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NOVEMBER 2024

REPORT

The Impact of Land Governance on Agroforestry

Lessons Learned from a Randomized Control Trial in Zambia

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The Impact of Land Governance on Agroforestry: Lessons Learned from a Randomized Control Trial in Zambia

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This document was produced for review by the United States Agency for International Development. It was prepared with support from the Integrated Natural Resource Management Task Order 7200AA18D00020, under the Strengthening Tenure and Resource Rights II (STARR II) IDIQ.

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Introduction

Economic theory has long held that when farmers and other landholders have secure rights to their land and trees, they are more likely to invest in long-term sustainable practices, like agroforestry (Acemoglu and Robinson 2012). Agroforestry practices, in turn, help restore soil fertility, control erosion, improve agricultural productivity, and potentially improve farmers' livelihoods, while sequestering carbon and strengthening farmers' resilience to climate-related stresses (Castle et. al. 2021; Branca et. al. 2021). While the hypothesized links between land rights strengthening and agroforestry adoption seem clear, in practice, the evidence for these linkages has been mixed, and varies across contexts.

Finding ways to encourage more farmers to adopt agroforestry has been a decades-long challenge. More than 30 years of research on determinants of agroforestry adoption that span a wide range of developing countries has highlighted several important factors that relate to greater adoption in particular contexts. Strengthening farmers' security over their land (land tenure security) is among the most commonly hypothesized strategies (interventions) for which several studies have offered glimmers of hope,[1] but evidence on its effectiveness has remained low overall (Meijer et. al. 2015; Castle et. al. 2021). This is partly because few studies have rigorously examined the extent to which strengthening farmers' land rights leads to greater agroforestry adoption. As a result, policy and program decision-makers continue to look for strategies that can effectively strengthen farmers' land rights and associated benefits, while also leading to widespread and sustained agroforestry adoption on farms.

To help inform this knowledge gap, USAID's Tenure and Global Climate Change (TGCC) activity in Zambia was designed to test whether improving farmers' land tenure security and governance also incentivizes them to adopt agroforestry as a means to adapt to and mitigate the impacts of climate change (in addition to increasing women's empowerment and a host of other important development outcomes). To do so, the activity paired a series of land tenure activities, including issuing customary land certificates to customary land owners and establishing village land committees, with agroforestry

[1] For example, among other recent studies, a meta-analysis of 204 agricultural technology adoption studies across 43 low and middle income countries found that secure land tenure was associated with farmers adopting better natural resource management practices (Ruzzante et al, 2021). This association was primarily driven by erosion control investments, which often require up front capital and longer time horizons to realize benefits. Ruzzante et al 2021 is a meta-analysis that draws on 367 regression results from 204 studies. The meta-analysis results are informative for Zambia, as 221 of the 367 results are from studies in East or Southern Africa. Inclusion criteria for the meta-analysis were fairly broad (study location has a Human Development Index below 0.8 and the study contains multivariate regression models from which covariates can be extracted), and the meta-analysis includes a sample of studies with observational data, which may overestimate effects when relevant covariates are omitted. Because the studies selected for the meta-analysis are not representative of all locations where adoption studies could be conducted, there is a risk the results could reflect or be more applicable to certain regions while not others, although this is not a concern for Zambia.

extension services. A randomized control trial (RCT) impact evaluation assessed the impacts of the TGCC program individually and across its different intervention components: land tenure, agroforestry, and combined (land tenure + agroforestry) programming.[2]

This policy brief summarizes the impact evaluation's findings and further unpacks key aspects of agroforestry results across the two main agroforestry species that TGCC promoted: *Faidherbia albidi* (Musangu) and *Gliricidia sepium* (Gliricidia). This brief provides evidence-based insights for Zambian and other policy makers on important linkages between land tenure strengthening and promoting agroforestry, from a context of rural customary land and smallholder agriculture characterized by low soil fertility and crop productivity and high levels of poverty and climate variability. The brief also highlights clear and practical implications for future programming to achieve integrated land tenure, livelihoods, and climate objectives via agroforestry or other natural climate solutions in similar programming contexts.

Key Policy Takeaways

TGCC's combined land tenure strengthening and agroforestry programming had a significant and positive impact on agroforestry uptake. TGCC resulted in a significant increase in agroforestry uptake among program beneficiaries who received the combined agroforestry and land tenure intervention. Importantly, neither the land tenure intervention nor the agroforestry intervention on its own led to greater agroforestry uptake when administered by itself. Among farmers who received the combined programming, a greater number adopted agroforestry. The key implication is that tenure strengthening or agroforestry extension programming on its own may not be sufficient to obtain impacts on agroforestry uptake.

Agroforestry impacts were mostly driven by farmers' greater uptake of Musangu. Of the six agroforestry options offered by TGCC, farmers focused on two tree species: Musangu and Gliricidia, with the latter being more prevalent across the study area. The analysis shows that TGCC's direct program support was more impactful on Musangu uptake and survival rates.

Gliricidia uptake also increased, but this appears to have happened through multiple channels, while Musangu uptake occurred primarily as a result of TGGC support. TGCC offered a range of agroforestry options, and farmers experienced different benefits and drawbacks

[2] For more information on TGCC, see: https://www.land-links.org/project/tenure-global-climate-change-zambia/

among them. Musangu's agroforestry potential in Zambia is well-recognized, but it also has high input and care costs and a longer timeframe to yield on-farm benefits. In the TGCC context, achieving a significant increase in farmers' adoption of Musangu required program support. In contrast, farmer adoption of Gliricidia took place through other routes as well, such as via farmer networks, communications campaigns, or other channels that encourage uptake in parallel to dedicated program support, making the direct contribution of the program's impacts harder to detect. Together, these insights indicate a need for programs to understand and consider the characteristics of the agroforestry options offered, farmer preferences, and species fit during program design, and to tailor programs and extension support accordingly.

For the TGCC programming population, literacy bears significantly on agroforestry uptake. Among farmers that only received the agroforestry intervention, literate beneficiaries were both more likely to plant agroforestry seedlings and to have more trees that remained alive, as of the follow-on phase of the impact evaluation (seven years after the intervention was delivered). This finding is supported by literature showing that more literate farmers have an increased willingness to take on risks related to new behaviors or practices, and an increased ability for individuals to take up information. For programs working with more literate populations, it may be possible to achieve positive results with a less comprehensive set of services. Conversely, for less literate populations, a more comprehensive set of interventions may be needed, as was provided via TGCC's combined intervention, to obtain increased agroforestry uptake and seedling survival.

Program and Evaluation Background

ZAMBIA CONTEXT

Zambia is a country endowed with considerable environmental wealth, including 44 million hectares of forest. However, it has one of the highest rates of deforestation in the world, with an estimated 250,000 hectares of forest destroyed per year (USAID 2022). Much of this deforestation and degradation is due to encroachment from agriculture, tree harvesting for fuel wood and sale, and uncontrolled burning.

While agriculture only contributes 3.4 percent to the country's overall economy, small-scale farming makes up almost a quarter of its employed population (IMF 2023). In Eastern Province, where TGCC operated, smallholder farmers grow a mix of subsistence crops, like maize and cash crops, like cotton and tobacco. The vast majority of rural land, including the area in which the TGCC project operated, is classified as customary land and is controlled by local chiefs. These traditional leaders have nearly unrestricted authority to grant use and occupancy rights, regulate transfers of land, control use of customary land, and hear disputes.

Agroforestry is widely viewed as a sustainable land use practice that can help improve farmers' livelihoods (by boosting crop productivity, reducing variability in yields, and providing crop diversification opportunities), while also mitigating climate change and providing broader environmental benefits (such as biodiversity conservation, erosion control, other ecosystem services, and landscape resilience).

THE TGCC PROGRAM

TGCC was a five-year (2013-2018) program that operated in several countries. In Zambia, TGCC explored the relationship between secure resource tenure, village-level governance, and the adoption of agroforestry practices, among other activities. Conducted during 2014-2017, the activity piloted participatory land mapping and certification of customary land rights for households, village land governance and administration, and provisioning of agroforestry extension services. The activity worked in 541 villages and provided customary land certificates for 17,871 parcels across five chiefdoms in Chipata District in Zambia's Eastern Province. TGCC's work in four of those chiefdoms (Maguya, Mkanda, Mnukwa, and Mshawa) was the focus for a follow-on impact evaluation.

The TGCC activity consisted of two main components: first, a land tenure intervention that raised awareness on customary land rights and governance, established Village Land Committees, conducted participatory mapping of household customary land parcels, and issued informal Customary Land Certificates (CLCs) to households; and second, an agroforestry intervention that provided agroforestry extension services, established farmers' groups, and utilized a lead farmer approach to promote planting of agroforestry species on fields, with a focus on Musangu and Gliricidia.

TGCC IMPACT EVALUATION

USAID independently commissioned an RCT impact evaluation of TGCC at the time of activity design, to obtain rigorous evidence-based learning on the impacts of the customary land certification process and the potential role of tenure security to increase farmer uptake of agroforestry and other climate smart agriculture practices. As part of the RCT design for the activity, villages across the four chiefdoms in Chipata District were randomized to receive one of four combinations of the TGCC intervention: the land tenure component only, the agroforestry component only, the combined land tenure plus agroforestry components, or no TGCC programming at all (control group). The impact evaluation collected three rounds of data: one shortly before TGCC began (2014), another at program closure (2017), and finally, through a follow-on phase (2021) seven years after the program started. This enabled substantial learning on the program's impacts at key junctures, and provided insights into TGCC's sustained impacts over time and reasons why.

More than six years after the program started, TGCC resulted in the following, as detailed in the impact evaluation (Persha et al, 2023):

- *Sustained, substantial, and positive impacts on households' tenure security and perceptions of village land governance;*
- *A significant increase in agroforestry uptake, and clear evidence for a causal link between the program's interventions, beneficiaries' stronger tenure security and confidence in land governance, and farmers' increased adoption of agroforestry;*
- *Neither the tenure intervention nor the agroforestry intervention alone yielded agroforestry impacts; impacts were only observed in households that had received both interventions;*
- *Positive perceptions among farmers on soil fertility and agricultural productivity, contributing to broader climate change mitigation and adaptation objectives. However, impact analysis did not find evidence for impacts on agricultural productivity or livelihoods; and*
- *Little evidence that TGCC's interventions increased women's empowerment, despite the fact that TGCC increased rates of land documentation for women and improved women's familiarity with land governance institutions. Qualitative findings suggested that TGCC made progress in addressing entrenched gendered norms that shape land dynamics in the program area, but many women continued to face challenges related to access, ownership, inheritance and control of customary land. More broadly, the evidence base calls particular attention to the roles of embedded cultural and social norms around land, gender and related issues, legal and regulatory processes, social, economic, and demographic aspects of women themselves, and a broader set of contextual factors. Results highlighted that more work must be done to better understand why customary land strengthening may improve women's empowerment in some contexts or for some individuals, but not others (for example, see Doss and Meinzen-Dick, 2020).*

Agroforestry Impact

Agroforestry adoption is a key component of natural climate solutions (NCS) to address global climate change within a reasonable timeframe (Griscom et al 2020). In addition to tree planting, trees must grow to maturity to produce tangible benefits. Emerging evidence suggests that species diversification plays a role in how efficiently carbon is absorbed from the atmosphere, which in turn, impacts climate change mitigation outcomes (Duan et al. 2023). TGCC's follow-on impact evaluation showed that TGCC led to increased uptake in agroforestry among households that received both the tenure intervention and the agroforestry intervention. This research brief extends that analysis to examine agroforestry outcomes in more detail, including examining *who* planted agroforestry trees, whether *certain species* were preferred, and *why*.

This brief presents analysis for previously unanalyzed outcomes obtainable from household survey data collected for the TGCC follow-on impact evaluation. The household survey included questions on whether the household currently had any trees on their land across six agroforestry species that TGCC support focused on,[3] the number of trees planted since 2017, and the total number of trees still alive at the time of the follow-on survey in 2021. The last two outcomes were collected only for the most commonly promoted agroforestry tree species, Gliricidia and Musangu, which were intended to be planted as perennials. The survey questions measure outcomes at the household-level aggregated across all parcels of land owned by that household. The analysis explores agroforestry patterns across species and presents differences at follow-on between each treatment and the control group overall and for certain sub-groups.[4]

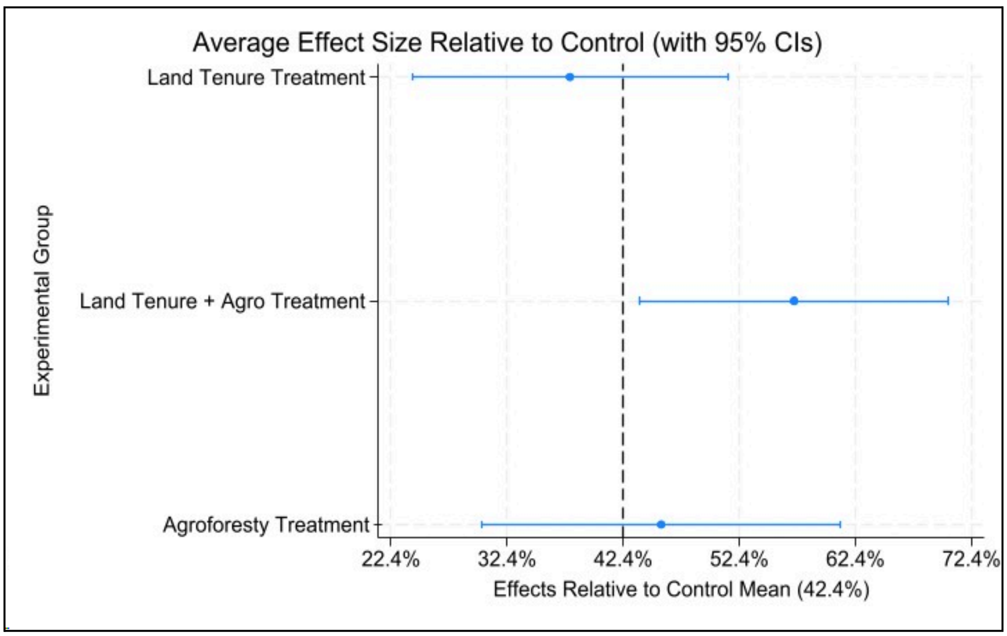
[3] Two perennial tree species: Gliricidia (*Gliricidia sepium*), Musangu (*Faidherbia albida*); and four short-lived shrub species:, Cowpea, Pigeonpea, Ububa, and Sesbania sesban

[4] All differences are regression adjusted to control for the intervention rollout.

1. **TGCC's land tenure and agroforestry programming significantly impacted agroforestry uptake.**

Figure 1 shows that the combined land tenure and agroforestry programming offered by the TGCC program resulted in a statistically significant impact on farmer engagement in agroforestry. As reported in the 2021 follow-on report and reconfirmed here, the magnitude of impact was relatively large. For households in villages that received both interventions, the program led to a 14.7 percent change. At follow-on, 42.4 percent of households in the control group were engaging in agroforestry compared to 57.1 percent in the combined (agroforestry plus tenure) treatment group.[5] Since they were randomly assigned, this represents the causal impact of providing the combined treatment relative to no intervention. Conversely, offering either the land tenure or agroforestry intervention alone did not have an overall impact on agroforestry uptake relative to the control group.

Figure 1: Margins Plot of Treatment Effects[6]



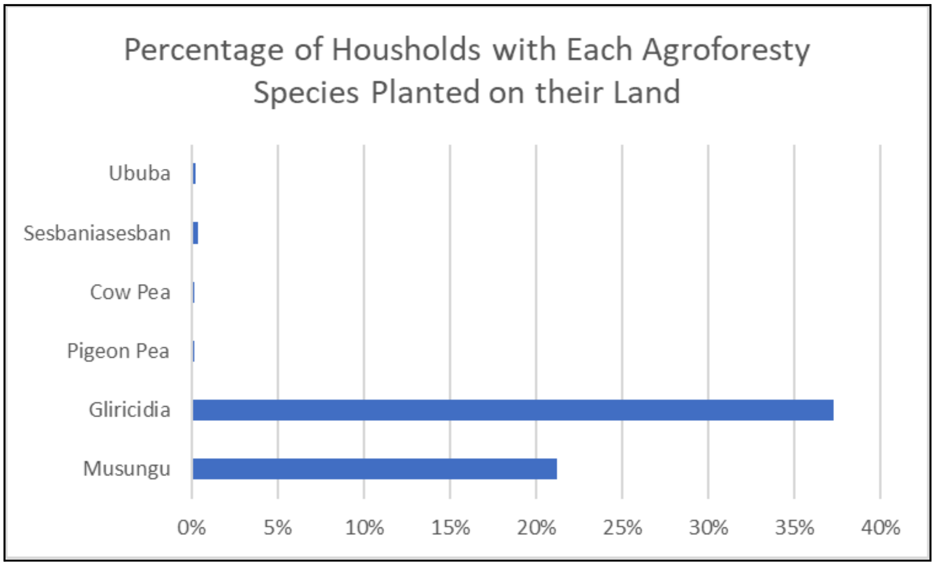
[5] In this brief we look at several aspects of agroforestry, namely uptake, number or trees planted, and number of trees still alive at follow-on. Each outcome provides a different lens through which to view agroforestry outcomes. Uptake provides information on the spread of agroforestry practices across the farmer population. Importantly, uptake can continue to spread well after the intervention as farmers learn from their neighbors so we first revisit this outcome from the endline report.

[6] Notes: The mean for any uptake of agroforestry species in the control group is 42.4%, measured along the horizontal axis. The vertical dashed line at 42.4% is set at the control group mean. Treatment groups are labeled along the vertical axis. The dots represent the point estimates for means of each treatment group, and the bracketed lines represent the 95 percent confidence intervals (CI) of each treatment group mean. When the CI crosses the control group mean, it indicates that differences between that treatment group and the control group are not statistically significant. When the CI does not cross the control mean, differences are statistically significant.

2. **Of the six agroforestry species TGCC offered, farmers focused on Musangu and Gliricidia.**

Figure 2 demonstrates that, of the six agroforestry species covered by the impact evaluation, only Musangu and Gliricidia trees were grown in substantial numbers (by approximately 21.2 percent and 37.3 percent of all households, respectively). The other four species included in the household survey were planted by less than one percent of households in the study area.

Figure 2: Percentage of Households with Agroforestry Species by Type[7]



These descriptive findings inform the team's analysis in several ways. First, they demonstrate that there is variation in the distribution of species across the study areas-–a necessary condition to further examine patterns underlying agroforestry uptake more broadly. Second, they identify the two species with sufficient numbers whose patterns can be explored statistically. Finally, they demonstrate that there is space for targeted interventions to play a role in increasing species diversification.

[7] Notes: Total number of households included is 2,567. Ububa is also referred to as Tephrosia Vogelii while Musungu is referred to as Faidherbia Albida.

3. TGCC resulted in measurable impacts on Musangu uptake and survival.

To explore these dynamics, we estimated treatment-control differences in the number of Gliricidia and Musangu trees planted by households since 2017 and the total number of trees still alive at follow-on for the two primary species.[8] The analysis suggests that the TGCC program resulted in a much larger measurable impact for Musangu than Gliricidia – in other words, relative to what would have happened in the absence of the program, TGCC clearly led farmers to plant a greater number of Musangu trees, but did not measurably impact the amount of Gliricidia planted.

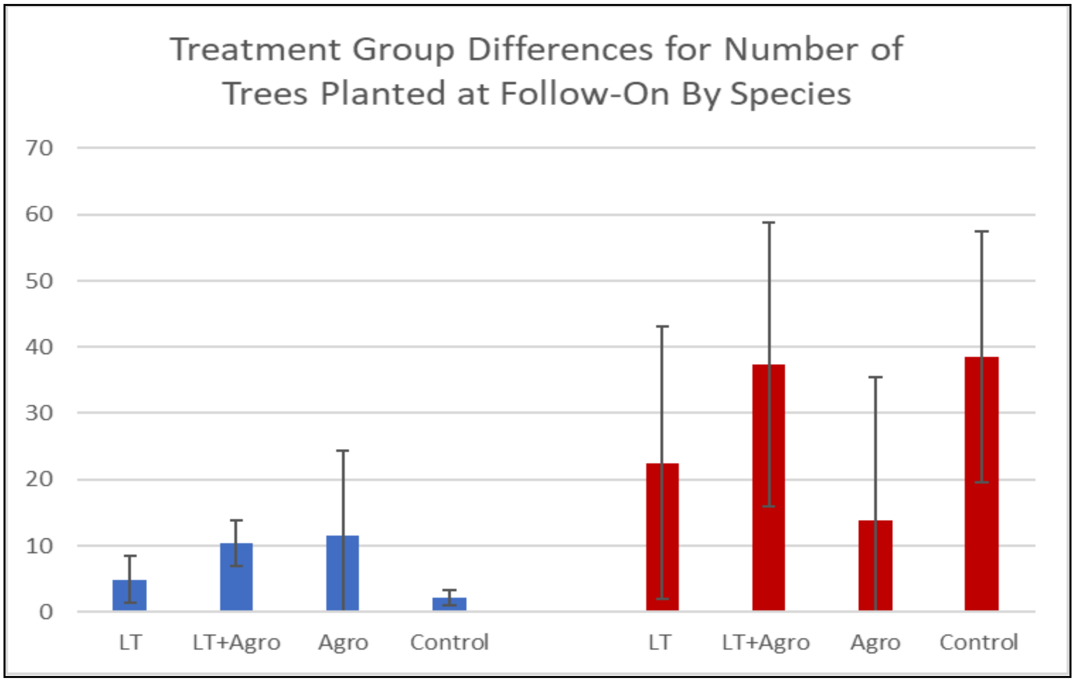
The team found that households in the combined treatment group planted approximately eight more Musangu trees, on average, than households in the control group (approximately 10 trees versus a control mean of two trees). For Gliricidia, there is no statistically significant difference in the number of trees planted, between the combined treatment group (approximately 37.4 trees planted) and the control group mean of 38.6 trees[9]. As noted above, this null result is due to the fact that Gliricidia adoption appears to have taken place through multiple channels, not solely through TGCC interventions. In other words, farmers did also plant more Gliricidia trees in the study area, but the TGCC program did not lead farmers to plant *substantially more* trees than they would have done if the program had not been there.

To put the impacts of the combined treatment group into perspective, about 53 percent of the population in the TGCC program area owns less than two hectares of land (or five acres) and more than 90 percent had less than five hectares (or just over 12 acres). Moreover, about 21 percent of the population planted Musangu and the average treatment effect was eight additional trees planted per household. Put together, the results suggest farmers who did plant trees as a result of being exposed to the combined land tenure and agroforestry treatment planted approximately 40 additional trees on their land, on average, since those impacts were concentrated in households that planted Musangu.

[8] The total number of trees alive at follow-on variable may include those planted prior to the intervention, but it should be noted that Zambia experienced a substantial drought from 2015 to 2016 where many farmers experienced low seedling survival rates.

[9] Figure 3 plots the means for each treatment and control group and corresponding 95 percent confidence intervals on the number of Musangu trees planted for each species while figure 4 plots the means and confidence intervals for Gliricidia by treatment groups. Readers should note the vertical axis is different for each figure as control means differ for Gliricidia and Musangu, however for both figures, higher group means correspond to an increase in trees planted (i.e. uptake). Figure 3 shows that households in the combined treatment group planted approximately 8 more Musangu trees on average than households in the control group (approximately 10 trees versus a control mean of 2 trees). Differences for the other treatment groups are positive for Musangu, but statistically insignificant. Figure 4 shows there is no statistically significant difference in the number of Gliricidia trees planted. The control mean is just under 40 trees per household, but the estimates have very wide confidence intervals so none of the differences are statistically significant.

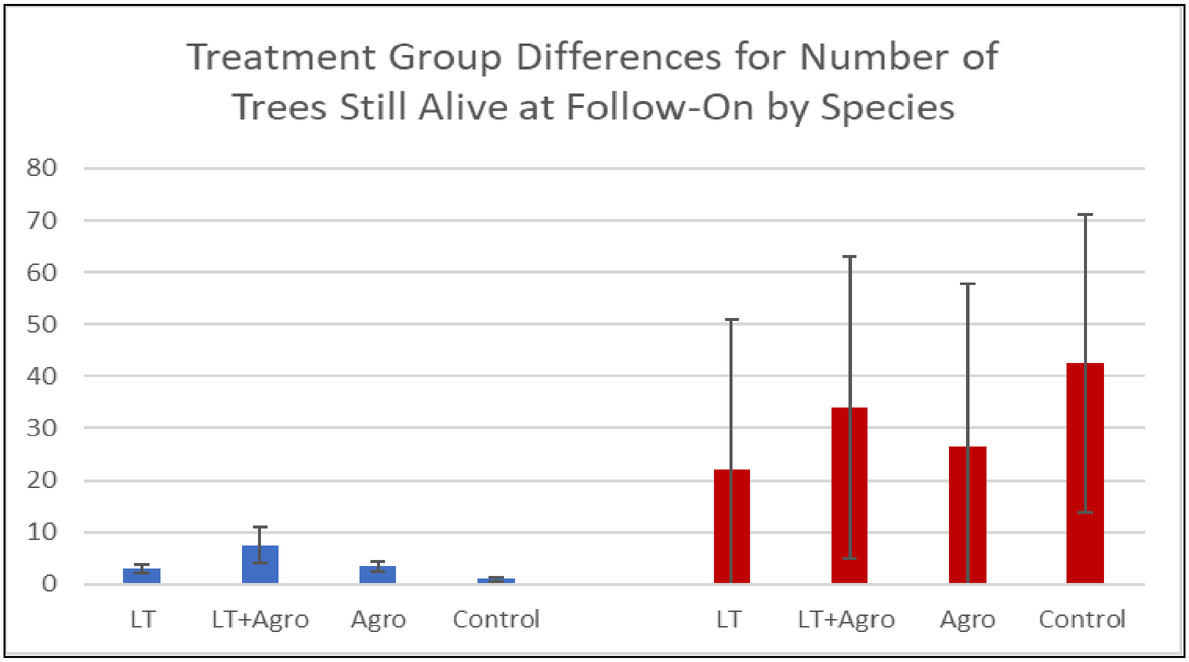
Figure 3: Treatment Group Differences in Trees Planted by Species[10]



In addition to the number of trees planted by households, and because we expect some loss of trees over time and potential differences in survival rates by species, the team also looked at the number of trees reported to be still alive on household parcels at the time of data collection for the follow-on impact evaluation in late 2021. Since the program's agroforestry support ended several years prior, this provides some additional insights into the extent to which households' efforts to plant trees on their farms are sustained over time. The team found that households that received any combination of the TGCC interventions (land tenure, agroforestry, or both) were more successful at keeping Musangu trees alive relative to control households. As for the number of trees planted, the team did not find evidence for an impact of the TGCC interventions on the number of Gliricidia trees farmers were able to maintain over the longer term (Figures 5 and 6).

[10] Note: Only the treatment group mean for the combined group for Musangu (blue) is statistically significant and higher than the Control group mean. None are significant for Glricidia (red).

Figure 4: Treatment Group Differences for Number of Trees Still Alive by Species[11]



It is important to understand differences in TGCC's impacts for the different agroforestry species promoted, since this can inform a range of programming design issues as well as how programming might impact agroforestry species diversity in the program area. Program and implementer documentation, along with qualitative data collected as part of the 2021 follow-on impact evaluation, provided insights into why TGCC had a greater measurable impact on the uptake and survival of Musangu than on Gliricidia. Given the complexity and relevance for future programming, additional follow-up is also warranted.

On net, the available information suggests that agroforestry implementers' efforts to widely promote Gliricidia, together with its shorter timeframe to yield benefits, could have prompted its adoption to spread more easily than Musangu, which requires a longer timeframe to provide on-farm benefits and also has qualities that may pose barriers to farmers' interest in planting or maintaining it on their farms. As a result, interest in and uptake of Gliricidia may have been spread from a relatively small intervention effort. In other words, achieving uptake and maintaining Gliricidia trees on land may be less dependent on the intensive set of interventions provided by TGCC. This could suggest that the interventions, such as those provided by TGCC, might be more impactful overall in focusing on species that do not spread as easily through multiple channels, like Musangu or other less common species.

[11] Note: All three treatment group means for Musangu (blue) are statistically significant and higher than the Control group mean. The largest difference is in the combined group. None are significant for Gliricidia (red).

Similarly, the agroforestry implementer or others' presence and subsequent promotion of Gliricidia throughout Eastern Province after the TGCC agroforestry intervention could have led to widespread availability and interest in Gliricidia planting in the control group that also swamped impacts gained due to the TGCC intervention(s). This may suggest, for example, that increased Gliricidia uptake could be achievable outside of the area targeted by TGCC, even with a lighter touch intervention, while obtaining an increase in the uptake of Musangu may be possible across more geographies, but is more strongly reliant on the combined tenure and agroforestry intervention TGCC offered.

The results underscore the importance of delving into nuanced mechanisms and species-specific fit with broader implementation context. Results also suggest that TGCC's interventions may have been more effective in achieving agroforestry impacts for a tree species that ultimately provides farmers with substantial on-farm benefits and mitigation potential, but requires a greater time investment and tolerance of particular characteristics that not all farmers may appreciate.

Qualitative data from the follow-on impact evaluation phase lends some support for these potential explanations, while also underscoring that the agroforestry implementer is well-known and well-regarded throughout the TGCC program area for a range of agricultural and beekeeping support that it continues to provide in Eastern Province. At the time of the follow-on, the qualitative data strongly suggested that Gliricidia was more widely planted throughout the TGCC program area than Musangu, and many respondents appeared to have had a better experience on-farm with Gliricidia. For example, some respondents noted that Gliricidia grows more quickly, and it is possible to start seeing soil fertility benefits within three years, compared to eight-to-10 years for Musangu. Others highlighted that various parts of the fast-growing Gliricidia trees could be used for firewood, medicine, or insecticides. Musangu, on the other hand, is slower-growing, thorny, and many respondents complained of needing to undertake substantial pruning, as well as effort to avoid stepping on the thorns from branches that dropped onto the ground.

> *"For Gliricidia, it grows fast and we have started seeing the benefits, so things are better, but Musangu delays in growing, so we have not seen any [benefits yet]."*
> *– Male FGD respondent, LT+Ag (Persha et al 2023)*

In sum, Gliricidia appears to be more easily spread with little support from interventions, like TGCC, while Musangu uptake appears to benefit more from TGCC's comprehensive set of land tenure and agroforestry extension interventions. This analysis does not, however, provide insight on the "right mix" of agroforestry species in the target area, although, presumably, it is not 100 percent of any one species; some species diversity is desired, not only to meet farmers' specific needs, but also from broader climate change mitigation and ecosystem resilience perspectives.

4. **There were differential impacts by farmer sub-groups.**

To address this point, the analysis focused on farmers as a group to examine how agroforestry outcomes varied depending on the services households received. Next, the team dove deeper to better understand whether the interventions helped certain farmers more than others. In particular, the team tested whether the TGCC interventions led to different agroforestry outcomes for sub-groups based on their gender, age, income, literacy, and a host of other variables. Of all variables tested, the only statistically significant difference in uptake was based on literacy, predominantly in the 'agroforestry only' treatment group.

5. **There was no difference in agroforestry uptake between women and men.**

Given that both the TGCC program and the subsequent Integrated Land and Resource Governance (ILRG) program in Zambia maintained a sustained focus on gender equality and women's empowerment, the team paid particular attention to sub-group results on the basis of gender.

Across multiple analyses conducted (not shown), the team did not find evidence for a difference in agroforestry uptake among men and women, as was also highlighted by the 2021 follow-on IE. In other words, the TGCC programming appeared to lead to similar rates of agroforestry uptake among men and women beneficiaries. Put in context with the wider evidence base for adoption of agroforestry and new agricultural technologies, this is a positive outcome, given that current evidence suggests women often have lower rates of participation and uptake in programs that promote agroforestry and/or the adoption of new agricultural practices or technologies (Doss, 2001; BenYishay et al 2020; Quisumbing and Doss 2021).

6. **Among the agroforestry-only group, there is a significant relationship between literacy and agroforestry uptake.**

For literacy, we use two variables in the survey that ask whether a person can read a newspaper article or write a paragraph themselves. We view literacy as a proxy for education levels and find that in the agroforestry-only treatment group, literate respondents were both more likely to plant agroforestry seedlings and have more trees that remained alive during the follow-on survey.

Figure 5: Differential Impact on Forestry Outcomes by Literacy Status

Forestry Outcome Variable		Land Tenure (Differential Effect)	LT + Agroforestry (Differential Effect)	Agroforestry (Differential Effect)
Any Agroforestry	Read	‘0.16*** (.061)	‘-0.025 (.057)	‘0.118** (.059)
	Write	0.140**(.060)	‘-0.040 (.059)	‘0.094 (.060)
Musungu Planted	Read	‘-3.48 (3.11)	‘-0.43 (3.26)	‘10.51* (5.64)
	Write	‘-3.75 (3.08)	‘-1.10 (3.29)	10.63* (5.92)
Gliricidia Planted	Read	1.56 (23.1)	‘-13.2 (30.1)	‘-4.28 (26.8)
	Write	0.81 (22.9)	‘-13.0 (29.8)	‘6.22 (26.7)
Musungu Alive	Read	1.46 (1.55)	‘-2.50 (5.6)	4.51** (1.86)
	Write	2.33* (1.36)	‘-2.36 (5.4)	4.41** (1.83)
Gliricidia Alive	Read	‘-11.8 (26.7)	0.68 (28.0)	4.66 (29.6)
	Write	‘-10.8 (26.6)	1.49 (28.1)	16.1 (29.9)

Figure 5 presents the differential impacts for each treatment group for those respondents who are literate compared to those who are not literate. First, the table shows that literate respondents are more likely to have agroforestry trees on their land in both the land tenure-only and agroforestry-only treatment groups (compared to the control group) by 14-16 percent and 12 percent, respectively. Digging deeper, we see that the results for the land tenure group cannot be explained by the increased planting of seedlings or survival of either Musangu or Gliricidia by literate respondents. However, literate respondents increased their planting of Musangu seedlings by about 10.5 seedlings and seedlings survived in higher numbers–about 4.5 trees on average–compared to the control in the agroforestry-only treatment group. Interestingly, the only treatment group that did not have better outcomes for literate respondents relative to others was the combined intervention. This does not negate the above results, it simply means that the combined treatment produced consistent results for all beneficiaries for Musangu uptake and survival for all respondents, irrespective of their literacy status.

Providing agroforestry extension support on its own led to improved agroforestry outcomes for literate respondents, but not for others, which suggests there may have been elements of the agroforestry intervention or its delivery that were more challenging for non-literate households to engage with or benefit from. The latter result is consistent with work on training programs in low literacy populations that suggest such programs should be designed to meet a person at their ability level (Banarjee et al 2007). In agroforestry and similar interventions, results from other contexts also show that program impacts may increase with education or literacy levels aimed at uptake of new technologies in the agricultural sector (Hedge & Bull 2011, Branca et al 2021). One plausible link between literacy and the uptake of new technologies is that literate farmers have an increased willingness to take on risk related to new behaviors or practices and an increased ability for individuals to take up information. Moreover, more educated individuals may be more easily able to convert participation in programs into more lucrative livelihoods or market opportunities.

Future research might aim to disentangle these patterns to better understand how particular components of agroforestry programming could effectively be provided to recipients irrespective of literacy levels (or similar concepts like education level), to increase impacts. It is entirely plausible that low literacy populations may need a more complete suite or alternative modes of extension services or delivery, while higher literacy populations may be able to effectively engage in agroforestry with a narrower set of interventions.

Discussion and Recommendations

The value of integrated programming depends on the population targeted. The follow-on results reveal a large and positive impact on agroforestry uptake across all households in villages that received the TGCC combined Land Tenure and Agroforestry interventions. By contrast, the impact analysis did not find evidence for a positive impact on agroforestry uptake among households in villages that only received the Land Tenure intervention, or those that only received the Agroforestry intervention.

This important finding implies two conclusions. First, improved land tenure is a necessary but not sufficient condition for increased uptake of agroforestry for the entire population covered in this study. When there is limited information about population characteristics, integrated programming that provides extension activities, tenure formalization, and village governance support allows farmers to make long-term investments in their land and will produce consistent impacts across diverse populations. Second, households with higher literacy levels may be able to achieve impacts with less programmatic support. For example, the agroforestry treatment alone increased agroforestry adoption by almost 12 percent and the number of Musangu trees planted by households on their land by 10.5 trees, on average, in the sub-population with higher literacy levels (compared to approximately 14 percent and 8 trees in the combined group for the entire population, respectively).

It takes time achieve results. While improved land tenure may lead to transformative economic impacts, these impacts often take time to materialize and studies conducted shortly after land tenure interventions fail to capture these impacts. The TGCC impact evaluation and follow-on impact evaluation provide a strong example of this dynamic; while evidence of improved agroforestry uptake was not present at the time of the 2017 endline, it was apparent by the time of the follow-on, in 2021. This finding has implications, both for the design of land tenure impact evaluations (lengthening the exposure period is critical, whether by lengthening the time to endline or by including a follow-on round), and for expectations around the time it takes to see impacts of land tenure programs.

Species must fit with farmer preferences. Despite TGCC implementers' efforts and incentives to increase the adoption of Gliricidia, it appears that the planting and maintenance of Musangu trees drove most of the measured change in treatment areas. However, part of this observed pattern was due, in part, to high levels of adoption of Gliricidia across all groups, including the control group. Counterintuitively, future projects using an integrated programming approach may want to focus more on 'harder-to-adopt' species, such as Musangu, as integrated programming may be more effective to increase adoption for those species. For 'easier-to-adopt' species, the increase in adoption from integrated programming may be too low to drive measured change. However, a mixed approach may provide the optimal outcome by balancing the benefit of increased adoption of a relatively rare species into a project area, thus increasing agroforestry species diversity in the landscape, while encouraging uptake of species that farmers were already more inclined to plant. This dynamic highlights the need to employ user-centered design practices and conduct careful consultations during project design, to identify diversity in beneficiary preferences, and to ensure that planned interventions align with beneficiary preferences (Jones et al. 2020).

There are strong links between literacy and intervention uptake. Literate beneficiaries had better agroforestry uptake outcomes in the group receiving only agroforestry extension services. This link between literacy and intervention uptake is consistent with several recent studies from similar contexts that found education level to be an important correlate or predictor of beneficiaries' likelihood of participating in or benefitting from the promotion of new agricultural technologies, agroforestry, and/or farmer extension programs (Hedge & Bull, 2011; Branca et al, 2021). These linkages provide important insights and raise new questions for future agroforestry programs.

From a targeting standpoint, these insights indicate that more literate (or, more educated) beneficiaries may be more successful in leveraging agroforestry extension services for various reasons, including their interest and willingness to take on risk, and the ability to absorb and retain technical information. This finding also raises questions as to whether materials used to socialize the interventions were delivered in a format that inadvertently excluded illiterate beneficiaries, leading to lower uptake levels. If true, this insight provides clear learnings for future program design and suggests that materials should be better targeted to beneficiaries' learning capabilities. For example, language should be targeted at the comprehension level of beneficiaries, and the use of visual aids, or other strategies, should be increased. However, using new delivery methods, like these, will require additional research to test which are most effective.

Gender did not play a significant role in uptake. The follow-on impact evaluation found no significant difference in the uptake of agroforestry practices between men and women. This gender parity can be viewed as an achievement, given female farmers may take up agroforestry interventions at lower rates than their male counterparts (BenYishay et al 2020; Quisumbing and Doss 2021). While the data we analyzed here cannot determine why no gender gap exists, outside literature suggests differential gender impacts found in agricultural programs are often rooted in how agricultural labor is divided, frequently putting relatively more burden on women who are often expected to fill multiple roles simultaneously (Doss, 2001). Indeed, the 2017 TGCC endline impact evaluation report found that female-headed households in treatment communities were slightly less likely to have planted Gliricidia trees than male-headed households (FHH: 23%, MHH: 28%, significant at the 1% level). Drawing from monitoring and evaluation conversations with TGCC implementers, the 2017 analysis also found that female-headed households were more likely to struggle to transport their seedlings from the nursery to their fields, particularly the large number of Gliricidia seedlings (Huntington 2018). There were no differences between men and women for Musangu. If female-headed households faced greater obstacles related to accessing, transplanting, maintaining, or benefiting from agroforestry trees on their farms, TGCC could have exacerbated inequalities in agroforestry outcomes and intended productivity and livelihood impacts over time. However, the null finding here suggests that, over the longer term, men and women achieved similar levels of agroforestry adoption by the time of the 2021 follow-on.

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