Adoption of Improved Seeds and Land Allocation, Evidence from DRC.

Tanguy Bernard, Sylvie Lambert, Karen Macours, Margaux Vinez*

IFPRI, Paris School of Economics

July 3, 2017

Abstract

There is a resurgent interest in agricultural input subsidies as instruments to increase adoption of yield increasing technologies in developing countries. But what is the impact of such technologies on land use in Africa, where land is considered relatively abundant? Using unique experimental data from the Equateur province in DRC, characterized by a large heterogeneity in access to land and home to the second largest tropical forest, we study the implications of such interventions for households agricultural decisions related to land use. We show that high subsidy levels lead to high adoption of improved seeds, especially when other access constraints are relieved. We also find that households re-optimize their use of complementary land inputs, leading to more clearing of forest. The effect on forest conversions is stronger when more households received a voucher. This competition for land is reinforced by the fact that the clearing of forest takes place through labor-sharing groups, allowing non-treated households both to become aware of the rush for forest, and to take part in it.

Key words: agricultural policies, technology adoption, input subsidies, land use change, Sub-Saharan Africa, Democratic Republic of Congo

*Corresponding Author, Paris School of Economics, 48 boulevard Jourdan 75014 Paris, France. email: margauxvinez@gmail.com

1 Introduction

Approximately 75% of the population in sub-Saharan Africa remains dependent on agriculture for its livelihoods. Increasing productivity for smallholder farmers is therefore one of the highest development priorities, and a cornerstone in the fight against poverty and hunger. It is generally believed that there exist profitable technologies that farmers are not adopting due to market imperfections and/or behavioral constraints (see World Bank, ed (2007) and Jack (2013) for reviews). As an example, by 2000, adoption of modern varieties of maize was estimated to be 17 percent of total area harvested in sub-Saharan Africa compared to 90 percent in East and Southeast Asia and the Pacific (Gollin et al., 2005). Understanding the role of the different constraints to the adoption of yield increasing technologies, broadly defined to include adoption of agricultural practices, crop varieties, inputs and associated products, is therefore key to inform policy design. Understanding whether the impacts of adoption affect households decision in factor markets is equally important, as such decisions may well multiply or reduce the impacts of adoption (Emerick et al., 2016). The impact of the adoption of improved varieties on land-use is a priory ambiguous.Between 1960 and 2005, the increase in agricultural production has been driven by intensification in Asia, while agricultural expansion has been the main driver in Africa, where cultivated area was multiplied by two (Hunt and Lipton, 2011; Grimm et al., 2014; World Bank, ed, 2007). This has raised concerns as land cover change is the third most important human induced cause of carbon emissions globally, and the second in developing countries. Moreover, agricultural expansion is the most important cause of tropical deforestation.

A priori, yield-increasing technological change could save land from conversion to agriculture by allowing more food to be produced on the same area. According to Borlaug (2007), intensification of cereal production saved over one billion ha of land from being converted between 1950 and 2000. But the impact of yield enhancing technologies on land use change is disputed, and basic economic theory suggests that anything that makes agriculture more profitable should stimulate expansion and deforestation. This is known as Jevon's paradox (Rudel et al., 2009; Meyfroidt et al., 2014).[1] Technology, by increasing profitability of agricultural land relative to other land uses, may increase returns to land and thus increase land pressure and deforestation (Angelsen et al., eds, 2001). At the same time, if intensification occurs far from the land frontier, it may increase the demand for labor and reduce the pressure on land in land abundant regions through migration (Villoria et al., 2014). Finally, if intensification occurs at a broader scale, reduced output prices may in turn reduce returns to land and reduce pressure (see Angelsen and Kaimowitz (1999)).

To inform this debate, we study the impact of input subsidies for improved seeds on land

[1]In the 19th century the increase in efficiency of the use of coal led to an overall increase of its use rather than a decrease

conversions. We use data we collected for a field experiment in the North West of the Democratic Republic of Congo. In 92 selected villages, households were randomly chosen to receive vouchers to buy improved seeds at a subsidized price for five of the main staple crops, namely maize, rice, groundnut, soya, and cassava. We randomly selected villages where vouchers would be distributed before the planting season, and distributed vouchers to randomly selected men or women in the households with price reductions of 30, 60, 90 or 100%. The proportion of households in a village receiving a voucher was randomly varied between 20, 45 and 70%. Households had 3 months to redeem their vouchers at the offices of local seed-multipliers, at prices fixed by the Ministry of Agriculture. In addition, part of the villages were randomly selected to have a truck delivery of seeds directly in the village a few days after the voucher distribution. There, households could redeem their voucher directly. The truck came to the village only a few days after the lottery, sparing households the travel cost but leaving little time to gather cash – while vouchers could be redeemed during 3 months at the offices of seed-multipliers for all households. The mix of seeds available also differed due to supply constraints, and there were notably more groundnuts available. Improved seeds were also available outside the experiment but in limited quantities and in a limited number of locations, and traditional non improved seeds were still available on the local market. We then conducted two household surveys, the first after the season following the lotteries, and the second one year later. This experimental design allows us to estimate the effect of the subsidies on adoption and land use decisions.

We first test whether giving households the opportunity to invest in higher yielding seeds increased adoption of improved seeds in the short term. We find relatively large effects of the subsidies on adoption in the agricultural season following the intervention and one year later, and larger effects for higher subsidy levels. In particular, the impact on adoption is strongest when the vouchers recipients don't have to bear the travel costs (truck villages). However, although more households used their vouchers in those villages, those who did bought smaller quantities of seeds on average compared to households in villages with lotteries but not truck delivery of seeds. This difference probably results both from lower selection on motivation and stronger liquidity constraints.

We then examine whether households who were given an opportunity to invest in improved seeds re-optimized their use of complementary land inputs by looking at the choice of plots cultivated. Since farmers in the region perceive a complementarity between forest soils and some crops (rice and maize for example, but not groundnuts), we expect the impact on land use to vary accordng to the dominent imrpoved crops bought in the village, and therefore no strong impacts on forest in villages with truck delivery. Indeed, our results suggest that the subsidy had an effect on both the intensive and the extensive margins of land use in villages without truck delivery, and a much smaller impact in villages with a truck delivery where more groundnuts were purchased. In the season following the voucher distribution, treated households were more likely to cultivate on plots they converted from secondary forest or savanna to agriculture, and they were more likely to cultivate at least one converted plot compared to households in control villages. One year later, the impact on the average number of plots cultivated is negative but the share of converted plots from the primary forest is higher than in control villages due to both a higher average number of converted plots and a lower average number of plots taken into cultivation after a fallow period. In 2014, households with vouchers without truck delivery are twice more likely to cultivate at least one plot converted from primary forest than households in control villages.

Using the random variation in the density of the intervention, we further document that land adjustments are particularly large in villages where a larger share of households obtained improved seeds, suggesting competition for land. This hypothesis is reinforced by the fact that non-treated households in villages without truck delivery are also more likely to use converted land although they were not more likely to use improved seeds compared to households in control villages. Finally, we also find that vouchers increased the time spent in labor-sharing groups for land preparation. This suggests that the vouchers increased the value of forest land because of a perceived complementarity between some crops and forest soils, increasing competition for land. Since labor sharing groups are commonly used to clear forest, they probably reinforced the competition for land by providing information about the higher demand for land, and by allowing non treated households to participate in it.

The remainder of the paper proceeds as follows. Section 2 presents some background facts on agriculture in Equateur and describes our experimental design and data. Section 3 presents results of the lotteries on adoption of improved seeds, and section 4 and 5 present the results on land conversions at the plot and household level, and section 6 presents spillover effects. Finally, we discuss the interpretation and conclude in section 7.

2 Context and Data

2.1 Background: DRC and the Equateur Province

With 234 billion ha of land, the Democratic republic of Congo is the second largest country in sub-Saharan Africa. In 2012, 71% of the population of 67 million estimated inhabitants lived under the poverty line, and three quarters of them in rural areas. DRC is also home to the second largest tropical forest in the world, and holds 80 billion hectares of arable land (Herdeschee et al., 2012). Rainfall patterns allow for two annual rain-fed cropping activities covering a variety of crops (Season A with planting starting in March, and Season B with planting starting in August). Subsistence farming occupies 60% of the active population, and generates 40% of GDP. During the Zairianisation in the 1970's [2], the agricultural sector was dislocated and large scale investments in agriculture were discouraged. Infrastructures then collapsed during the Congo Wars (1996-2003), and inadequate infrastructure for the transport of agricultural products limits commercialization. Although agricultural production started to recover between 2006 and 2010, yields and aggregate production remain very low.

Agricultural productivity is particularly low in Equateur province in DRC [3], a remote region with very extensive slash-and-burn agriculture, high levels of food insecurity and extreme poverty, and arguably severe constraints to economic development in other sectors. While historically plantation agriculture [4] played an important role in the development of the Province, many plantations are abandoned, and households rely mostly on subsistence smallholder agriculture through shifting cultivation of staples [5], as well as gathering of forest products, fishing and hunting. While agricultural potential is believed to be large, road density is very low, commercialization is hampered by long distances from farm to market, and most farmers don't have access to improved varieties or technologies. Traditional slash and burn clearing methods are used, and the only capital inputs used are generally hand held tools. Farmers traditionally purchase "'seeds"' from the food market or exchange it with neighbors.

To strengthen the agricultural sector in the province of Equateur, the Ministry of Agriculture started implementing the Agricultural Rehabilitation and Recovery Support Project (PARRSA: Projet d'Appui à la Réhabilitation et à la Relance du Secteur Agricole) in 2011 with the support of the World Bank. PARRSA works in 9 territories [6] in the three north-

[2]"'Zairianisation"' is a nationalist political process launched in 1973 by president Mobutu, by which, among other changes, agricultural businesses that belonged to foreigners were transferred to citizens of the DRC. In many cases, the new owners did not continue to farm the land they received and many plantations were abandoned.

[3]An administrative reform recently changed the administrative divisions. What was until 2015 the province of Equateur is now divided in five smaller provinces.

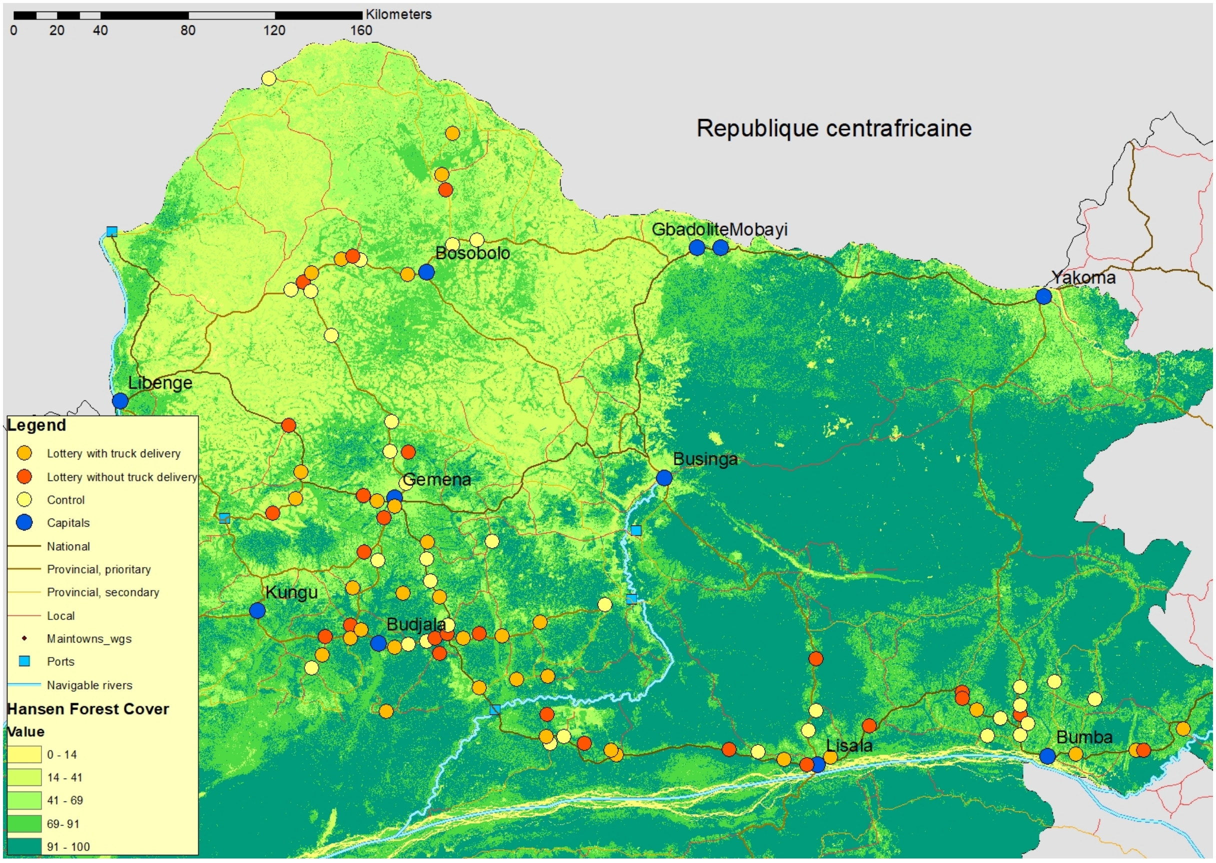
[4]palm oil, coffee, cotton, hevea, cocoa

[5]maize, rice, groundnuts, cassava, soya, niebe, yam, plantain

[6]Bosobolo, Budjala, Bumba, Gemena, Kungu, Lisala, Mobayi Mbongo, and Yakoma.

ern districts of the Equateur Province[7]. The study area comprises roughly 150.000 square kilometers, and is at the heart of the Congo Bassin Forest. It is characterized by a large heterogeneity in access to land both between and within villages: while some village are located at the forest frontier, others are located further away and access to natural resources varies widely.

Figure 1 – Map of forest cover and forest cover loss in the project area



Source: FACET Atlas and own GPS data

2.2 Evaluation design

The Agricultural Rehabilitation and Recovery Support Project aims at improving agricultural productivity in the region through a variety of mechanisms (see appendix). We focus on this paper on a one-time seed price voucher program implemented in February-March 2013. Seed vouchers provided subsidized access to seeds of improved varieties of maize, rice, groundnut, and soya, or stems of an improved variety of cassava. The varieties were selected mainly for

[7]Nord Ubangi, Sud Ubangi, and Mongala.

their high yield characteristics and for their resistance to a very widespread disease (mozaique) in the case of cassava.

A set of 92 villages was selected for possible targeting of seed subsidies. The 92 villages are a subset of villages selected for a larger, orthogonal extension experiment, and were selected for being relatively accessible by truck. The 92 villages were stratified based on size (below or above median size), remoteness (a subjective indicator of accessibility), and treatment status of the PARRSA extension intervention (see appendix for details on the larger study). Respecting this stratification, 32 villages were randomly selected as control villages for the seed vouchers, 25 as voucher distribution villages, and 35 as voucher distribution and truck delivery villages.

The PARRSA team then distributed seed vouchers offering price reductions in the 60 treatment villages, through public lotteries organized in each of them. Starting from census data collected at baseline, randomly selected households received vouchers offering either 30, 60, 90 or 100% reduction on a maximum of 10 kg of cereal or pulse seeds (or equivalent amounts of manioc stems). The voucher was given to the man (the household head) or his wife based on a second level random draw. For polygamous households, and if the voucher was to be given to a woman, an additional random draw determined to which of the wives the voucher was given. Among the 60 villages, 35 were randomly selected to be visited by a truck with seeds of the seed-multipliers in the days following the voucher distribution, effectively removing a potential access constraint. Voucher recipients in the remaining 25 villages, as well as households of the 35 truck villages that did not redeem their voucher when the truck passed their village, could redeem their vouchers and buy seeds at the offices of the seed-multipliers, located commonly in the local urban centers. Reaching the offices of the seed-multipliers typically required several hours (and up to several days) of travel (cf map in Figure 1). The potentially more limited supply of different types of seeds (and in particular the absence of groundnut seeds) further affects access in this experimental variation.

The share of households receiving vouchers in each village experimentally varied in order to assess the potential spillovers and general equilibrium effects. In one third of randomly selected treatment villages, 70% of households received a voucher (high density), in another third 45% of households received vouchers (medium density) and in the last third only 20% received vouchers (low density). In each treatment village, equal shares of 30%, 60%, 90% and 100% subsidy vouchers were distributed. Across the 60 villages a total of 4344 vouchers was distributed. Careful administrative records were kept documenting the names, gender and subsidy levels of all beneficiaries.

The different experimental variations allow testing of the importance of liquidity and access constraints for the adoption of improved seeds. We hypothesize that the initial price at which farmers get access to improved seeds can be an important obstacle in the context of Equateur, where households mainly live from subsistence agriculture. We then test whether initial price subsidies for a limited amount of seeds lead to more sustained adoption and higher demand on the long run, once households have had an opportunity to learn about returns from their own experimentation. In addition, given the extremely difficult road access in almost the entire region covered by the project, we also hypothesize that transportation costs may add to the existing liquidity constraints. The intervention that sends trucks to the villages was designed to test this hypothesis.

2.3 Data

A baseline survey was administered between March 2012 and July 2012. In each village, a group of 4 to 5 people was selected to answer a community level questionnaire and establish the village census. The group was composed of knowledgeable people in the village, including the village chief, the director of the school, the director of the health center, and other notables, depending on availability. The same group of people was asked some basic characteristics of 20 households from the village randomly picked in the census list. For those 20 households, we hence have baseline proxy information on variables related to agriculture, demographics, and participation in producer organizations.

A first follow-up was conducted between November and December 2013, i.e. after the agricultural season immediately following the lotteries. Data was collected in the 92 villages involved in the lottery experiment. Sample selection for the follow-up survey was done based on the initial census and the administrative data from the public lotteries. In particular, in each of the treatment villages, we randomly drew 2 beneficiaries, a man and a women, for each level of subsidy (including zero). An additional man or woman was added for both the 0 and 100% subsidy levels to maximize power. This gives a first group of 12 households, for whom detailed information about agricultural production in the season after voucher distribution, in addition to information on take-up, perceptions and social networks was collected. Given that the voucher distribution was random, these 12 households can be compared to 12 randomly drawn households in the control. In all villages, the samples were stratified on baseline membership in producer organizations, on having leadership positions in the village, and on polygamy. All the regressions will control for strata dummies to take this design into account. For the second follow-up survey in the 92 villages, the same 12 households for whom we had detailed agricultural information in the first follow-up survey were surveyed again between June and July 2014 (Follow-up wave 2014). In this survey round, special effort was done to obtain an exhaustive list of plots, resulting in an large increase of the number of plots reported.

3 Results: Impact on Adoption of Improved Seeds

The aim of this section is to study how subsidies impacted adoption of improved seeds in the short term. The vouchers provided a subsidy to buy improved seeds from specific seed-multipliers, and involved co-financing from the beneficiaries (cash and/or travel costs, except for subsidies of 100% in villages with a truck delivery). We therefore expect some mismatch between voucher receipt and voucher use, and start by presenting some descriptive statistics about voucher utilization.

3.1 Voucher utilization and quantities bought

We draw on the administrative data collected during the voucher distribution, and the seed sales (obtained both for sales from the trucks (delivery) and at the seed-multipliers offices). Each voucher indicated the name and identifier of the household which received it, and all sales were registered (including identity of the buyer, identifier of the voucher, and quantities of seeds bought). We focus on maize, rice and groundnuts as the vast majority of sales occurred for these 3 crops.

The administrative data shows that vouchers were very successful in convincing households to get seeds, and that voucher take-up is higher for higher subsidy levels. In the sample of interest for this paper (1095 households), 533 households received a voucher, and 318 redeemed it to buy seeds either directly from a truck or from seed-multipliers. In villages with truck delivery, use of vouchers was very high. Only 9 out of the 103 households did not use their 100% voucher (probably because they were absent on the day the truck came), and 77% of the 90% vouchers used it as well. This figure drops to 56 and 48% for 60 and 30% vouchers respectively, but remains relatively high. As expected, voucher use is lower in villages where households had to cover travel costs, but remains high. In those villages, only 84% of households used their 100% vouchers (although they were entitled to 10 kg of free seeds). 68% for 90% vouchers, 29% for 60% vouchers, and 16% for 30% vouchers.

In terms of quantities, households who had to make an additional effort to get seeds (because they were not delivered to their village) bought more seeds, potentially suggesting stronger selection and motivation. Liquidity constraints were also higher in truck villages, due to the short delay between voucher distribution and delivery. In those villages, households who used their voucher bought an average of 9.6 kilograms regardless of the level of the subsidy. When a truck delivery took place after the lottery, however, households with lower levels of subsidies (30 and 60%) only bought an average of 5.4 kilograms while households with high subsidies (90 and 100) bought close to 10 kilograms on average. The quantities of improved seeds households received is critical in analyzing the impact of the subsidies on sustained adoption and land use since they determine the area that can be sown. This can differ dramatically between crops, and in this region agronomists generally consider that for one hectare of land approximately 20 kg of seeds are necessary for maize, 60 kg for rice and around 100 kilograms (of pods) for groundnuts. The average production in real conditions is believed to reach approximately 1500 to 2000 kilograms per hectare for maize, 2500 to 3000 for rice and 800 to 1000 kilograms for groundnuts. Keeping seeds from one year to the next is always a challenge, and to the extent it is harder to keep some seeds when quantities are lower, these numbers suggest that it may have been harder to sustain adoption for groundnuts, especially considering that groundnuts can be eaten directly without preparation. If we differentiate by crops, we find that households in villages without truck bought very small quantities of groundnuts compared to households who received a voucher and benefited from a truck delivery of seeds: 0.3 kg on average (and 1.4 kg for those who used their voucher), compared to 2.5 kg for trucks (and 4.6 kg on average for those who used their voucher). Differences are much smaller for maize and rice. Those who used their voucher bought on average 3.1 kg of rice without truck, compared to 2.5 with truck. For maize, households with vouchers without truck bought on average 1.9 kg compared to 1.2 kg in truck villages. Supply constraints seem to have determined part of these differences: groundnuts in particular were mostly available from trucks.

To sum up, the treatment had a positive impact on improved seed purchases in 2013. While less households used their vouchers when the travel cost had to be paid by the voucher recipient, those who did bought larger quantities of seeds. This probably results from both a stronger selection when households had to cover the travel cost (not only did they have to find cash, but also they had to travel to the offices of the seed-multipliers) and from stronger liquidity constraints when the truck came to deliver seeds. Indeed, the truck came to the village only a few days after the lottery, so in those villages households who wanted to buy seeds from the truck had less time to gather money. They also had the option to buy more later if they covered their travel costs, but seldom used this option.

3.2 Adoption just after the intervention, season A 2013

Because voucher use and eventually use of improved seeds on household plots is likely to be endogenous to household characteristics, we look at the impact of the exogeneously determined treatment status on adoption, defined as the use of improved seeds on one of the household plots. We look successively at the two years following the voucher distribution, focusing on spring planting, the main season for agricultural production (season A, since some farmers don't cultivate in the second season). Our estimates are thus Intent to Treat ones, where the reported effect is that of being given a voucher. All estimates presented in this section are limited to households who were surveyed both in 2013 and in 2014 [8], and include controls for a set of strata dummies.

The regressions include all households (whether they received a voucher or not) in treatment villages, as well as households in control villages. Tables 1 to 4 present the results, and each table shows the impact of the different variations in the interventions on seed adoption in the first season after voucher distribution (column 1), and one year after the voucher distribution (column 2). They show the persistence of adoption by looking at the probability to use improved seeds in both years in column 3. Finally, they also show spillover effects on households who were not directly targeted in treated villages. We first discuss all results for A 2013, and then those for A 2014.

Strong impact on adoption, stronger in truck villages
The treatment had a clear positive impact on adoption, and a stronger impact when associated with a truck delivery. Table 1 reports the results for a simple specification, without differentiating by subsidy level. It shows that lotteries had a strong and significant impact on adoption for voucher recipients, and that this impact is stronger in villages where a truck delivery took place. In A 2013, adoption is 18.9 percentage points higher for households who received a voucher but no truck delivery (significant at the 1% level) compared to households in control villages. In the absence of any demand side intervention, adoption of improved seeds in season A 2013 is rather low: only 9% of the households surveyed in the villages where no lottery took place report using improved seeds. The impact of the voucher distribution is much larger in the villages where a truck delivery followed the distribution of vouchers in the village: in those villages, adoption among voucher recipients is 45 percentage points higher (significant at the 1% level) than in control villages.

Sensitivity to price
Table 2 shows results differentiating by levels of subsidies, separately for villages with and without truck delivery, and separating households who did not receive a voucher in treated villages. Table 3 presents the same results by grouping low levels of subsidy (30 and 60%) and high levels of subsidy (90 and 100%) together. We find that higher levels of subsidy have a higher impact on adoption.

The first column of table 2 shows that adoption is very sensitive to price: lower prices are associated with higher adoption rates. This result is consistent with similar findings in the health literature (see Cohen et al. (2015); Tarozzi et al. (2014); Dupas (2014) for example). Adoption is much stronger with higher levels of subsidies indicating strong liquidity constraints, but there is no strong drop off between 90% and 100 subsidy. If anything, the results

[8] Almost all households who where surveyed in 2013 were surveyed in 2014 as well, but additional households were added to the sample in A 2014.

may indicate a non-linearity between 60 and 90% in the absence of truck delivery [9].

For households in villages with lotteries but no truck delivery, price reductions of 30 and 60% have a small positive but non significant impact on adoption compared to control villages. When the price is close to zero (90% reduction) or at zero (100% reduction) however, adoption is higher by 25 percentage points (significant at the 1% level) and reaches 39%. The difference between lower and higher subsidy levels is significant, as evidenced by the P-values of the test of the difference between coefficients for different levels of vouchers presented at the bottom of table 2. Moreover, adoption is stronger for all levels of subsidies for households in villages who benefited both from a voucher distribution and truck delivery of seeds as compared to villages who received only vouchers. Average adoption rates reach 32%, 40%, and 60% respectively for those who received a 30, 60 or 90% voucher, and up to 68% for households who got seeds for free. Again, the difference of impact between low level and high level subsidies is significant, while the difference between 30 and 60% on the one hand and 90 and 100% on the other hand is not significant. Adoption is stronger for all levels of subsidies for households who benefited both from a voucher distribution and a truck delivery as compared to control villages but also to villages who received only vouchers.

Impact of the proportion of households treated
Table 4 presents the results for different proportions of targeted households in treated villages (this proportion varied randomly between 20, 45, and 70% of the households). For households who received vouchers without truck delivery, this proportion does not have any significant impact on the probability that a household adopts, meaning that more people other than me receiving a voucher does not influence my decision to use the voucher or not, for the same level of reduction. In villages with truck delivery, higher percentages of treated households are associated with lower adoption rates compared to villages where 20% of households were treated. However, in 2013 this difference is small in magnitude and not significant, as evidenced by the P-values for the differences in coefficients at the bottom of table 4.

Spillovers
Table 1 shows that the lotteries had spillover effects on adoption of improved seeds on non-voucher recipients, but only in truck villages. In A 2013, adoption is 11 percentage points higher for households who did not receive a voucher in village with only a lottery compared to households in control villages (significant at the 1% level). This effect is significantly smaller than for voucher recipients, but still economically significant. However, the coefficient for non-recipients in villages with vouchers without truck delivery is not significantly different from zero. A possible explanation is that the sale was made in public when the truck came for the delivery, making it easier for people to know who had seeds and to get some from them.

[9] Miguel and Kremer (2004) find that increasing price of deworming from 0 to a very small price decreases adoption from 75 to 19%

It also allowed them to buy directly from the truck even when they did not have vouchers, without incurring the travel costs.

3.3 Sustained adoption, season A 2014

Use of improved seeds in season A 2014 is still low in control villages, but higher than in A 2013, indicating an overall increase in the availability of improved seeds in the region [10]: 19% of the households in control villages report using improved seeds in that year. The high levels of adoption in the season one year after the intervention suggest potential for learning to take place. Also, because of the nature of improved seeds, households who bought seeds in one year can continue using them the next year if they manage to keep some. If the seeds are of good quality and if farmers carefully select the seeds they keep, seeds will continue having a higher yield potential than locally available ones one or two years after the purchase. We hence test whether households who received vouchers in 2013 are using improved seeds one year later, in season A 2014, and whether in particular those who adopted in 2013 sustained their adoption in 2014. We find that the intervention had lasting effects on adoption of improved seeds, bearing in mind the small quantities obtained in 2013.

Adoption is sustained
The evidence presented in table 1 points to a positive impact of the subsidy persisting one year after the intervention: in villages where vouchers were distributed without truck delivery, adoption is 13.2 percentage points higher than in control villages (significant at the 10% level). In villages with both a voucher distribution and a truck delivery, adoption is 19.2 percentage points higher than in control villages (significant at the 1% level). The difference between villages with and without truck delivery is smaller and is no longer significant after one year. This could be explained by a strong selection and/or larger quantities bought by households in villages without truck delivery, where the cost of using the voucher was higher. Table 2 and 3 show that the difference between high levels of subsidies and low levels of subsidies is smaller in 2014 than in 2013, and are no longer significant.

The third column in Table 1 also shows a relatively high impact on the persistence of adoption one year after the intervention. While only 5% of households in the control used improved seeds in both years, this increases to 30% in villages with voucher distribution and truck delivery, and to 18% in other voucher villages. This could be driven by households being able to either keep enough good quality seeds from their harvest to sow again them the next year, or by households who obtain new seeds one year after trying them for the first time. Comparing column 2 and 3 also indicates that part of the increase in adoption in A 2014 is still driven by new households adopting.

[10]Possibly induced by the supply side intervention of the PARRSA project

Spillovers and impact of proportion of households treated

On the other hand, we no longer find significant effects for households that did not receive vouchers by 2014. Hence there appear to be no longer-term spillovers in village with lotteries, whether with or without truck delivery, and regardless of the percentage of treated households in the village. In other words, households who did not directly receive a voucher at the lottery are not more likely to use improved seeds than households in control villages in 2014.

On the other hand table 4 shows that while the intensity of voucher distribution had little impact on adoption in A 2013, it does make a difference in the following year, in particular in villages with truck delivery. Column 2 shows in particular that the impact is 15 (23) percentage points lower in villages in which the percentage of households who got a voucher is 45 (70 respectively) as compared to villages where only 20% of households were treated. The same pattern is observed in table 3, suggesting this is driven by people re-using seeds. In other words, the probability for a given household to keep using improved seeds is enhanced when a smaller share of households in the village received a voucher.

3.4 Summary

Overall, the results demonstrate that (1) there is more adoption when costs are lower: adoption in season A 2013 is very sensitive to price, indicating strong liquidity constraints, and adoption is higher when the access constraint was relieved. However, the difference in impact on adoption between the different levels of subsidy is lower in villages with truck delivery, and decreased everywhere between the first and the second year after the lotteries, in particular in villages without truck delivery ; (2) for those that use the vouchers, in villages with truck delivery they buy a different mix of crops and the quantities of seeds bought are less compared to treated households in villages without truck, suggesting selection and possibly motivation of households who use vouchers are different ;(3) there are spillover effects on adoption of improved seeds, but only in the season following the distribution and in villages where the lottery was followed by a truck delivery ; (4) the probability for a given households to adopt in the season following the voucher distribution is not influenced by the proportion of other households who received a voucher in villages without truck. But the higher the share people receiving subsidies, the lower the impact on adoption in season A 2014 in villages with truck delivery.

3.5 Tables

Table 1 – Results of OLS regression: Adoption of improved Seeds just after the Intervention and two Seasons after the Intervention

	Season A 2013	Season A 2014	Both seasons
Voucher x no truck	0.189***	0.132**	0.132***
	(0.052)	(0.062)	(0.048)
No voucher, Lottery no truck	0.046	0.052	0.055
	(0.051)	(0.059)	(0.044)
Voucher x truck	0.447***	0.192***	0.245***
	(0.042)	(0.049)	(0.037)
No voucher, Lottery truck	0.114**	0.061	0.039
	(0.052)	(0.058)	(0.037)
Strat Vars	Yes	Yes	Yes
Observations	1022	1065	1008
Mean Control	0.09	0.19	0.05
P-value test with/without voucher in no truck	0.01	0.13	0.14
P-value test with/without voucher in truck	0.00	0.02	0.00
P-value test voucher with-without truck	0.00	0.30	0.02

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Note: Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 2 – Results of OLS regression: Adoption of improved Seeds just after the Intervention and two Seasons after the Intervention

	Season A 2013	Season A 2014	Both seasons
Voucher 30 no truck	0.090	0.157*	0.086
	(0.073)	(0.087)	(0.060)
Voucher 60 no truck	0.065	0.039	0.098
	(0.069)	(0.079)	(0.066)
Voucher 90 no truck	0.247***	0.012	0.031
	(0.081)	(0.070)	(0.058)
Voucher 100 no truck	0.254***	0.156**	0.191***
	(0.070)	(0.077)	(0.069)
Voucher 30 truck	0.234***	0.073	0.106**
	(0.060)	(0.065)	(0.052)
Voucher 60 truck	0.310***	0.080	0.114**
	(0.066)	(0.065)	(0.047)
Voucher 90 truck	0.503***	0.239***	0.322***
	(0.074)	(0.067)	(0.064)
Voucher 100 truck	0.593***	0.206***	0.306***
	(0.053)	(0.057)	(0.047)
No voucher, Lottery no truck	0.046	0.052	0.055
	(0.051)	(0.060)	(0.044)
No voucher, Lottery truck	0.113**	0.061	0.039
	(0.053)	(0.058)	(0.038)
Strat Vars	Yes	Yes	Yes
Observations	1022	1065	1008
Mean in the control	0.09	0.19	0.05
P-value Test 30-60 no truck	0.74	0.18	0.86
P-value Test 60-90 no truck	0.09	0.74	0.40
P-value Test 90-100 no truck	0.95	0.09	0.08
P-value Test 30-60 truck	0.26	0.94	0.89
P-value Test 60-90 truck	0.05	0.04	0.00
P-value Test 90-100 truck	0.30	0.67	0.84
P-value Test voucher 30-no voucher in no truck	0.53	0.22	0.65
P-value Test voucher 30-no voucher in truck	0.03	0.86	0.25

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Note: Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies. The last rows present the P-value of the difference between coefficients for different levels of vouchers, for villages with truck and villages without truck separately.

Table 3 – Results of OLS regression: Adoption of improved Seeds just after the Intervention and two Seasons after the Intervention

	Season A 2013	Season A 2014	Both seasons
Voucher low x notruck	0.077	0.098	0.091*
	(0.059)	(0.070)	(0.054)
Voucher high x notruck	0.251***	0.096	0.126***
	(0.052)	(0.062)	(0.048)
Voucher low x truck	0.274***	0.076	0.110***
	(0.054)	(0.052)	(0.039)
Voucher high x truck	0.556***	0.219***	0.312***
	(0.046)	(0.049)	(0.039)
No voucher, Lottery no truck	0.046	0.052	0.055
	(0.051)	(0.059)	(0.044)
No voucher, Lottery truck	0.113**	0.061	0.039
	(0.052)	(0.058)	(0.037)
Strat Vars	Yes	Yes	Yes
Observations	1022	1065	1008
Mean Control	0.09	0.19	0.05
P-value test low-high no truck	0.00	0.97	0.44
P-value test low-high truck	0.00	0.00	0.00
P-value test low no truck - low truck	0.01	0.76	0.75
P-value test high no truck - high truck	0.00	0.05	0.00

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Note: Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 4 – Results of OLS regression: Adoption of improved Seeds just after the Intervention and two Seasons after the Intervention

	Season A 2013	Season A 2014	Both seasons
Voucher no truck x density 20	0.141*	0.093	0.071
	(0.083)	(0.091)	(0.053)
Voucher no truck x density 45	0.171*	0.085	0.119
	(0.091)	(0.083)	(0.084)
Voucher no truck x density 70	0.196***	0.115	0.133*
	(0.059)	(0.102)	(0.069)
Voucher truck x density 20	0.460***	0.243***	0.302***
	(0.055)	(0.059)	(0.039)
Voucher truck x density 45	0.440***	0.117**	0.189***
	(0.043)	(0.047)	(0.040)
Voucher truck x density 70	0.385***	0.102	0.168***
	(0.058)	(0.063)	(0.043)
No voucher, Lottery no truck	0.046	0.054	0.056
	(0.051)	(0.059)	(0.044)
No voucher, Lottery truck	0.114**	0.061	0.040
	(0.052)	(0.057)	(0.037)
Strat Vars	Yes	Yes	Yes
Observations	1022	1065	1008
Mean Control	0.09	0.19	0.05
P-value test 20-45 without truck	0.80	0.94	0.62
P-value test 45-70 without truck	0.80	0.81	0.89
P-value test 20-45 with truck	0.73	0.03	0.02
P-value test 45-70 with truck	0.39	0.80	0.68
P-value test 20-70 with truck	0.28	0.06	0.01

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Note: Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

4 Results: Impact on Land Conversions, plot level

The results so far suggest that input subsidies have the potential to strongly increase adoption of improved seeds and hence intensify production on existing fields. We now turn to our main question of interest: do input subsidies lead to a change in the type of land that is chosen for cultivation and thereby to an expansion of agricultural land, or to an intensification on already cultivated land? In a context where competition for land close to the village center is important, labor is scarce, and clearing of forest may give rights to land under certain conditions, we expect some adjustments to take place. To examine this question, we first provide some descriptive statistics on the type of land that is cultivated, before turning to the impact of input subsidies on the type of land that is chosen for cultivation just after the voucher distribution and one year later. Again, all regressions presented are limited to the plots of households who were sampled both in A 2013 and in 2014, and include controls for a set of strata dummies. We find that subsidies led to an increase in the relative probability to use land converted from forests compared to land already under cultivation, especially in villages without truck delivery.

4.0.1 Descriptives

We study this question in a context where farmers use shifting cultivation methods that alternate short cultivation periods and long periods of natural fallow destined to restore soil fertility. Expansion is inherently linked to slash and burn agriculture: each year, during the short dry season that occurs between December and February, households make decisions regarding which fields to cultivate: they can (1) continue cultivating on plots that they were already cultivating in the previous season (2) re-open a field on a piece of land that they had previously left fallow (3) open a new field on a piece of land that has never been cultivated or that had been left fallow for a very long time (a process we refer to as conversion to agriculture). Farmers typically cultivate multiple plots at the same time, each of which can have a different origin. Conversions can include land in secondary forest, primary forest, savanna, or in abandoned tree plantations [11]. If forests are available, households can typically acquire some of it through clearance (possibly after authorization from the land chief), through inheritance, or through gift from family (or through renting and private purchase in rare cases). The same holds for savanna, except that clearing in those types of land does not necessarily open ownership rights to the land. Importantly, conversion of forest often gives the right to appropriate the land and is the customary way to secure current and future access to land.

[11] As plots converted from abandoned plantations are rare, we group them together with secondary forest in the rest of the paper.

Table 5 presents descriptive statistics on the sample of all plots that are cultivated in Season A 2014 for households who where surveyed both in A 2013 and in 2014, including households who did not receive vouchers in lottery villages. We examine the type of land that has been chosen for cultivation in season A 2014, by looking at the vegetation that was present on the field just before cultivation. We find that half of the plots that are under cultivation in A 2014 were already under cultivation the year before. Half of them, however, were not under cultivation: 25% were in fallow, and 20% was converted to agriculture from either primary forest (4%), secondary forest (13%), or from savanna or ex plantations (3%). In the bottom panel of table 5, all converted lands are combined into one single variable, that we will focus on in the remainder of the paper.

Table 5 – Type of vegetation on the plot in the preceding season

	Type of land last year	
Primary Forest	0.04	(0.20)
Secondary Forest	0.13	(0.34)
Fallow	0.25	(0.43)
Savanna	0.03	(0.18)
Cultivated land	0.54	(0.50)
Conversion	0.21	(0.41)
Fallow	0.25	(0.43)
Cultivated land	0.54	(0.50)

Source: Follow up survey wave 2014
Note: Sample of all plots cultivated in A2014. Sample restricted to the plots cultivated by households surveyed both in 2013 and 2014. Standard deviation in parentheses.

4.0.2 Impact on the choice of plots for cultivation

To assess the impact of the input subsidy on the choice of plots of different origins for cultivation, we first use the sample of all the plots cultivated, and run a multinomial logistic regression with land that was already under cultivation the previous year as reference. Tables 6 and 8 show the average marginal effects for 2013, and tables 7 and 9 for 2014, with standard errors clustered at the village level. The marginal effects read as the change in the relative probability for a field to be chosen in one type of land rather than in land that was already cultivated during the previous season. In the first specification, we pool all vouchers together, but look at households who did not receive a voucher in a lottery village separately. Then we allow for different impacts between low and high subsidy levels.

Impact of lotteries

We find that subsidies led to an increase in the relative probability of a cultivated plot converted from forest, in particular in treated villages where no truck came. In the first year, when households had little time to adjust, they converted more secondary forest. In the second year, they turned to primary forest.

First, table 6 shows that, in villages without truck delivery, receiving input subsidies increases the relative probability of choosing a plot in converted land in A 2013 relative to plots that were already cultivated the year before. In those villages, the probability that a plot cultivated in A 2013 was converted from another use increased by 8.8 percentage points (significant at the 5% level) for households who received a voucher, and 7.4 for households who did not receive a voucher (significant at the 10% level), indicating spillovers effects. The difference between voucher recipients and non-voucher recipients is not significant. Hence households reacted immediately to the voucher distribution by taking different types of land in use for cultivation. While such a strong short-term adjustment is remarkable, it is worth noting that we observe a large variation in planting times between March and June, making it possible for farmers to react even after receiving the vouchers in February or early March. However, the average effect is positive but not significant for households in villages with trucks, and there is no effect for households who did not receive a voucher in those villages.

Input subsidies also had an impact on the choice of plots for cultivation one year after the intervention. The average marginal effects show that the impact of lotteries on the choice of plots in 2014 is still large and significant in villages without truck delivery, where the probability for a plot to be on converted land increased by 6.6 percentage points for voucher-recipients (table 7). Given that 20% of the plots are on converted plots in A 2014, this increase is large and meaningful.

Differences between low and high levels of subsidy

Second, tables 8 and 9 differentiate between low and high subsidy levels. In villages without truck delivery, the impact on conversion is equally strong for low levels of subsidies as it is for high levels, both in 2013 and in 2014. In villages with truck delivery, the impact on conversion is stronger for households with low levels of subsidies: the probability that a plot cultivated in A 2013 was converted from another use increased by 6.5 percentage points (significant at the 5% level) for these households compared to households in control villages, but the difference with high levels is not significant. These results suggest that households who had to make an effort to invest (either because of the low level of subsidy or to overcome the access constraint) are more likely to have converted forest. Overall, households with higher cost of adoption hence seem to convert more.

Summary

While it may seem surprising that the treatment that had a lower impact on adoption had the strongest impact on land use, we should keep in mind that truck deliveries also meant a different mix of crops (more groundnuts relative to maize and rice), smaller quantities of seeds, and potentially a different type of household selecting into take-up. The mix of crops is important because crops have very different perceived complementarity for forest soils: while rice and maize can be sown directly after forest clearance, groundnuts is considered more suited for a later rotation. Moreover, the stronger selection in villages without truck and the extra effort they had to make means that households who adopted were more likely to crowd in other inputs that they perceived as complementary, in this case land inputs. In addition, while households in treated villages without truck probably got their seeds later, making land use adjustments more difficult, tables 19 to 24 of the appendix show that households invested in secondary forest the first year, and then primary forest only the second year, the latter being much more difficult and lengthy to clear.

Table 6 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013

	Conversion	Fallow	Cultivated land
Voucher x no truck	0.088**	–0.069	–0.020
	(0.037)	(0.043)	(0.037)
No voucher, Lottery no truck	0.074*	–0.070	–0.004
	(0.044)	(0.051)	(0.041)
Voucher x truck	0.046	–0.030	–0.016
	(0.031)	(0.037)	(0.030)
No voucher, Lottery truck	0.016	–0.030	0.014
	(0.046)	(0.052)	(0.047)
Strat Vars	Yes	Yes	Yes
Observations	1882	1882	1882

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2013

Note: Sample of all plots cultivated in A2013. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 7 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014

	Conversion	Fallow	Cultivated land
Voucher x no truck	0.066**	–0.038	–0.028
	(0.033)	(0.033)	(0.030)
No voucher, Lottery no truck	0.031	–0.008	–0.022
	(0.033)	(0.033)	(0.037)
Voucher x truck	0.020	–0.023	0.003
	(0.030)	(0.024)	(0.022)
No voucher, Lottery truck	0.030	–0.033	0.003
	(0.031)	(0.029)	(0.028)
Strat Vars	Yes	Yes	Yes
Observations	4519	4519	4519

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2014

Note: Sample of all plots cultivated in A2014. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 8 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013

	Conversion	Fallow	Cultivated land
Voucher low x notruck	0.109***	–0.040	–0.069**
	(0.042)	(0.045)	(0.035)
Voucher high x notruck	0.072*	–0.091	0.018
	(0.041)	(0.055)	(0.048)
Voucher low x truck	0.065*	–0.085**	0.020
	(0.033)	(0.042)	(0.037)
Voucher high x truck	0.031	0.012	–0.043
	(0.037)	(0.041)	(0.031)
No voucher, Lottery no truck	0.074*	–0.070	–0.004
	(0.044)	(0.051)	(0.041)
No voucher, Lottery truck	0.016	–0.030	0.014
	(0.046)	(0.052)	(0.046)
Strat Vars	Yes	Yes	Yes
Observations	1882	1882	1882

Source: Follow up 2013

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2013

Note: Sample of all plots cultivated in A2013. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 9 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014

	Conversion	Fallow	Cultivated land
Voucher low x notruck	0.072**	–0.034	–0.038
	(0.033)	(0.032)	(0.035)
Voucher high x notruck	0.062	–0.041	–0.020
	(0.038)	(0.038)	(0.034)
Voucher low x truck	0.027	–0.039	0.011
	(0.035)	(0.030)	(0.027)
Voucher high x truck	0.014	–0.012	–0.003
	(0.030)	(0.025)	(0.024)
No voucher, Lottery no truck	0.031	–0.008	–0.022
	(0.033)	(0.033)	(0.037)
No voucher, Lottery truck	0.030	–0.033	0.003
	(0.031)	(0.029)	(0.028)
Strat Vars	Yes	Yes	Yes
Observations	4519	4519	4519

Source: Follow up 2014

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2014

Note: Sample of all plots cultivated in A2014. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

5 Results: Impact on Land Conversions, household level

To better understand the results of the multinomial estimates, it is important to analyze whether the subsidies also affected the total number of plots under cultivation, the total area farmed, and the share of households who convert land. In the following tables (10 to 12), we therefore report estimates of the effect of the subsidies on a number of measures of land use at the household level. The top panel of each table report results for 2013, and the bottom panel for 2014. As in previous tables, we use data from the follow up waves 2013 and 2014, and we estimate a household level intent to treat regression.

Total number of plots
In table 10, we present results of an OLS regression in which the dependent variable is the total number of plots of different types cultivated by the household, and the main regressors are dummies for having received a subsidy without truck delivery or for having received a subsidy with truck delivery. We consider all plots regardless of the crops cultivated on them. Results from the first column suggest that the lottery in 2013 does not have a significant effect on the total number of plots cultivated in 2013. However, it reduced the number of plots in 2014. For most treatment groups, the coefficient is negative but is only significant for households who received a low subsidy and those who did not receive a subsidy in villages with lotteries but without deliveries, and it is positive for high subsidy levels in truck villages (but not significant). This may be explained by the fact that converted plots require more labor for land preparation, so households may decide to cultivate on smaller number of plots when they clear forest to compensate.

Number of converted plots
In villages without truck delivery in 2013, households who received subsidies cultivate on average more converted plots compared to control villages. In coherence with earlier results at the plot level, this result is driven mainly from conversions in secondary forest and savanna, but also from a relatively lower number of plots from fallows or cultivated plots (depending on treatment arms) compared to control villages. In 2014, households who received a subsidy cultivated 0.14 and 0.16 more plots converted from primary forest respectively (significant at the 10% level) compared to control villages, and 0.098 for non-voucher recipients (not significant). This is accompanied by relatively lower total number of plots compared to control villages, of 0.59, 0.41, and 0.83 plots respectively. This is driven by both fallows and cultivated land, as well as secondary forest to a lesser extent. Again, the pattern is very similar for low vouchers, high vouchers, and controls in those villages.

Results from truck villages follow a similar trend, although most coefficients are not statistically different from zero. In 2013, recipients of vouchers with low subsidies use on average 0.088 more plots in primary forest compared to households in control villages, and 0.13 less fallows (significant at the 10% level). There is no strong difference in the total number of plots in that year, and all coefficients are very small for non-voucher recipients. In 2014, the average number of plots in the primary forest is higher by 0.095 and 0.047 for low and high vouchers respectively compared to households in control villages, while there is virtually no difference between non-recipients and control villages. Tables 11 shows similar results using the area (which can be subject to important measurement issues).

Probability for a given household to use at least one converted plot
To further analyze whether the increase in conversions is driven by households who convert more fields, or from an increase in the share of household who use converted land, we examine the impact of the lotteries on a dummy indicating whether households farmed at least on field of different types. Results are presented in table 12.

We find that households who received low vouchers without truck delivery are more likely to cultivate at least one plot converted from secondary forest by 5.4 percentage points in 2013 (not significant), and by 4.1 percentage points for plot converted from savanna (not significant) as compared to control villages. For households with high vouchers, the probability to cultivate a plot opened in secondary forest increases by 9.3 percentage points (significant at the 10% level) compared to control villages, and 4.4 percentage points for conversions in the savanna (significant at the 5% level). Probabilities to use fallows or cultivated plots are negatively impacted, but coefficients are not significantly different from zero. For non-recipients, the effects are smaller but positive (and not significant) for fields in primary and secondary forest and savanna, and negative (and not significant) for fallows and cultivated land. Interestingly, by 2014, it is specifically the probability to use converted plots from primary forest that increased strongly. The impact is large, as the probability of conversion from primary forest more than doubles for low and high vouchers. The difference between both years is also intuitive. As clearing of primary forest is more labor intensive and typically needs to be done during the low season, the timing of the voucher distribution in 2013 prevented such immediate reaction to occur at a large scale. However by 2014 we observe the full reaction.

In villages with truck deliveries, the impact is small in 2013 and 2014. In 2014, but the probability to use at least one plot in the primary forest increased by 6.9 and 4.2 percentage points respectively for low and high voucher (not significant) relative to households in control villages. The effect on non-recipients in those villages is close to zero.

Summary
Overall, our results suggest that the subsidy had an effect both on the intensive and on the extensive margins, and in particular in villages with lotteries but no truck delivery. In those villages, all households increased the number of converted plots they cultivated compared to the control group in the short run. The total number of plots cultivated changed little compared to the control group, and one year later the number of plots is smaller, probably due

to a trade-off between the type of land and the labor requirements. But the share of converted plots is higher than in the control group due to both the increase in the number of converted plots and the decrease in the number of fallow and cultivated plots. Those results are very consistent with those of the previous section. In addition, table 25 of the appendix shows that vouchers in truck villages had a strong impact on the probability to cultivated groundnuts in 2013 compared to control villages, further suggesting that this could explain part of the difference between villages with and without truck in terms of land use results. However, the impact vanishes in 2014, as more people in the control start producing groundnuts.

Table 10 – Results of OLS regression: Number of Plots Cultivated, by Type of Land and by Treatment

	Total	Conversion	Primary Forest	Secondary Forest	Fallow	Savanna and other	Cultivated
2013							
Voucher low x notruck	–0.117	0.164*	0.051	0.062	–0.123	0.051	–0.158*
	(0.142)	(0.094)	(0.067)	(0.063)	(0.083)	(0.033)	(0.091)
Voucher high x notruck	–0.019	0.129	–0.029	0.106	–0.168*	0.052**	0.021
	(0.141)	(0.085)	(0.039)	(0.064)	(0.097)	(0.026)	(0.117)
Voucher low x truck	0.024	0.121	0.088*	–0.009	–0.137*	0.043	0.040
	(0.117)	(0.073)	(0.052)	(0.056)	(0.077)	(0.027)	(0.087)
Voucher high x truck	0.034	0.063	0.021	0.015	0.033	0.026	–0.061
	(0.117)	(0.069)	(0.046)	(0.053)	(0.082)	(0.020)	(0.083)
No voucher, Lottery no truck	–0.040	0.122	0.036	0.027	–0.149*	0.059	–0.013
	(0.144)	(0.092)	(0.050)	(0.062)	(0.088)	(0.058)	(0.116)
No voucher, Lottery truck	–0.014	0.024	0.015	–0.001	–0.053	0.010	0.014
	(0.150)	(0.085)	(0.050)	(0.060)	(0.121)	(0.012)	(0.106)
Extension	0.137	–0.036	0.014	–0.024	0.138**	–0.025	0.035
	(0.095)	(0.058)	(0.038)	(0.039)	(0.061)	(0.025)	(0.069)
Strat Vars	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1035	1035	1035	1035	1035	1035	1035
Mean Control	1.65	0.50	0.17	0.32	0.49	0.02	0.66
2014							
Voucher low x notruck	–0.591*	0.184	0.140**	–0.119	–0.313*	0.164	–0.467**
	(0.308)	(0.141)	(0.062)	(0.099)	(0.165)	(0.125)	(0.228)
Voucher high x notruck	–0.419	0.187	0.163**	–0.061	–0.279	0.085	–0.272
	(0.292)	(0.161)	(0.074)	(0.114)	(0.184)	(0.103)	(0.228)
Voucher low x truck	–0.136	0.088	0.095	–0.073	–0.207	0.066	–0.026
	(0.305)	(0.144)	(0.059)	(0.104)	(0.162)	(0.098)	(0.223)
Voucher high x truck	0.060	0.085	0.047	0.062	–0.041	–0.024	0.025
	(0.287)	(0.121)	(0.043)	(0.106)	(0.146)	(0.066)	(0.212)
No voucher, Lottery no truck	–0.836***	–0.052	0.098	–0.122	–0.255	–0.029	–0.499**
	(0.301)	(0.129)	(0.062)	(0.108)	(0.164)	(0.059)	(0.222)
No voucher, Lottery truck	–0.113	0.112	0.013	0.065	–0.186	0.035	–0.055
	(0.300)	(0.138)	(0.048)	(0.125)	(0.149)	(0.085)	(0.214)
Strat Vars	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1067	1065	1065	1065	1065	1065	1063
Mean Control	4.21	0.92	0.12	0.67	0.96	0.13	2.33

Table 11 – Results of OLS regression: Total Area Farmed, by Types of Land, by Treatment

	Total	Conversion	Primary Forest	Secondary Forest	Fallow	Savanna and other	Cultivated
2013							
Voucher low x notruck	–0.226	0.148	0.027	0.021	–0.135	0.100	–0.239**
	(0.193)	(0.137)	(0.069)	(0.075)	(0.086)	(0.091)	(0.095)
Voucher high x notruck	–0.025	0.017	–0.047	0.020	–0.054	0.079***	0.011
	(0.204)	(0.094)	(0.041)	(0.075)	(0.099)	(0.029)	(0.125)
Voucher low x truck	–0.357**	–0.034	0.041	–0.086	–0.179**	0.019	–0.144
	(0.173)	(0.085)	(0.065)	(0.058)	(0.070)	(0.016)	(0.102)
Voucher high x truck	0.105	0.057	0.061	–0.018	0.039	0.022	0.010
	(0.232)	(0.101)	(0.071)	(0.068)	(0.102)	(0.017)	(0.144)
No voucher, Lottery no truck	–0.157	0.029	0.029	–0.020	–0.146	0.038	–0.039
	(0.212)	(0.115)	(0.057)	(0.080)	(0.093)	(0.036)	(0.140)
No voucher, Lottery truck	0.173	0.042	0.094	–0.056	0.031	0.034	0.100
	(0.270)	(0.147)	(0.122)	(0.080)	(0.142)	(0.029)	(0.141)
Strat Vars	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1035	1035	1035	1035	1035	1035	1035
Mean Control	1.41	0.55	0.18	0.36	0.37	0.01	0.49
2014							
Voucher low x notruck	–0.367	0.100	0.106*	–0.060	–0.205	0.171*	–0.262
	(0.292)	(0.125)	(0.055)	(0.108)	(0.124)	(0.096)	(0.170)
Voucher high x notruck	0.157	0.038	0.198**	–0.186*	0.057	0.261	0.065
	(0.441)	(0.137)	(0.087)	(0.100)	(0.214)	(0.173)	(0.257)
Voucher low x truck	–0.350	0.037	0.080	–0.052	–0.229*	0.071	–0.159
	(0.304)	(0.126)	(0.052)	(0.103)	(0.125)	(0.060)	(0.187)
Voucher high x truck	0.225	0.071	0.074*	–0.002	0.017	0.067	0.141
	(0.291)	(0.106)	(0.041)	(0.094)	(0.128)	(0.074)	(0.184)
No voucher, Lottery no truck	–0.291	0.051	0.038	–0.008	–0.184	0.084	–0.155
	(0.408)	(0.141)	(0.051)	(0.130)	(0.128)	(0.068)	(0.267)
No voucher, Lottery truck	0.112	0.320	0.013	0.301	–0.053	0.057	–0.157
	(0.402)	(0.303)	(0.050)	(0.304)	(0.131)	(0.067)	(0.168)
Strat Vars	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1067	1067	1067	1067	1067	1067	1067
Mean Control	2.80	0.74	0.10	0.59	0.58	0.12	1.48

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Note: Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 12 – Results of OLS regression: Dummies for whether Households Cultivated on Different Types of Land, by Treatment

	(1) Primary Forest	(2) Secdondary Forest	(3) Fallow	(4) Savanna and other	(5) Cultivated
2013					
Voucher low x notruck	0.030	0.054	–0.074	0.041	–0.077
	(0.054)	(0.049)	(0.068)	(0.025)	(0.075)
Voucher high x notruck	–0.017	0.093*	–0.131	0.044**	–0.004
	(0.038)	(0.056)	(0.080)	(0.022)	(0.078)
Voucher low x truck	0.076	–0.009	–0.145***	0.037*	–0.012
	(0.047)	(0.048)	(0.051)	(0.022)	(0.059)
Voucher high x truck	0.020	0.007	0.010	0.028	–0.059
	(0.042)	(0.045)	(0.061)	(0.020)	(0.065)
No voucher, Lottery no truck	0.051	0.023	–0.071	0.028	0.006
	(0.049)	(0.054)	(0.070)	(0.028)	(0.078)
No voucher, Lottery truck	0.011	–0.004	–0.065	0.009	–0.016
	(0.043)	(0.051)	(0.065)	(0.011)	(0.076)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	1035	1035	1035	1035	1035
Mean Control	0.16	0.29	0.40	0.02	0.58
	(1)	(2)	(3)	(4)	(5)
2014					
Voucher low x notruck	0.125**	–0.039	–0.054	0.066	–0.071*
	(0.052)	(0.066)	(0.076)	(0.059)	(0.038)
Voucher high x notruck	0.113**	–0.062	–0.123	0.004	–0.029
	(0.043)	(0.063)	(0.075)	(0.041)	(0.026)
Voucher low x truck	0.069	–0.041	–0.065	0.023	0.022
	(0.047)	(0.059)	(0.069)	(0.047)	(0.021)
Voucher high x truck	0.042	0.021	–0.013	–0.021	0.023
	(0.033)	(0.061)	(0.063)	(0.036)	(0.021)
No voucher, Lottery no truck	0.070	–0.019	–0.045	0.007	–0.058
	(0.052)	(0.072)	(0.078)	(0.048)	(0.043)
No voucher, Lottery truck	0.017	0.044	–0.087	0.015	0.001
	(0.043)	(0.067)	(0.068)	(0.046)	(0.031)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	1066	1066	1066	1066	1066
Mean Control	0.09	0.45	0.56	0.08	0.92

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Note: Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

6 Results: General Equilibrium Effects

In this section, we examine whether vouchers had an impact on land use for non-treated households and whether the proportion of households treated matters.

6.1 Impact of the Density of the Intervention

The impact of the intervention on land conversions seems to be stronger in villages in which a larger proportion of households received subsidies, as evidenced by tables 13 and 14. General equilibrium effects in this setting could result from increased perceived value of (and hence competition for) land, and strategic clearing for assuring land access in the future. It can also result however from collective action for land preparation. While we cannot separate these two mechanisms, we present evidence suggsting both may have been at play.

In the first year, vouchers without truck increase the probability that households choose a plot converted from forest or savanna rather than from cultivated land by 4.4 percentage points in villages in which 20% of the households were treated, and by 11 and 9.8 percentage points higher respectively in villages where 45 or 70% of households were treated. Similarly, in 2014 the effect on land conversions is driven by villages with larger shares of households targeted. Remember that in villages without truck delivery, we found that subsidies led to equal probability of adoption by each household, independent of the share of households receiving vouchers (see above). As in villages with a high percentage of vouchers there are hence overall more people adopting, the increased conversion potentially indicates increased competition for land.

In contrast, the impact is not different for different proportions of treated households in villages with truck delivery in both years. Recall however that in those villages, adoption probabilities in season A 2014 were lower in villages with higher density of vouchers. Hence while more people received vouchers, the recipients were less likely to use improved seeds the following year, and if they did, these were more likely to be groundnuts for which agronomic returns of clearing are much lower than for rice or maize. Overall this translates into less difference between villages with different intensities of treatment in terms of adoption of improved seeds. Consistent with that pattern, we also do not see differences in conversion between those different villages.

6.2 Spillovers

In the previous sections, we uncovered some important spillover effects on land conversions for non treated households in lottery villages without truck (table 10). By looking at different densities of intervention, it becomes clear that these spillover effects are stronger when higher proportions of households are treated in a villages. This further confirms the hypothesis of an increase in the competition for land.

6.3 Impact on Labor for Land Preparation

Tables 15 and 16 show the impact on total household labor for land preparation in 2013 and 2014, with the dependent variable expressed in inverse hyperbolic sine transformation. We find an overall increase in the total amount of time spent in labor sharing groups in all treatment arms, stronger for higher density levels.

This suggests that the expected value of land went up for all, and not only for treated households. After the voucher distribution, the value of forest land went up because some treated households perceived a complementarity between the seeds for some crops and forest soils. As a results of this relative increase in the value of land, more households were willing to make the additional investment in labor required to clear forest. Since land preparation and in particular the felling of trees and clearing of the land are traditionally performed in groups, households organized more labor sharing groups to open new fields in the forest, a labor intensive and costly investment that sometimes confers some rights to the land thus cleared. Qualitative interviews suggest that farmers do this task in groups because it allows them to commit to complete a cumbersome task that they could otherwise be tempted to quit before completion, and that it has the advantage of allowing for clear and public demarcations of plots (since all the members of the group work on all fields in rotation), which is key for avoiding future land disputes. Because more labor sharing groups organized, other households in the villages were drawn into them, and became aware of the rising competition for land, reinforcing the effect. The fact that higher densities of intervention led to higher probabilities to convert is coherent with this interpretation.

This could also suggest that the effect on conversions could be driven no only by a crowding in of land inputs by those who decided to invest in high yielding seeds, but also that the program "nudged" people to be more interested in agriculture, and that everybody wants to participate and invest one way or another as a result.

Table 13 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013

	Conversion	Fallow	Cultivated land
Voucher no truck x level 20	0.044	–0.114**	0.070
	(0.064)	(0.046)	(0.051)
Voucher no truck x level 45	0.118***	–0.167**	0.049
	(0.045)	(0.078)	(0.047)
Voucher no truck x level 70	0.098*	0.038	–0.136**
	(0.055)	(0.053)	(0.062)
Voucher truck x level 20	0.060	0.013	–0.073
	(0.044)	(0.065)	(0.053)
Voucher truck x level 45	0.034	–0.064	0.030
	(0.042)	(0.046)	(0.040)
Voucher truck x level 70	0.046	–0.043	–0.003
	(0.042)	(0.053)	(0.035)
No voucher x AM Level 20	0.065	0.029	–0.095
	(0.066)	(0.072)	(0.064)
No voucher x AM Level 45	–0.029	–0.063	0.092**
	(0.063)	(0.077)	(0.044)
No voucher x AM Level 70	0.173***	–0.149	–0.024
	(0.057)	(0.094)	(0.076)
No voucher x Truck Level 20	0.001	–0.060	0.059
	(0.059)	(0.064)	(0.075)
No voucher x Truck Level 45	0.060	–0.090	0.030
	(0.070)	(0.058)	(0.057)
No voucher x Truck Level 70	–0.011	0.062	–0.051
	(0.073)	(0.098)	(0.070)
Strat Vars	Yes	Yes	Yes
Observations	1882	1882	1882

Source: Follow up 2013

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2013

Note: Sample of all plots cultivated in A2013. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 14 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014

	Conversion	Fallow	Cultivated land
Voucher no truck x level 20	–0.018	0.039	–0.021
	(0.041)	(0.044)	(0.042)
Voucher no truck x level 45	0.090***	–0.116**	0.026
	(0.031)	(0.056)	(0.057)
Voucher no truck x level 70	0.102**	–0.041	–0.062
	(0.052)	(0.045)	(0.038)
Voucher truck x level 20	0.012	–0.037	0.025
	(0.039)	(0.028)	(0.024)
Voucher truck x level 45	–0.000	0.007	–0.007
	(0.038)	(0.027)	(0.030)
Voucher truck x level 70	0.044	–0.035	–0.009
	(0.041)	(0.047)	(0.036)
No voucher x AM Level 20	–0.039	0.055	–0.016
	(0.080)	(0.036)	(0.075)
No voucher x AM Level 45	0.033	–0.041	0.009
	(0.039)	(0.058)	(0.051)
No voucher x AM Level 70	0.075**	–0.029	–0.046
	(0.038)	(0.062)	(0.065)
No voucher x Truck Level 20	0.021	–0.039	0.019
	(0.047)	(0.050)	(0.047)
No voucher x Truck Level 45	–0.007	–0.016	0.023
	(0.048)	(0.047)	(0.046)
No voucher x Truck Level 70	0.072**	–0.039	–0.032
	(0.033)	(0.036)	(0.028)
Strat Vars	Yes	Yes	Yes
Observations	4519	4519	4519

Source: Follow up 2014

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2014

Note: Sample of all plots cultivated in A2014. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 15 – Results of OLS regression: Total Labor on Household's fields in Season A 2014

	Total ihst	HH ihst	Labor Sharing ihst	Paid ihst
2013				
Voucher low x notruck	–0.118	–0.125	0.196	–0.192
	(0.190)	(0.208)	(0.233)	(0.211)
Voucher high x notruck	0.035	0.014	0.128	0.080
	(0.192)	(0.203)	(0.241)	(0.225)
Voucher low x truck	–0.159	–0.296*	0.233	0.023
	(0.173)	(0.162)	(0.243)	(0.212)
Voucher high x truck	0.249	–0.039	0.726***	0.244
	(0.154)	(0.166)	(0.217)	(0.210)
No voucher, Lottery no truck	0.170	0.154	0.516*	–0.285
	(0.186)	(0.245)	(0.267)	(0.262)
No voucher, Lottery truck	0.061	0.041	0.427*	0.150
	(0.171)	(0.195)	(0.220)	(0.238)
Strat Vars	Yes	Yes	Yes	Yes
Observations	1022	1022	1023	1023
Mean Control	4.05	3.17	1.32	1.74
2014				
Voucher low x notruck	–0.070	–0.193	0.288	–0.511**
	(0.189)	(0.203)	(0.252)	(0.239)
Voucher high x notruck	–0.008	–0.195	0.462*	–0.147
	(0.223)	(0.238)	(0.254)	(0.259)
Voucher low x truck	0.071	–0.109	0.550**	–0.216
	(0.192)	(0.202)	(0.245)	(0.233)
Voucher high x truck	0.138	–0.141	0.169	0.481**
	(0.140)	(0.167)	(0.209)	(0.229)
No voucher, Lottery no truck	–0.343	–0.510**	0.066	–0.281
	(0.261)	(0.240)	(0.299)	(0.317)
No voucher, Lottery truck	0.119	–0.486**	0.469*	0.368
	(0.175)	(0.196)	(0.274)	(0.284)
Strat Vars	Yes	Yes	Yes	Yes
Observations	1065	1065	1065	1065
Mean Control	4.21	3.35	1.68	1.81

Source: Follow up surveys waves 2013 and 2014

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Note: Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.
ihst: inverse hyperbolic sine transformation
Total: Total labor on household's fields in Season A 2014
HH: total labor from members of the Household
Labor Sharing: total labor from Labor Sharing groups
Paid: total paid labor

Table 16 – Results of OLS regression: Total Labor on Household's fields in Season A 2014

	Total ihst	HH ihst	Labor Sharing ihst	Paid ihst
Voucher no truck x density 20	–0.300	–0.101	–0.291	0.166
	(0.282)	(0.275)	(0.281)	(0.236)
Voucher no truck x density 45	0.175	0.023	0.413	–0.155
	(0.249)	(0.227)	(0.292)	(0.304)
Voucher no truck x density 70	–0.022	–0.079	0.275	–0.104
	(0.260)	(0.315)	(0.287)	(0.230)
Voucher truck x density 20	0.044	–0.229	0.594*	0.088
	(0.173)	(0.193)	(0.331)	(0.242)
Voucher truck x density 45	0.018	–0.084	0.356	0.170
	(0.186)	(0.205)	(0.225)	(0.260)
Voucher truck x density 70	0.130	–0.147	0.563**	0.169
	(0.210)	(0.158)	(0.272)	(0.272)
No voucher x AM density 20	0.223	0.006	0.344	0.163
	(0.182)	(0.281)	(0.322)	(0.263)
No voucher x AM density 45	0.121	0.027	0.237	–0.114
	(0.324)	(0.561)	(0.550)	(0.499)
No voucher x AM density 70	0.169	0.349	0.843**	–0.733*
	(0.329)	(0.328)	(0.390)	(0.373)
No voucher x Truck density 20	0.134	–0.102	0.477	0.138
	(0.204)	(0.249)	(0.392)	(0.354)
No voucher x Truck density 45	0.130	0.341	0.358	0.088
	(0.330)	(0.365)	(0.269)	(0.355)
No voucher x Truck density 70	–0.083	–0.126	0.457	0.235
	(0.233)	(0.234)	(0.390)	(0.367)
Strat Vars	Yes	Yes	Yes	Yes
Observations	1022	1022	1023	1023
Mean Control	4.05	3.17	1.32	1.74
Voucher no truck x density 20	–0.075	–0.084	0.158	–0.669**
	(0.282)	(0.289)	(0.330)	(0.307)
Voucher no truck x density 45	–0.343	–0.352	0.284	–0.198
	(0.342)	(0.272)	(0.318)	(0.318)
Voucher no truck x density 70	0.267	–0.156	0.662**	–0.139
	(0.188)	(0.339)	(0.323)	(0.341)
Voucher truck x density 20	0.032	–0.423*	0.540*	0.064
	(0.211)	(0.243)	(0.306)	(0.244)
Voucher truck x density 45	0.041	–0.000	–0.071	0.309
	(0.224)	(0.225)	(0.254)	(0.347)
Voucher truck x density 70	0.260	0.056	0.537**	0.152
	(0.184)	(0.222)	(0.243)	(0.255)
No voucher x AM density 20	–0.715**	–0.511	–0.088	–0.575
	(0.323)	(0.315)	(0.281)	(0.347)
No voucher x AM density 45	–0.127	–0.443	–0.348	–0.138
	(0.514)	(0.469)	(0.496)	(0.598)
No voucher x AM density 70	–0.215	–0.574*	0.552	–0.163
	(0.395)	(0.345)	(0.505)	(0.512)
No voucher x Truck density 20	0.049	–0.606***	0.674*	0.183
	(0.199)	(0.205)	(0.388)	(0.376)
No voucher x Truck density 45	–0.102	–0.357	0.117	0.258
	(0.371)	(0.401)	(0.521)	(0.409)
No voucher x Truck density 70	0.412**	–0.473	0.574*	0.681
	(0.177)	(0.290)	(0.325)	(0.519)
Strat Vars	Yes	Yes	Yes	Yes
Observations	1065	1065	1065	1065
Mean Control	4.21	3.35	1.68	1.81

Source: Follow up surveys waves 2013 and 2014
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Note: Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.
ihst: inverse hyperbolic sine transformation
Total: Total labor on household's fields in Season A 2014
HH: total labor from members of the Household
Labor Sharing: total labor from Labor Sharing groups
Paid: total paid labor

7 Conclusion

This paper studies the relationship between adoption of improved seed varieties and land expansion in Equateur Province in DRC. In a context of extensive slash-and-burn agriculture without any modern inputs, the randomized introduction of improved seeds through price subsidies provides exogenous variation to study how households adjust their land holdings.

Randomized price subsidies, with or without lifting additional access constraints, led to large and significant increases in adoption of improved seeds, inducing more households to try these new seeds out. Households benefiting from the subsidies reacted by shifting from already cultivated land or fallows, to newly cleared land in the secondary forest or savanna the first year, and to primary forest the second year. This reaction is stronger where the cost of adopting the improved seeds was higher.

While preparing such lands is much more labor-intensive, the newly converted land is also more fertile right after clearing. The stronger selection and the extra effort they had to make in villages without trucks led them to crowd in other inputs that they perceived as complementary, in this case land inputs. Hence the reaction of households may well be partly driven by a perceived complementarity between high value inputs for some crops and land fertility in forest soils. This is further consistent with the effects being much stronger in villages without truck delivery of the seeds, where mostly maize and rice were supplied, compared to truck villages where the vouchers induced more households to cultivate groundnuts (for which clearing of land has lower agronomic returns).

The results further show that the adjustment is particularly large in villages where more households adopt the new seeds — a difference that results from randomly varying the share of households receiving vouchers in a village. In addition to complementarity, this suggests a potential role of perceived competition for land, and strategic clearing for assuring land access in the future. However, the impact of the intervention on land conversions could also result from collective action for land preparation, since we find that the subsidies increase the total amount of household labor devoted to labor sharing groups for land preparation. Indeed, clearing the forest is a tiring task, and non-vouchers recipients may have been drawn into labor sharing groups to help voucher recipients clear the land they needed, nudging them to clear land as well. While we can not separate these two mechanisms, results suggest that both may have played a role.

References

Angelsen, Arild and David Kaimowitz, "Rethinking the Causes of Deforestation: Lessons from Economic Models," *The World Bank Research Observer*, February 1999, *14* (1), 73–98. 00655.

_ , _ , and Center for International Forestry Research, eds, *Agricultural technologies and tropical deforestation*, Wallingford, Oxon, UK ; New York, NY, USA: CABI Pub. in association with Center for International Forestry Research, 2001.

Borlaug, Norman, "Feeding a Hungry World," *Science*, October 2007, *318* (5849), 359–359.

Cohen, Jessica, Pascaline Dupas, and Simone Schaner, "Price Subsidies, Diagnostic Tests, and Targeting of Malaria Treatment: Evidence from a Randomized Controlled Trial †$," *American Economic Review*, February 2015, *105* (2), 609–645.

Dupas, Pascaline, "Short-Run Subsidies and Long-Run Adoption of New Health Products: Evidence From a Field Experiment," *Econometrica*, January 2014, *82* (1), 197–228.

Emerick, Kyle, Alain de Janvry, Elisabeth Sadoulet, and Manzoor H. Dar, "Technological innovations, downside risk, and the modernization of agriculture," *The American Economic Review*, 2016, *106* (6), 1537–1561.

Gollin, Douglas, Michael Morris, and Derek Byerlee, "Technology Adoption in Intensive Post-Green Revolution Systems," *American Journal of Agricultural Economics*, 2005, *87* (5), 1310–1316.

Grimm, Michael, Claude Wetta, and Aude Nikiema, "Burkina Faso: Shipping around the Malthusian trap," Technical Report, WIDER Working Paper 2014.

Herdeschee, Johannes, Kai-Alexander Kaiser, and Daniel Mukoko Samba, *Resilience dun Geant Africain: Accelerer la Croissance et Promouvoir l emploi en Republique Democratique du Congo, Volume I Synthese, contexte historique et macroeconomique*, Kinshasa: MEDIASPAUL, 2012.

Hunt, Diana and Michael Lipton, *Green Revolutions for Sub-Saharan Africa?*, Chatham House, 2011.

Jack, B. Kelsey, "Market inefficiences and adoption of agricultural technologies in developing countries," *Center for International Development*, 2013.

Meyfroidt, Patrick, Kimberly M. Carlson, Matthew E. Fagan, Victor H. Gutierrez-Velez, Marcia N. Macedo, Lisa M. Curran, Ruth S. DeFries, George A. Dyer, Holly K. Gibbs, Eric F. Lambin, Douglas C. Morton, and

Valentina Robiglio, "Multiple pathways of commodity crop expansion in tropical forest landscapes," *Environmental Research Letters*, 2014, *9* (7), 074012.

Miguel, Edward and Michael Kremer, "Worms: identifying impacts on education and health in the presence of treatment externalities," *Econometrica*, 2004, pp. 159–217.

Rudel, Thomas K., Laura Schneider, Maria Uriarte, B. L. Turner, Ruth DeFries, Deborah Lawrence, Jacqueline Geoghegan, Susanna Hecht, Amy Ickowitz, Eric F. Lambin, Trevor Birkenholtz, Sandra Baptista, and Ricardo Grau, "Agricultural intensification and changes in cultivated areas, 1970–2005," *Proceedings of the National Academy of Sciences*, December 2009, *106* (49), 20675–20680.

Tarozzi, Alessandro, Aprajit Mahajan, Brian Blackburn, Dan Kopf, Lakshmi Krishnan, and Joanne Yoong, "Micro-Loans, Insecticide-Treated Bednets, and Malaria: Evidence from a Randomized Controlled Trial in Orissa, India †$," *American Economic Review*, July 2014, *104* (7), 1909–1941.

Villoria, Nelson B., Derek Byerlee, and James Stevenson, "The Effects of Agricultural Technological Progress on Deforestation: What Do We Really Know?," *Applied Economic Perspectives and Policy*, May 2014, p. ppu005.

World Bank, ed., *World Development Report 2008: Agriculture for Development*, Washington DC: World Bank Publications, 2007. OCLC: 237205625.

A Details on the project and experimental design

A.1 The project : Dissemination of seeds, techniques and technologies to improve agricultural production

The Agricultural Rehabilitation and Recovery Support Project (PARRSA for its acronym in French) was implemented by the Ministry of Agriculture , starting in 2011, with the Support of the World Bank. PARRSA operates in 9 territories in the three northern districts of Equateur Province in DRC. [12] PARRSA aims to improve agricultural productivity in the region through a variety of mechanisms. Agricultural extension and advisory services in Equateur province have been virtually absent for years and the availability of high quality improved seeds is severely constrained. A first important objective of PARRSA is therefore the regeneration of the market for improved seeds. In the phase prior to the phase covered by the evaluation, the project assisted the national research institute (INERA) to resume improved seed production in the region for maize, rice, groundnut, niebe, and soya and provided subsidies for the multiplication of improved seeds by selected agri-multipliers in the region. The varieties were selected mainly for their high yield characteristics and for their resistance to a very widespread disease (mozaïque) in the case of cassava.

The evaluation focuses on subsequent interventions, implemented to encourage the demand for seeds, including disseminate information about the improved seeds and related techniques through demonstration plots and extension activities, as well as seed subsidies. In parallel, the project also targeted 2,500 kilometers of feeder and access roads for rehabilitation.

A.2 Experimental design

A.2.1 Presentation of the evaluation

The evaluation aims at providing experimental evidence on the impact of several interventions targeting demand constraints to the adoption of improved seed varieties and subsequent welfare gains among poor smallholders in Equator province in the DRC. We measure the impact of extension through demonstration plots, different levels and modalities of seed price subsidies in a context of extensive slash and burn agriculture and strong gender division in agricultural tasks. We introduce experimental variations that allowed targeting extension and subsidies specifically to women and hypothesize that such gender targeting could increase both the sustainability of adoption and the translation of the adoption of improved seeds in better nutrition, health and education outcomes. The evaluation specifically focuses on such welfare outcomes given the high levels of poverty, malnutrition, food insecurity and child mortality in

[12] Nord Ubangi, Sud Ubangi, and Mongala.

the region studied, and the importance of crop income in households income portfolio. Given the extreme difficult road access in the region studied, the interventions were stratified based on market access, and an experimental variation was introduced that eliminated transportation costs for improved seeds. To study diffusion patterns of the improved technologies we introduce experimental variation in the density of the subsidies

A.2.2 Extension services

The extension interventions was implemented by local NGOs who organized a group of farmers from a targeted village around a demonstration plot. An extension agent was in charge of the introduction of the new seeds and adapted practices, and the group works in common on the field, following the indications given by the agent. In a first set of randomly chosen villages most members of the group are men. In the second randomly chosen villages the extension agents had to organize groups around the demonstration plots with a majority of women. In both type of villages, relatively small demonstration plots were first organized by local PARRSA teams during 3 seasons (from spring 2012 to spring 2013). As of the fall of 2013, NGOs started organizing more intensive extension activities, and respect for men or women targeting was imposed as a condition in the NGOs contracts with PARRSA.

The theory of change of the extension intervention is relatively straightforward. By introducing improved seeds on demonstration plots, households in targeted villages have the opportunity to directly learn about the returns to such improved seeds. Households that participate in the works on the demonstration plots also learn about complementary practices such as row planting. And potentially, all households could get access to improved planting material resulting from the harvests on the demonstration plots, though this should be relatively limited. Overall the extension intervention is expected to increase demand for and subsequent adoption of improved seeds.

A.2.3 Lotteries and vouchers

Given the subsidies received by the supply side for seed multiplication, there was an open question of the optimal pricing of seeds for the final user. A subset of 92 villages was selected for possible targeting of seed subsidies. The PARRSA team then distributed seed vouchers in a random subsample of 60 villages, wih the remaining 32 villages serving as control). Seed vouchers offering price reductions were distributed through public lotteries, organized in each of the 60 villages. Starting from census data collected at baseline, randomly selected households received vouchers offering either 30, 60, 90 or 100% reduction on a maximum of 10 kg of cereal or pulse seeds (or equivalent amounts of manioc sticks). Once a households was randomly selected, a second draw determined randomly whether the voucher was given to the man (the household head) or his wife. In case of polygamous households, and if the voucher was to be given to a woman, the third random draw determined to which of the wives the voucher was given. Among the 60 villages, 35 were in addition randomly selected to be visited by a truck with seeds of the agri-multipliers in the days or weeks following the voucher distribution, effectively removing a potential transportation constraint. Voucher recipients in the remaining 25 villages, as well as households of the 35 truck villages that did not redeem their voucher when the truck passed their village, could redeem their vouchers and buy seeds in the offices of the seedmultipliers, located typically in the local urban centers. The share of households receiving vouchers in each village also varied in order to assess the potential spillovers and general equilibrium effects.

The different levels of subsidies and targeting allows testing the importance of liquidity and transportation constraints for the adoption of improved seeds. Indeed, we hypothesize that the initial price at which farmers get access to improved seeds can be an important obstacle in the context of Equateur, where households mainly live from subsistence agriculture and liquidity constraints are severe. The theory of change we are testing is whether initial price subsidies for a limited amount of seeds lead to more sustained adoption and higher demand on the long run, once households have had an opportunity to learn about returns from their own experimentation. In addition, given the extremely difficult road access in almost the entire region covered by the project, we also hypothesize that transportation costs may add to the existing liquidity constraints. The intervention that sends trucks to the villages was designed to test this hypothesis.

A.2.4 Experimental design : selection into the program

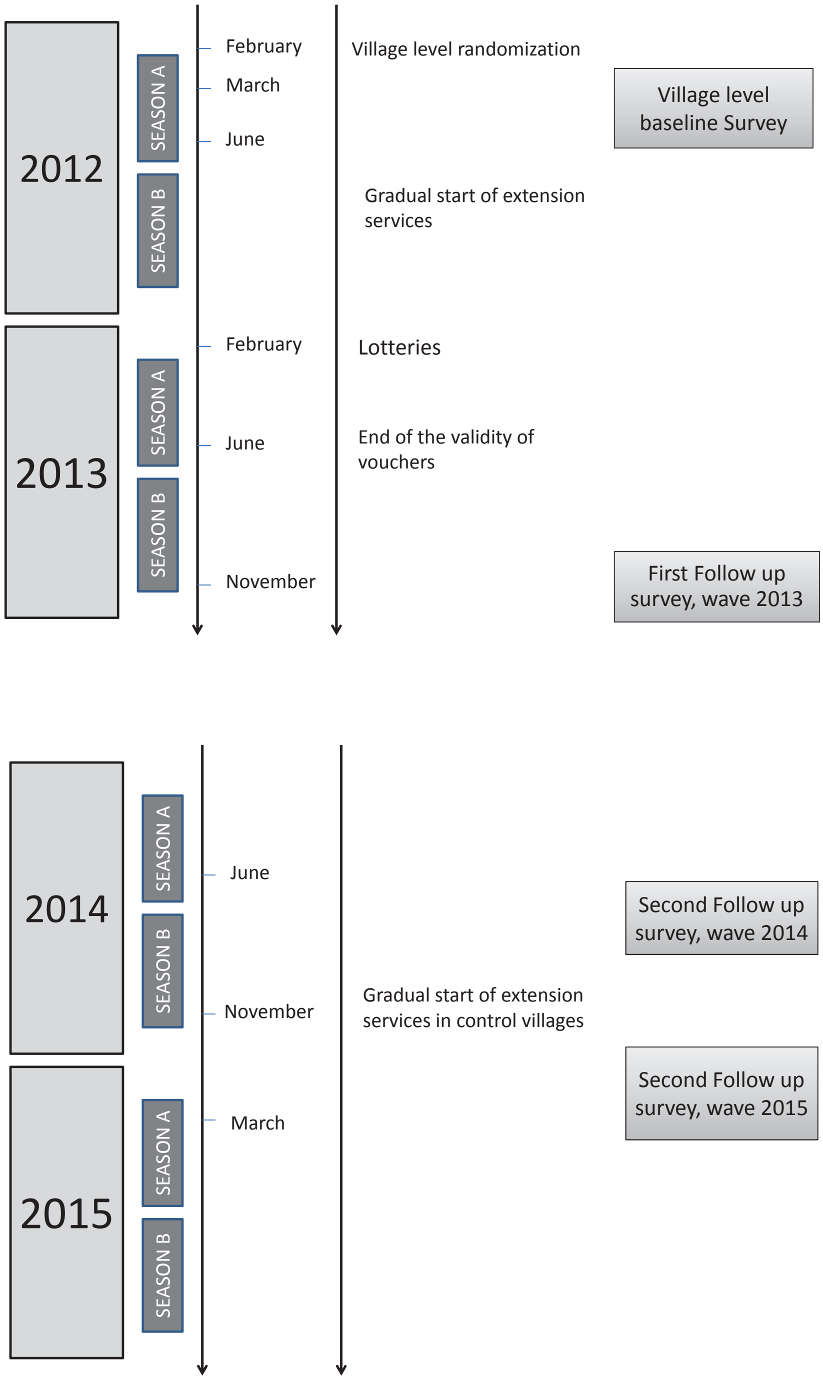
Identification for the extension intervention and its gender targeting was based on randomized assignment. As the extension intervention is based on demonstration plots or fields to which all villagers can have access, this intervention was randomized at the village level. The local district offices of PARRSA first selected 201 villages as potential candidates for the initial phase of the intervention. The sample size was determined by operational constraints, and reflected the number of villages PARRSA envisioned being able to attend to in a first phase. The villages are spread over the 9 territories targeted by PARRSA and cover an extensive geographical area (154 Groupements). Village level baseline data was collected for 201 villages, and for an additional 201 randomly selected neighboring villages. As we hypothesize important treatment heterogeneity by accessibility, the 201 candidate villages were stratified by organizing them in triplets based on similar proximity to roads and markets. In each district, a public lottery was organized in February 2012 (prior to the first season of 2012). For each of the triplets, one candidate village was selected as a women treatment, one village as men treatment, and the third village as control. In the control group, no PARRSA extension activities are to take place until the second season of 2014.

Identification for the seed subsidy vouchers and their gender targeting was also based on random assignment. First, among the original 201 villages selected for the extension intervention, a subsample of 92 villages were purposely selected to enter the seed subsidy vouchers experiment, based on being relatively accessible by truck. The 92 villages are spread across Sud Ubangi, Mongala and North Ubangi, and across 5 (out of 9) territories in those districts. The 92 villages were stratified based on size (below or above median size), remoteness (a subjective indicator of accessibility), and treatment status of the PARRSA demonstration plots/OAC intervention (control, women treatment, men treatment). Respecting this stratification, 32 villages were randomly selected as control villages for the seed vouchers, 25 as voucher villages, and 35 as voucher and truck villages. The number of treatment villages was based on logistical and cost constraints. This randomization was done by computer, orthogonally to the extension treatment. Stratification on remoteness should allow shedding light on the mechanism underlying any potential difference between voucher and voucher+truck villages, while the stratification on size was done to analyze potential differences in diffusion patterns based on village size.

In each of the 60 voucher villages, a public lottery was organized through which subsidy vouchers for improved seeds were distributed. In 1/3 of randomly selected villages, 70% of households received a voucher through this lottery (high density), in 1/3 random villages 45% of households received vouchers (medium density) and in the last 1/3 villages only 20% received vouchers (low density). The variation in voucher density was introduced to study whether diffusion of improved seeds is a function of village level intensity of initial exposure. In each treatment village, equal amounts of 30%, 60%, 90% and 100% subsidy vouchers were distributed through the lottery, with half of them randomly assigned to the household heads, while the other half assigned to the (or a) wife of the household head. In case of polygamous households, a randomization was conducted to determine which women would receive the voucher. Across the 60 villages a total of 4344 vouchers was distributed. Given these large numbers, and the household level randomization, the design results on substantial statistical power to detect the direct impacts of receiving vouchers, differences between different levels of subsidies, and differences between men and women beneficiaries. The differences in the level of subsidies were chosen to get a better estimate of willingness to pay and advise on optimal pricing, and to test any potential non-linearities (e.g. by analyzing differences between 90 and 100% subsidy).

A.3 Timeline

Figure 2 – Timeline



A.4 Data : baseline survey, followup surveys, and sampling strategy

A baseline survey was administered between March 2012 and July 2012 in 895 villages, including the 201 villages of the experiment. In each village, a group of 4 to 5 people was selected to answer a community level questionnaire as well as indirect household surveys for 20 randomly chosen households. For those 20 households, basic household characteristics related to agriculture, demographics, and poverty are available. The group was composed of knowledgeable people in the village, including the chief of the village, the director of the school, the director of the dispensary, and other notables, depending on availability. Census data was also collected.

A first follow-up was conducted between November and December 2013, i.e. after the agricultural season directly following the lotteries. Data was collected in the 92 villages involved in the lottery experiment. For the 60 voucher treatment villages, administrative records about the beneficiaries identity and type of seed voucher received during the lotteries is also available. This administrative data was used for the sample selection of the follow-up surveys. In particular, in each of the voucher villages, we randomly drew beneficiaries, stratified by level of subsidy and gender (Male/Female; 0%, 30%/60%/90%/100%).
An additional men or women was added for 0 and 100% subsidy levels to maximize power. This gives a first group of 12 households, for whom detailed information about agricultural production in the season after voucher distribution, in addition to information on take-up, perceptions and social networks was collected. Given that the voucher distribution was random, these 12 households can be compared to 12 randomly drawn households in the control. In all villages, the samples were further stratified on baseline membership in producer organizations, on having a leadership positions in the village, and on polygamy. In addition, the same survey instrument was also implemented for the person that was the village leader at the time of the lottery.
For an additional 10 random households (1 men and 1 women for each subsidy level) a short survey was implemented on take up, perceptions and social networks. This sample again includes 2 people with leadership positions. The sampling of the first followup survey was targeted to understand take up and mechanisms leading to final outcomes, including importantly the potential to understand different diffusion mechanism through social networks, and the potential example roles of local leaders to encourage adoption by others.

For the second follow-up survey in the 92 villages, the same 12 households for whom we had detailed agricultural information in the first follow-up survey have been resurveyed. To increase power,six additional households, for whom only a short survey was implemented in 2013, were added to the sample (two each with 0, 90 and 100% subsidies (one men, one women for each household) in the voucher villages. Finally, an additional 6 household with 0 or 100% reduction and 2 with 90% reduction were added in the voucher+truck villages.

Based on qualitative field work following voucher distribution, we hypothesized that diffusion of information about the new technologies might only circulate within very narrow social circles. We therefore added to the sample by targeting a brother of the household head for the original 12 households living in the same village (maximum 10 such brothers in each village). As there can be large inequalities in access to land based on order in the fraternity, we surveyed in particular the oldest brother (or a random brother in case the original household is the oldest brother). Since the households of each of those brothers were equally eligible for vouchers, they will have also been randomly exposed to different subsidy levels and gender targeting. As such, this sample will not only allow us to analyze diffusion within families, but will also allow to analyze to what extent impacts differ depending on households access to land (forest) resources. For all these households, men and women were interviewed separately, and two women were interviewed in polygamous households (In case of polygamous households with more than 2 women, the first wife and a randomly selected other wife were selected). In monogamous households with more than one adult woman with children, the spouse of the household head and the mother of the youngest child was interviewed. This sampling allows analyzing potential heterogeneity in child health, nutrition and education outcomes within households. Because of the length and complexity of the survey, we visited households twice : a first wave was conducted between June and July 2014 (Followup wave 2014), and a second wave was conducted between November 2014 and March 2015 (Followup wave 2015). [13]

B Additional Tables

[13]The second wave was originally scheduled to immediately follow the first wave, but was postponed due an Ebola outbreak in Equateur.

Table 17 – Results of OLS regression: Dummies for whether Households Cultivated on Different Types of Land, by Treatment. Including households who used improved seeds only.

	Primary Forest	Secdondary Forest	Fallow	Savanna and other	Cultivated
2013					
Voucher low x notruck	–0.243***	0.168	–0.174	–0.004	0.079
	(0.083)	(0.130)	(0.168)	(0.017)	(0.180)
Voucher high x notruck	–0.218**	0.182*	–0.241*	0.074*	0.044
	(0.083)	(0.098)	(0.129)	(0.040)	(0.131)
Voucher low x truck	–0.043	0.032	–0.154	0.046	0.115
	(0.093)	(0.069)	(0.114)	(0.031)	(0.120)
Voucher high x truck	–0.124	0.056	–0.097	0.048*	–0.028
	(0.082)	(0.064)	(0.104)	(0.028)	(0.110)
No voucher, Lottery no truck	–0.203*	0.028	–0.165	–0.018	0.061
	(0.105)	(0.145)	(0.179)	(0.017)	(0.155)
No voucher, Lottery truck	–0.096	–0.030	–0.193	0.019	0.152
	(0.099)	(0.090)	(0.130)	(0.018)	(0.125)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	300	300	300	300	300
Mean Control	0.27	0.18	0.55	0.00	0.45
2014					
Voucher low x notruck	0.010	–0.079	–0.064	0.061	0.007
	(0.065)	(0.090)	(0.096)	(0.063)	(0.035)
Voucher high x notruck	0.132*	–0.037	–0.020	–0.024	–0.007
	(0.069)	(0.089)	(0.087)	(0.044)	(0.041)
Voucher low x truck	0.038	–0.002	–0.036	0.036	0.026
	(0.057)	(0.074)	(0.079)	(0.057)	(0.033)
Voucher high x truck	0.052	0.018	0.076	–0.031	0.027
	(0.046)	(0.081)	(0.073)	(0.041)	(0.028)
No voucher, Lottery no truck	0.036	0.059	0.002	–0.040	–0.041
	(0.082)	(0.095)	(0.100)	(0.045)	(0.048)
No voucher, Lottery truck	0.036	0.057	–0.004	–0.043	0.011
	(0.065)	(0.106)	(0.090)	(0.042)	(0.041)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	462	462	462	462	462
Mean Control	0.13	0.42	0.56	0.08	0.96

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 18 – Results of OLS regression: Dummies for whether Households Cultivated on Different Types of Land, by Treatment. Excluding households who used improved.

	Primary Forest	Secdondary Forest	Fallow	Savanna and other	Cultivated
2013					
Voucher low x notruck	0.087	0.036	–0.070	0.051*	–0.112
	(0.056)	(0.050)	(0.069)	(0.030)	(0.077)
Voucher high x notruck	0.055	0.032	–0.123	0.030	–0.015
	(0.046)	(0.062)	(0.083)	(0.019)	(0.075)
Voucher low x truck	0.075	–0.020	–0.207***	0.032	–0.058
	(0.050)	(0.055)	(0.056)	(0.026)	(0.064)
Voucher high x truck	0.030	–0.024	–0.004	–0.006	–0.026
	(0.054)	(0.070)	(0.097)	(0.007)	(0.093)
No voucher, Lottery no truck	0.097*	0.027	–0.063	0.034	–0.011
	(0.056)	(0.058)	(0.075)	(0.035)	(0.082)
No voucher, Lottery truck	0.033	–0.002	–0.062	0.009	–0.081
	(0.049)	(0.060)	(0.078)	(0.014)	(0.089)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	722	722	722	722	722
Mean Control	0.14	0.30	0.39	0.02	0.61
2014					
Voucher low x notruck	0.235***	–0.008	–0.049	0.074	–0.147**
	(0.070)	(0.079)	(0.090)	(0.082)	(0.059)
Voucher high x notruck	0.100*	–0.081	–0.193**	0.022	–0.049
	(0.053)	(0.069)	(0.095)	(0.051)	(0.039)
Voucher low x truck	0.105*	–0.076	–0.094	0.008	0.015
	(0.059)	(0.078)	(0.078)	(0.052)	(0.029)
Voucher high x truck	0.048	0.022	–0.137*	–0.005	0.011
	(0.042)	(0.075)	(0.081)	(0.048)	(0.038)
No voucher, Lottery no truck	0.101	–0.085	–0.092	0.045	–0.076
	(0.078)	(0.082)	(0.100)	(0.072)	(0.068)
No voucher, Lottery truck	0.006	0.032	–0.157*	0.057	–0.008
	(0.050)	(0.075)	(0.084)	(0.063)	(0.045)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	603	603	603	603	603
Mean Control	0.07	0.46	0.56	0.07	0.90

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 19 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013

	Primary Forest	Secondary Forest	Fallow	Savanna other	Cultivated land
Voucher x no truck	0.008	0.049*	–0.069	0.033**	–0.021
	(0.025)	(0.026)	(0.043)	(0.016)	(0.038)
No voucher, Lottery no truck	0.022	0.019	–0.071	0.035*	–0.005
	(0.024)	(0.033)	(0.050)	(0.021)	(0.042)
Voucher x truck	0.025	–0.001	–0.032	0.026	–0.019
	(0.022)	(0.025)	(0.037)	(0.016)	(0.031)
No voucher, Lottery truck	0.007	0.004	–0.031	0.009	0.012
	(0.028)	(0.032)	(0.050)	(0.017)	(0.049)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	1882	1882	1882	1882	1882

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2013

Note: Sample of all plots cultivated in A2013. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 20 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013

	Primary Forest	Secondary Forest	Fallow	Savanna other	Cultivated land
Voucher low x notruck	0.035	0.047	–0.042	0.033*	–0.073**
	(0.031)	(0.031)	(0.045)	(0.018)	(0.035)
Voucher high x notruck	–0.019	0.053*	–0.088	0.034**	0.021
	(0.025)	(0.029)	(0.055)	(0.016)	(0.048)
Voucher low x truck	0.044*	–0.007	–0.085**	0.030*	0.019
	(0.023)	(0.031)	(0.042)	(0.017)	(0.038)
Voucher high x truck	0.009	0.005	0.009	0.023	–0.047
	(0.027)	(0.028)	(0.040)	(0.016)	(0.032)
No voucher, Lottery no truck	0.022	0.019	–0.071	0.035*	–0.005
	(0.024)	(0.033)	(0.050)	(0.021)	(0.042)
No voucher, Lottery truck	0.007	0.004	–0.031	0.009	0.012
	(0.028)	(0.032)	(0.050)	(0.017)	(0.049)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	1882	1882	1882	1882	1882

Source: Follow up 2013

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2013

Note: Sample of all plots cultivated in A2013. Sample excludes all plots cultivated by households who did not receive a voucher in a lottery village. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 21 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013

	Primary Forest	Secondary Forest	Fallow	Savanna other	Cultivated land
Voucher no truck x level 20	–0.024	0.049	–0.113**	0.016	0.071
	(0.044)	(0.047)	(0.046)	(0.011)	(0.051)
Voucher no truck x level 45	0.026	0.062	–0.170**	0.039**	0.044
	(0.037)	(0.040)	(0.077)	(0.020)	(0.048)
Voucher no truck x level 70	0.013	0.045	0.040	0.036**	–0.134**
	(0.032)	(0.034)	(0.052)	(0.017)	(0.063)
Voucher truck x level 20	0.055**	–0.016	0.014	0.019	–0.071
	(0.026)	(0.036)	(0.065)	(0.018)	(0.053)
Voucher truck x level 45	0.028	–0.003	–0.066	0.014	0.026
	(0.034)	(0.041)	(0.044)	(0.014)	(0.041)
Voucher truck x level 70	–0.008	0.017	–0.041	0.034**	–0.001
	(0.032)	(0.035)	(0.054)	(0.017)	(0.035)
No voucher x AM Level 20	0.050	0.061	0.090	–0.182***	–0.018
	(0.033)	(0.052)	(0.072)	(0.049)	(0.070)
No voucher x AM Level 45	–0.014	0.028	–0.002	–0.179***	0.167***
	(0.046)	(0.059)	(0.077)	(0.047)	(0.050)
No voucher x AM Level 70	0.069***	0.038	–0.140	0.047**	–0.014
	(0.024)	(0.044)	(0.090)	(0.020)	(0.079)
No voucher x Truck Level 20	0.008	0.031	–0.001	–0.172***	0.134*
	(0.041)	(0.040)	(0.065)	(0.047)	(0.078)
No voucher x Truck Level 45	0.044	0.064	–0.029	–0.186***	0.108*
	(0.041)	(0.046)	(0.058)	(0.049)	(0.062)
No voucher x Truck Level 70	0.009	–0.040	0.061	0.021	–0.051
	(0.043)	(0.066)	(0.100)	(0.016)	(0.071)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	1882	1882	1882	1882	1882

Source: Follow up 2013

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2013

Note: Sample of all plots cultivated in A2013. Sample excludes all plots cultivated by households who did not receive a voucher in a lottery village. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 22 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014

	Primary Forest	Secondary Forest	Fallow	Savanna other	Cultivated land
Voucher x no truck	0.041***	–0.005	–0.037	0.025	–0.024
	(0.013)	(0.026)	(0.032)	(0.017)	(0.031)
No voucher, Lottery no truck	0.035**	–0.004	–0.007	–0.005	–0.019
	(0.014)	(0.028)	(0.034)	(0.021)	(0.036)
Voucher x truck	0.019	–0.000	–0.023	0.001	0.004
	(0.013)	(0.023)	(0.024)	(0.020)	(0.022)
No voucher, Lottery truck	0.007	0.016	–0.032	0.005	0.004
	(0.015)	(0.027)	(0.029)	(0.016)	(0.028)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	4519	4519	4519	4519	4519

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2014

Note: Sample of all plots cultivated in A2014. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 23 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014

	Primary Forest	Secondary Forest	Fallow	Savanna other	Cultivated land
Voucher low x notruck	0.041***	–0.010	–0.031	0.031*	–0.031
	(0.013)	(0.028)	(0.030)	(0.017)	(0.037)
Voucher high x notruck	0.041***	–0.001	–0.040	0.019	–0.018
	(0.015)	(0.030)	(0.039)	(0.020)	(0.034)
Voucher low x truck	0.026*	–0.012	–0.038	0.013	0.012
	(0.015)	(0.026)	(0.030)	(0.020)	(0.027)
Voucher high x truck	0.013	0.009	–0.010	–0.013	0.001
	(0.013)	(0.025)	(0.026)	(0.021)	(0.024)
No voucher, Lottery no truck	0.035**	–0.004	–0.007	–0.005	–0.019
	(0.014)	(0.028)	(0.034)	(0.021)	(0.036)
No voucher, Lottery truck	0.007	0.016	–0.032	0.005	0.004
	(0.015)	(0.027)	(0.029)	(0.016)	(0.028)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	4519	4519	4519	4519	4519

Source: Follow up 2014

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2014

Note: Sample of all plots cultivated in A2014. Sample excludes all plots cultivated by households who did not receive a voucher in a lottery village. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 24 – Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014

	Primary Forest	Secondary Forest	Fallow	Savanna other	Cultivated land
Voucher no truck x level 20	0.021	–0.034	0.039	–0.006	–0.021
	(0.014)	(0.034)	(0.044)	(0.016)	(0.041)
Voucher no truck x level 45	0.051***	0.029	–0.115**	0.009	0.027
	(0.019)	(0.033)	(0.057)	(0.027)	(0.053)
Voucher no truck x level 70	0.044***	–0.011	–0.033	0.045**	–0.044
	(0.014)	(0.041)	(0.042)	(0.019)	(0.047)
Voucher truck x level 20	0.030*	0.068**	0.066*	–0.438***	0.273***
	(0.016)	(0.031)	(0.036)	(0.093)	(0.062)
Voucher truck x level 45	0.013	–0.003	0.007	–0.012	–0.005
	(0.018)	(0.030)	(0.027)	(0.021)	(0.029)
Voucher truck x level 70	0.030*	–0.013	–0.033	0.021	–0.006
	(0.017)	(0.034)	(0.046)	(0.022)	(0.038)
No voucher x AM Level 20	0.015	0.056	0.156***	–0.456***	0.229***
	(0.027)	(0.046)	(0.045)	(0.098)	(0.088)
No voucher x AM Level 45	0.041**	–0.001	–0.040	–0.010	0.011
	(0.021)	(0.037)	(0.057)	(0.024)	(0.054)
No voucher x AM Level 70	0.049***	–0.010	–0.024	0.021	–0.036
	(0.014)	(0.044)	(0.063)	(0.027)	(0.065)
No voucher x Truck Level 20	–0.011	0.042	–0.033	–0.033	0.035
	(0.018)	(0.038)	(0.048)	(0.032)	(0.053)
No voucher x Truck Level 45	0.013	–0.020	–0.015	–0.002	0.025
	(0.018)	(0.046)	(0.047)	(0.016)	(0.046)
No voucher x Truck Level 70	0.022	0.022	–0.038	0.022	–0.028
	(0.024)	(0.033)	(0.033)	(0.020)	(0.034)
Strat Vars	Yes	Yes	Yes	Yes	Yes
Observations	4519	4519	4519	4519	4519

Source: Follow up 2014

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Follow up survey wave 2014

Note: Sample of all plots cultivated in A2014. Sample excludes all plots cultivated by households who did not receive a voucher in a lottery village. Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

Table 25 – Results of OLS regression: Crops Cultivated, by Treatment

	Maize	Rice	Groundnut
Voucher low x notruck	–0.026	–0.046	–0.021
	(0.075)	(0.100)	(0.083)
Voucher high x notruck	–0.041	–0.027	0.023
	(0.068)	(0.105)	(0.080)
Voucher low x truck	–0.060	–0.039	0.183**
	(0.065)	(0.088)	(0.070)
Voucher high x truck	–0.045	–0.041	0.195***
	(0.062)	(0.080)	(0.066)
No voucher, Lottery no truck	0.008	–0.030	–0.032
	(0.083)	(0.098)	(0.075)
No voucher, Lottery truck	–0.040	–0.113	0.083
	(0.069)	(0.083)	(0.073)
Strat Vars	Yes	Yes	Yes
Observations	1035	1035	1035
Mean Control	0.63	0.34	0.29
Voucher low x notruck	0.081*	–0.043	–0.020
	(0.043)	(0.093)	(0.095)
Voucher high x notruck	0.009	0.005	–0.037
	(0.046)	(0.102)	(0.086)
Voucher low x truck	–0.029	–0.081	0.085
	(0.051)	(0.080)	(0.076)
Voucher high x truck	–0.001	–0.066	–0.022
	(0.039)	(0.071)	(0.076)
No voucher, Lottery no truck	–0.079	–0.059	–0.083
	(0.058)	(0.100)	(0.081)
No voucher, Lottery truck	–0.026	–0.122	–0.081
	(0.053)	(0.074)	(0.076)
Strat Vars	Yes	Yes	Yes
Observations	1067	1067	1067
Mean Control	0.86	0.30	0.51

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Note: Robust standard errors clustered at the household level in parentheses. All regressions control for a full set of strata dummies.

List of Tables

1 Results of OLS regression: Adoption of improved Seeds just after the Intervention and two Seasons after the Intervention 15
2 Results of OLS regression: Adoption of improved Seeds just after the Intervention and two Seasons after the Intervention 16
3 Results of OLS regression: Adoption of improved Seeds just after the Intervention and two Seasons after the Intervention 17
4 Results of OLS regression: Adoption of improved Seeds just after the Intervention and two Seasons after the Intervention 18
5 Type of vegetation on the plot in the preceding season 20
6 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013 23
7 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014 23
8 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013 24
9 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014 25
10 Results of OLS regression: Number of Plots Cultivated, by Type of Land and by Treatment 29
11 Results of OLS regression: Total Area Farmed, by Types of Land, by Treatment 30
12 Results of OLS regression: Dummies for whether Households Cultivated on Different Types of Land, by Treatment 31
13 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013 34
14 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014 35
15 Results of OLS regression: Total Labor on Household's fields in Season A 2014 36
16 Results of OLS regression: Total Labor on Household's fields in Season A 2014 37
17 Results of OLS regression: Dummies for whether Households Cultivated on Different Types of Land, by Treatment. Including households who used improved seeds only. 48
18 Results of OLS regression: Dummies for whether Households Cultivated on Different Types of Land, by Treatment. Excluding households who used improved. 49
19 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013 50

20 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013 51
21 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2013 52
22 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014 53
23 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014 53
24 Results of multinomial Logistic Regression: Type of Land cultivated, already Cultivated Land as Reference, marginal Effects, A2014 54
25 Results of OLS regression: Crops Cultivated, by Treatment 55