Executive Summary

One Acre Fund (1AF) commissioned evaluation firm Laterite to conduct a randomized control trial of tree-planting activity in two districts in Kenya during the 2019 long rains season. The central findings were as follows:

1. **One-year after program participation, 1AF farmers were growing 7.5 additional grevillea trees (relative to control farmers)**. This number increases to 31.2 additional grevillea trees when restricting the analysis to 'adopters' (the subset of farmers who successfully germinated seeds and transplanted seedlings into the ground).
2. **Factoring in all revenues and costs over a ten year period, Laterite projects a Net Present Value of $14.57 per tree**, which equates to $109 per participating farmer (or $455 per adopting farmer) from just the one year of tree-planting in 2019.
3. **These findings are substantially greater than 1AF's internal findings for tree-planting in Kenya in 2019.** 1AF believes the two districts in which the Laterite study took place are overall a more hospitable area for tree-planting (e.g., local market prices per tree are substantially higher) compared to the 40 districts in which 1AF's internal measurement took place. While lower self-reported impact results do not in and of themselves substantiate the rigor of 1AF's internal measurement methods, we do believe they are suggestive that 1AF has taken a conservative approach to estimating tree impact to date.
4. **The study also points to opportunities for improvement**. Most notably, the overall percentage of farmers successfully growing trees from our tree kits was quite low, at 25% – generally in line with internal findings that point to the complexity of this production method. In response, we are shifting efforts towards a model in which 1AF grows (or contracts local entrepreneurs to grow) tree seedlings, and we deliver those seedlings directly to farmers, which should increase both the adoption rate among farmers and overall number of trees planted per adopter, albeit with higher program cost. In addition, the qualitative findings emphasized the importance of species diversification; One Acre Fund is now offering additional varieties where appropriate for the local context. We are also integrating learnings from Laterite's approach to measuring tree program impacts.
5. **We believe the very strong NPV per tree (whether using Laterite's or 1AF's internal findings), which does not even include the meaningful but difficult-to-monetize environmental benefits of tree-planting, validates 1AF's perspective that trees are a highly valuable asset-building product for rural households.** Furthermore, although not in the scope of the Laterite study, 1AF's internal results also show a very high cost-effectiveness, or SROI, for tree-planting. To our knowledge, the Laterite study represents one of the few RCTs of smallholder-led agroforestry in Africa, and we are hopeful the results will encourage more NGOs and governments to pursue this powerful asset-building product, as 1AF will do alongside our staple-crop program (which addresses more immediate needs for food security and income for daily expenditures).

Background

Starting in 2014, One Acre Fund (1AF) began delivering tree kits to farmers in Kenya following several years of R&D work into asset-building products for the rural poor. Our research found timber trees in particular provide both a strong financial return to farmers (driven by low input and labor costs; low susceptibility to disease and theft; and high market demand for tree products) and strong environmental benefits (e.g., erosion control, soil enhancement, and carbon sequestration). Since 2014, the One Acre Fund tree program has proliferated; as of year-end 2021, this program serves nearly 2 million farmers across 9 countries and reached the milestone of 100 million trees cumulatively planted by farmers.

One Acre Fund believes in building a rigorous evidence base for each of our activities in order to understand our impact and improve our programs. From the early years of the tree program, we have been conducting tree adoption and survival studies to continuously improve our offerings, and as our tree programs became more mature and complex, in 2019 we began running more rigorous studies (comparing 1AF farmers to highly similar non-participating farmers) to measure tree program impact.

At a high-level, calculating tree program impact requires rigorous measurement of two components: (i) the number of incremental trees farmers realize impact from because of the 1AF intervention, and (ii) the value of each tree for the farmer. On the former: we run tens of thousands of surveys each year to understand the true incremental count of trees One Acre Fund farmers plant relative to a counterfactual (i.e., the tree-planting practices of highly-similar non-1AF farmers); also accounting for any substitution of other tree species and tree survival rates. On the latter: to understand the value of a tree to a farmer, we conduct farmer and market surveys to determine the typical use, age of sale and price of the tree products (usually sold in the markets), as well as the value and timing of input and labor costs that must be removed to calculate a net present value per tree. Since environmental and soil benefits are difficult to precisely monetize, these have been omitted from 1AF's (and the Laterite RCT's) impact measurement, but they are surely highly important benefits to the smallholder farmers planting trees.

Our internal measurements have fluctuated over the years depending on the type of program, the tree species and the country context (in particular, average land available for tree-planting, which affects the average number of trees planted). For instance, our most recent tree evaluations (from trees distributed in the 2020 year) measured impact (NPV of tree revenues less costs) ranging from $98.0 per client in Ethiopia to $17.4 per client in Malawi.

While One Acre Fund has invested in our own rigorous, internal measurement of the impact of our tree program, we recognize the importance of independent assessments. We further acknowledge that our quasi-experimental methods are inferior to a randomized control trial method, which is better able to control for any selection bias or other confounding variables. Therefore, in 2019, with generous support from a private foundation, we commissioned the East-Africa based research and evaluation firm Laterite to conduct a randomized control trial (RCT) of tree-planting activity in Kenya, our largest country for this work.

Farmers First

Methods

The randomized trial was conducted in the Kericho and Uasin Gishu districts of Kenya, where 1AF expanded the tree program in the 2019 long rains season. (It was conducted in an expansion area to ensure that none of the trial participants had any pre-exposure to the program). The study design was a clustered randomized trial in which 226 training groups of about 8-12 One Acre Fund farmers each were randomly selected to be given tree kits (treatment farmers), or to serve as a control group; with a resulting final sample size of 1852 farmers. The treatment farmers each received a tree kit, which contained 10 grams of grevillea[1] tree seeds, a planting bag, sockets for seedlings, tree fertilizer, and a set of trainings specifically on planting and maintaining trees.

Farmers were surveyed at baseline and 1 year after tree distribution. (A limited number were also surveyed and participated in qualitative follow-up 2 years after tree distribution). The study was originally intended to measure impact over a two-year time period; however, quantitative data collection had to be curtailed due to COVID, and the full data collection effort occurred only 1 year after tree distribution. We believe these results are still highly valid, especially as the literature suggests that after 1 year, tree survival is fairly well assured (with most tree deaths taking place in the first dry season after planting)[2] and any increases in tree death beyond the first year are likely to be roughly equal between the treatment and control groups. Put another way, the incremental number of trees per treatment farmer (relative to control farmer) was unlikely to have changed between year 1 and year 2.

Among the key research questions were:

(1) Does a farmer's knowledge of best practices for tree planting and tree maintenance improve as a result of the tree program, and does that knowledge increase likelihood of tree survival?
(2) How many, if any, incremental trees do farmers realize after program participation?
(3) What is the net present financial value of the incremental trees planted as a result of the 1AF program?

In order to estimate the incremental number of trees among treatment farmers, Laterite enumerators visually counted all the trees on all farmers' plots of land (treatment and control) at baseline and year 1. This allowed Laterite to estimate the incremental number of trees due to program participation, whether One Acre Fund farmers were planting more grevillea trees, and whether it was at the expense of another tree species.

To estimate the net present value of each additional tree, Laterite used a multi-pronged approach. They surveyed farmers on how much they would be willing to pay for each tree species at each year of growth and did so for each specific use (e.g. firewood, timber, construction). Willingness to pay estimates can sometimes be unreliable, so Laterite combined these data with an "earnings model" based on survey data

[1] Grevillea is a timber species well-suited to the Kenyan context given it grows fast and has a range of environmental benefits, including leaves that fix nitrogen in the soils

[2] For instance, see: Kinuthia et al. (2019) *Tree survival does not always depend on soil water conservation-what and where matters: Lessons from East Shewa Ethiopia*. World Agroforestry Centre; which finds that the highest mortality rate was observed between 6 and 12 months.

from farmers who actually earned money from various uses. While earnings data is generally considered more reliable, there was a much smaller sample size of farmers who had earned revenue from various uses; therefore, Laterite took a weighted average of these two sources, weighting willingness to pay data more heavily given its larger sample size.

Results

Training

Laterite found a statistically positive treatment effect (albeit marginal in magnitude) on the number of tree-planting knowledge questions that farmers answered correctly when attending trainings, and also in the relationship between tree-planting knowledge and tree survival rates. Additionally, Laterite detected training spillover (a positive halo effect of the program), with 21% of control farmers self-reported attending the 1AF tree trainings. That said, Laterite also found clear room for improvement; for instance, ~38% of intervention farmers in the midline study reported not having attended the tree trainings provided by 1AF, with almost a third of these citing lack of awareness of the training.

Incremental (Surviving) Trees

Laterite found that one year after program participation, treatment farmers were growing on average **7.5 incremental grevillea trees (p<.001)**. However, not all farmers successfully germinated seeds and planted them in the ground. Of those who transplanted at least 1 seedling in the ground (who may be considered an "adopter" and more inherently interested in tree planting), they had an incremental **31.2 trees (p<.001)** compared to control farmers. The tables below (from the midline report) show these calculations.

Table 10: Impact of the program on grevillea tree numbers

Dependent variable	Model	Coefficient [Std. Error]	P-Value	R_2
Number of grevillea trees planted in the last 12 months	Difference in differences with controls	7.5448*** [1.3793]	0.000	0.0169
No. of observations			**1,728**	

Table 11: Local average treatment effect on grevillea tree numbers.

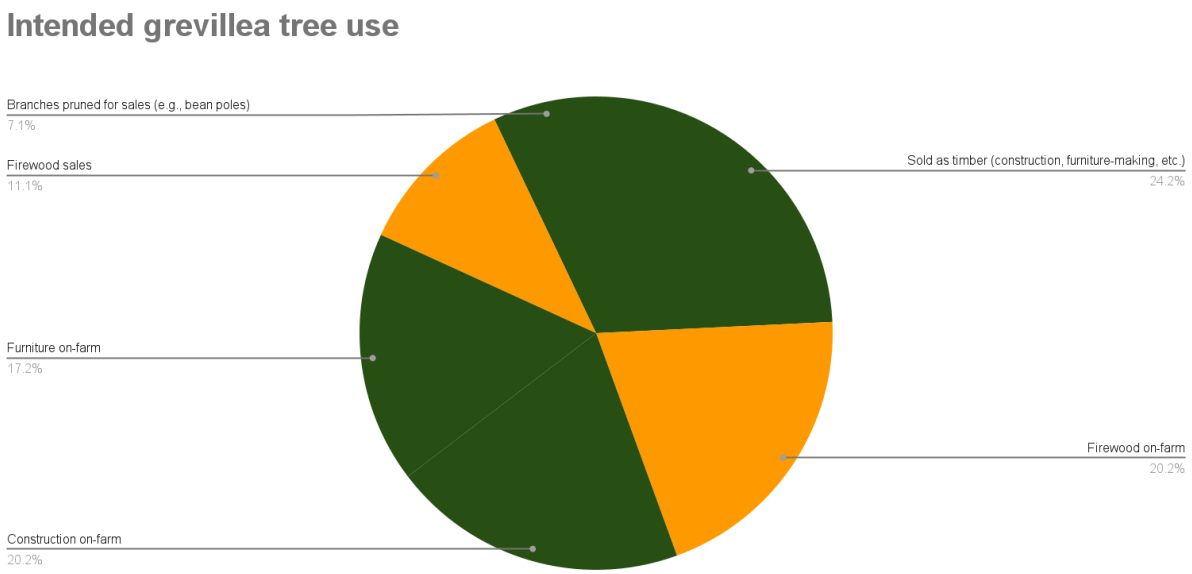
Dependent variable	Model	Coefficient [Std. Error]	P-Value	R_2
Number of grevillea trees planted in the last 12 months	IV Regression for Partial Compliers	10.9283*** [1.9828]	0.000	0.0074
	IV Regression for Full Compliers	13.3727*** [2.4235]	0.000	0.0074
	IV Regression for Planted Seeds	11.3456*** [2.0430]	0.000	0.0206
	IV Regression for Seedlings Planted on the Ground	31.2984*** [5.5330]	0.000	0.0555
No. of observations			**1,728**	

Note –Full complier defined as a treatment farmer who received the grevillea tree kit and attended the tree training or a control farmer who did not receive the kit and did not attend the tree training. Partial complier defined as a treatment farmer who either received the kit but failed to

attend the training or did not receive the kit but attended the training; or a control farmer who did not both receive the tree kit and the tree training.

Other findings of note:

- Laterite found one-year tree survival rates of 67%, roughly equivalent to 1AF's internal findings.
- Having planted trees in 2019 is statistically associated with planting trees again in 2020 ($p<.001$).
- 95% of farmers at the endline are interested in planting more timber and fruit trees in the ensuing year; indicating saturation is not an issue for the vast majority.
- Laterite concluded that farmers do not incur a major opportunity cost in terms of land-use because of the Tree Program. The treatment effect on a higher share of farmers planting grevillea and more grevillea trees being planted on the treatment farmers' land does not displace other types of plants or livestock, except possibly vegetables, and does not affect whether farmers have grazing land. Farmers and key informants argue that grevillea trees are excellent trees for intercropping and explain that grevillea trees are usually planted with other crops, including coffee, and provide shade to avoid drying.
- When asked about the overall uses of their grevillea trees (with farmers allowed to select multiple uses), 95% of grevillea growers report using the species for firewood (either for own consumption or sale), 59% for selling (timber or branches) and 52% for construction (of structures or furniture). [Figure 4]. However, when farmers who recently planted grevillea trees were asked how they intend to allocate the total number of trees by ultimate future use, we see a somewhat different picture, with firewood (for own consumption or sale) accounting for only 31% of total tree use, with non-carbon releasing uses, at least for the life of the wood (construction, furniture, bean poles, and timber sold for these uses) accounting for the bulk. Per Figure 6, here is how farmers allocate their intended uses across 100% of trees:



- Laterite found an upward trend in the proportion of farmers that plant timber trees for environmental reasons, with treatment farmers gaining a richer understanding of the multiple benefits of growing trees and the value of intercropping grevillea trees in their farms.

Tree $ Value

Benefits. As noted above, to estimate the net present value of trees, Laterite calculated a tree value at various ages, based on typical uses, relying on a combination of farmers' willingness to pay as well as actual earned revenues. Laterite found that grevillea trees start realizing value at year 3 (from tree prunings), that they will realize 20% of the estimated value at that year and that this will decline over time as farmers reap value from the tree. They also assume, based on survey data, that farmers will sell 65% of their trees at year 7. Their model covers a conservative 10-year time horizon. Importantly, Laterite finds that much of tree value comes from ongoing use (prunings), specifically firewood, before the tree is harvested.

Costs. Laterite included the cost of the tree kit, loan interest and estimated labor to plant and maintain the trees. As noted above, they do not find any meaningful opportunity costs associated with the land farmers plant trees on, likely because they are often planted on non-crop land (e.g. at a field perimeter).

Altogether, Laterite finds that the **net present value[3] (NPV) of one year's worth of tree-planting is $109 per participating farmer (equivalent to 7.5 incremental trees multiplied by $14.57 of NPV per tree)**.

[3] This model assumes a 7.5% discount rate based on a review of impact evaluations of similar asset-building interventions in other low and middle-income countries ranging from 5-10%

Farmers First

When examining only farmers who transplanted at least one tree in the ground ("adopters"), the NPV would be considerably greater - at $455 per adopting farmer (31.2 incremental trees multiplied by the $14.57 NPV per tree).

Figure 12: Net Present Value

Year	0	1	2	3	4	5	6	7	8	9	10	Total
Revenue												
Tree Revenue (Unsold U	KES 637	KES 837	KES 1,155	KES 1,434	KES 1,701	KES 1,833	KES 2,008	KES 2,078	KES 2,209	KES 2,532	KES 2,314	
Realized Revenue (Unsold Ur	0%	0%	0%	20%	19%	18%	17%	16%	15%	15%	14%	
# Trees Not Sold	7.5	7.5	7.5	7.5	7.5	7.5	7.5	3.0	3.0	3.0	3.0	
Tree Revenue (Sold Unit	KES 730	KES 917	KES 1,280	KES 1,594	KES 1,897	KES 2,015	KES 2,200	KES 2,243	KES 2,379	KES 2,797	KES 2,448	
# Trees Sold	0	0	0	0	0	0	0	4.5	0	0	0	
Total Revenue	KES 0	KES 0	KES 0	KES 2,151	KES 2,424	KES 2,481	KES 2,582	KES 11,109	KES 1,026	KES 1,117	KES 970	
Discount Rate	1.00	0.93	0.87	0.80	0.75	0.70	0.65	0.60	0.56	0.52	0.49	
Discounted Revenue (N	KES 0	KES 0	KES 0	KES 1,731	KES 1,815	KES 1,728	KES 1,673	KES 6,696	KES 575	KES 582	KES 470	**KES 15,272**
Costs												
Maintenance Cost (Day)	KES 308	KES 154	KES 154	KES 154	KES 154	KES 154	KES 154	KES 154	KES 154	KES 154	KES 154	
Tree Kit Cost (Unit)	KES 67	KES 0	KES 0	KES 0	KES 0	KES 0	KES 0	KES 0	KES 0	KES 0	KES 0	
# Trees Left	7.5	7.5	7.5	7.5	7.5	7.5	7.5	3.0	3.0	3.0	3.0	
Total Cost	KES 1,414	KES 289	KES 289	KES 289	KES 289	KES 289	KES 289	KES 228	KES 228	KES 228	KES 228	
Discount Rate	1.00	0.93	0.87	0.80	0.75	0.70	0.65	0.60	0.56	0.52	0.49	
Discounted Cost (NPV)	KES 1,414	KES 269	KES 250	KES 233	KES 216	KES 201	KES 187	KES 137	KES 128	KES 119	KES 110	**KES 3,265**
Income												
Total Income for Tree Pr	(KES 1,414)	(KES 289)	(KES 289)	KES 1,862	KES 2,135	KES 2,192	KES 2,293	KES 10,881	KES 798	KES 889	KES 742	KES 19,800
Discount Rate	1.00	0.93	0.87	0.80	0.75	0.70	0.65	0.60	0.56	0.52	0.49	
Discounted Income (NP	(KES 1,414)	(KES 269)	(KES 250)	KES 1,499	KES 1,599	KES 1,527	KES 1,486	KES 6,559	KES 447	KES 464	KES 360	**KES 12,007**
Discounted Income $ (N	$ (12.87)	$ (2.45)	$ (2.28)	$ 13.64	$ 14.55	$ 13.90	$ 13.52	$ 59.68	$ 4.07	$ 4.22	$ 3.28	**$ 109.26**

Comparison with internal results

Part of the value in undertaking a rigorous external evaluation is to compare the estimates of such a study with 1AF's internal estimates in the same geographic area and time period. (High confidence in internal measurement is vital to a full understanding of a program's impact, given external evaluations cannot be run in every country and in every year; given cost, ethical, and other considerations). Unfortunately, in this case, we are unable to make a perfect comparison between the Laterite study and 1AF's internal measurement for several reasons:

- Internal data collection covers all 40 districts 1AF reaches in Kenya, whereas the Laterite study covers only 2 districts. (1AF's internal measurement was not sufficiently powered to examine results in the 2 districts in isolation). There are likely important geographic differences between the two datasets; for instance, the two districts studied by Laterite seem to show higher timber prices in local markets.

- The Laterite study was conducted in an expansion area to ensure that none of the trial participants had any pre-exposure to the program. In an expansion area, farmers may behave differently to those who have been exposed to the tree planting program for a longer period. For example, farmers in expansion areas may generally have higher enthusiasm to take up tree planting, but alternatively in some expansion areas it may take some time and efforts to nudge farmers to make a behavior change. At the same time, farmers in older areas may be fatigued with tree planting after so many years of program implementation.

- Another key difference between the 2019 external RCT evaluation and the 2019 internal study is that while the external study considered the ongoing usage of a tree while determining tree value, the internal study only considered a tree value if and when it was fully cut down and sold to tree traders or other such use. To attempt to compensate for this difference, we have added some assumptions around tree ongoing use to our internal tree value data and recreated the internal NPV per tree in the table below. This tree ongoing use data is based on internal data being collected in 2021 and 2022, and is therefore preliminary.

With these limitations in mind, we find that incremental tree per client and per adopter is much higher in the external evaluation than the 2019 1AF internal evaluation, even when we incorporate the value of ongoing use (NPV per client is $19.17 in our internal estimates, compared to $109 in the external evaluation). We believe the gap is largely related to the geographic differences of the two studies described above, and we are pleased that 1AF is reporting more conservative tree NPVs (as the opposite result may have implied upward bias in 1AF's internal methods, although such bias cannot be ruled out given the different geographic contexts studied).

	Laterite 2019 RCT	1AF 2019 Internal Study
Incremental trees per client (received tree kit from 1AF)	7.5***	3.7***
Incremental trees per adopter (planted seedling in the ground)	31.2***	10.6***
NPV per tree used by 1AF (no ongoing use value accounted for)	N/A	$2.7
NPV per tree (assuming ongoing use value)	$14.57	$5.18
NPV per client (assuming ongoing use value)	$109	$19.17

*** Indicates results are statistically significant at the 0.1% significance level, which means they are statistically highly significant (less than one in a thousand chance of being wrong). Statistical significance levels were not calculated for the NPV measurements.

Substitution effects:

An important consideration in the measurement of incremental (surviving) trees of a species of interest is to understand if, and the degree to which, 1AF farmers may be planting more of the 1AF provided species (grevillea) at the cost of other tree species they would have planted without program intervention; i.e., was there a 'substitution effect' that needs to be accounted for in reported figures. If substitution effects are discovered, one should remove the foregone impact of those substituted trees from the total impact of the tree program.

As noted directly above, Laterite found a highly statistically significant treatment effect of ~7.5 grevillea trees per farmer (or ~31 grevillea trees per adopter). Laterite did not find any treatment effect on the number of total timber trees per farmer, but did find a statistically significant (albeit weak) treatment

effect of 14 total trees (of all types) per farmer. Laterite hypothesizes (although notes it does not have enough statistical power to prove) that this third finding is due to the cumulative positive but negligible effects of the treatment on the number of trees planted in each tree category (i.e., the program likely exerted small, positive effects on several species which could not be detected individually, but show up in the aggregate when total trees are studied). With regards to the second finding (no effect on total timber trees), Laterite has two hypotheses;. The first driver may be substitution effects, noting that the increased proportion of 1AF farmers planting grevillea is matched by the increased proportion of farmers in the control group planting more cypress and eucalyptus trees. The second hypothesis is that a higher share of farmers across both treatment and control planted timber trees at midline compared to baseline, particularly the cypress variety. In other words, the large increase in overall timber species growing, outside of grevillea, for both 1AF and control farmers may have obscured the ability to detect overall timber impacts. Both these hypotheses cannot be fully confirmed by Laterite due to lack of statistical power.

Ultimately, Laterite did not detect a statistically significant decrease in any given timber species to definitively conclude there was a substitution effect; and indeed chose not to model a substitution-induced reduction in incremental trees in their tree value (NPV) model, as shown above.

Nevertheless, the Laterite study highlighted the potential for substitution effects, which is something 1AF had already begun exploring for integration into our internal tree measurement starting in 2020. We are now regularly exploring whether there is a statistically significant decrease in any non-1AF-provided species, and if so, reducing our reported impact by the foregone substitution impact. And even if such effects aren't detected at any individual species level, we will still examine differences in 'total number of trees planted' or '% of 1AF farmers vs. control planting certain types of species'; and if we find effects at these levels, adjust our impact downwards by some disclosed factor.

Having incorporated substitution effect evaluation into our measurement in time for the 2020 season, we can confirm that in Kenya (for 2020 tree planting), 1AF did not detect any substitution effects using any of the approaches shown directly above. This lends support to Laterite's decision not to include such effects in their tree value (NPV) model. We will continue testing for substitution effects in all internal tree impact evaluations going forward.

Study Limitations

As with all studies, there are some important limitations to bear in mind when interpreting the RCT results. First, as noted above, program expansion areas were not fully similar to other program areas. The study area had a higher number of pre-existing timber trees compared to other districts, and the study area appears to also have a higher value local timber market. Second, input delivery for the core program inputs was delayed due to supply issues, which condensed the training schedule and squeezed out some tree trainings. Finally, the generalizability of these findings may be limited to the tree seed kit program for grevillea trees; whereas 1AF's Kenya program is now moving to offer a greater variety of species and is trialing a different production and distribution model (tree seedlings), as described below.

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Internal Learnings

As with all of our external evaluations, One Acre Fund attempts to draw both programmatic and measurement lessons from the findings. This evaluation has highlighted how challenging farmers may find it to prioritize caring for and transplanting seedlings into the ground. For example, the evaluation found that over two thirds of the treatment farmers planted the grevillea seeds in tree bags at midline; however, only a quarter (25%) of the treatment farmers were successful in transplanting germinated seedlings successfully into the ground. Additionally, in focus group discussions, both farmers and 1AF field officers preferred a program model that offered tree seedlings (rather than tree seeds), as the former are easier to plant and more likely to survive. After considering all facets (farmer demand, impact, cost, etc.), 1AF has decided to shift efforts in Kenya towards a model in which 1AF grows (or contracts local entrepreneurs to grow) tree seedlings, and delivers those seedlings directly to farmers, which should increase both the adoption rate among farmers and overall number of trees planted per adopter, albeit with higher program cost.

In addition, the qualitative findings from this report have emphasized that farmers have significant demand for other tree species, such as cypress and eucalyptus, and also that 1AF farmers could be planting less of these species as they plant more grevillea. In response to the demand for these species, One Acre Fund is now offering them, though only in areas in which it is environmentally responsible to do so, and also piloting non-timber species, such as fruit and nut trees and soil improver trees, for further diversification. And, as noted above, 1AF is now carefully integrating the measurement of substitution effects into all of our tree impact models. Finally, most farmers reported attending only one or two Tree Program trainings from four delivered by Field Officers; improving training attendance is another opportunity for 1AF.

The most important measurement lesson was that much of the value of trees may come from their ongoing use, which 1AF had not measured in the past. We therefore were under-estimating the true impact of trees over the long term. We earlier valued trees at $2.7 in NPV, which increases to $5.18 once we incorporate tree ongoing use in estimating value. We have thus changed our data collection strategy and are now surveying farmers throughout the year about their ongoing use of tree species and also obtaining data on the value of those various uses. In addition, we had been subtracting opportunity costs associated with the land that farmers planted trees on, with the assumption that farmers would otherwise be generating profit from that land. However, this external evaluation found treatment farmers who planted trees did not displace other productive uses, as trees were generally planted on non-crop land (such as a field perimeter) or successfully intercropped. Therefore, we will further test this finding in our internal measurement to ensure a more accurate understanding of tree opportunity costs. Both of these changes will likely increase our estimated program impact.