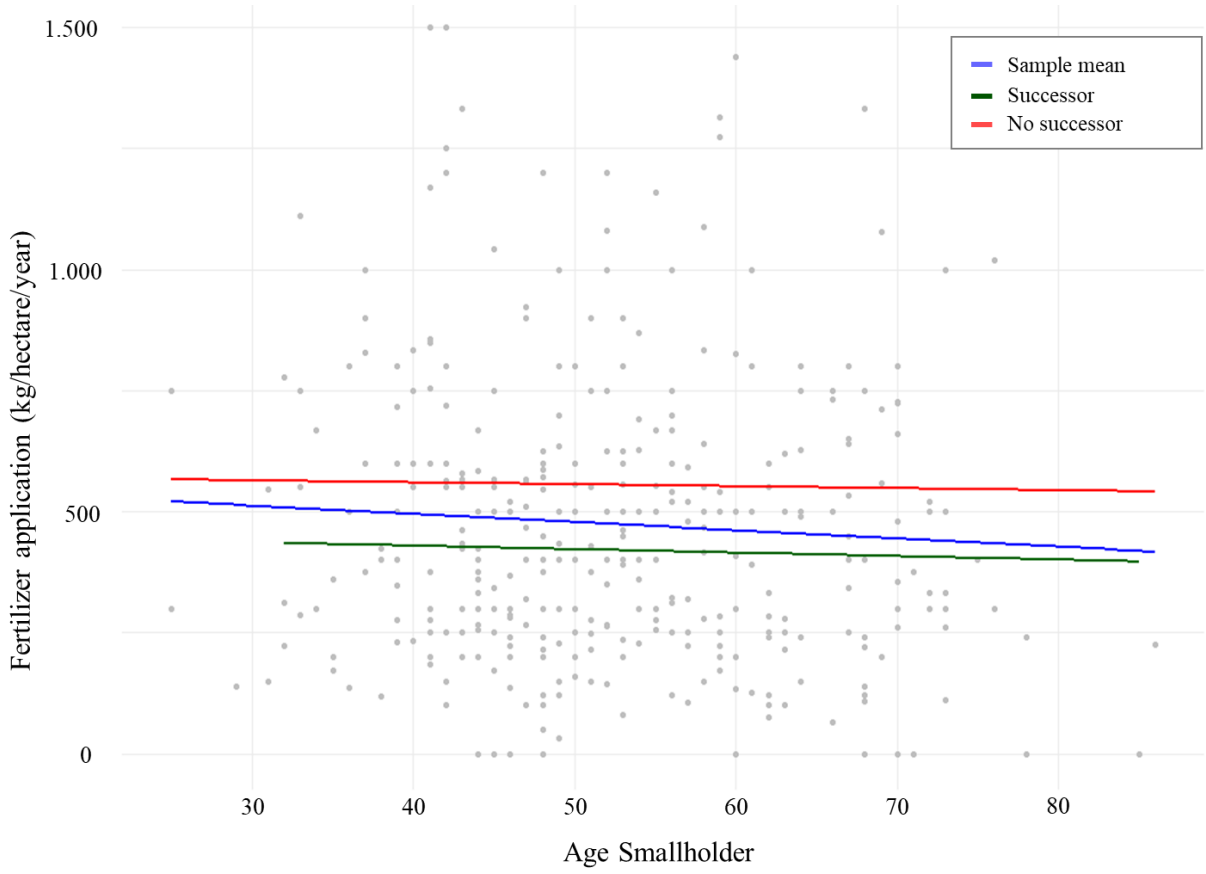


Figure 16
Replanting behavior over age of smallholders by succession type