The VLFRs supported by FORVAC in Liwale and Nachingwea have been effective at reducing deforestation- “the forest that pays is the forest that stays”.

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Summary

Forest and woodland resource use in Tanzania is amongst the most intense in eastern and southern Africa (McNicol et al., 2018). From 2010 to 2015, Tanzania was in the top ten globally for forest conversion rates (FAO, 2015). Agricultural expansion and charcoal production are the dominant causes of forest loss in Tanzania, but are important for meeting food security, energy and livelihood needs (Curtis et al., 2018; Doggart et al., 2020; Dziba et al., 2020). Community-based forest management (CBFM) seeks to decentralise forest management by engaging villages to manage forests sustainably, in an effort to reduce deforestation by providing an incentive to protect community forests. In Tanzania, Village Land Forest Reserves (VLFRs) are a mode by which CBFM is practised. Managed by village councils, VLFRs can be used by villages to produce timber and non-timber forest products. The Forestry and Value Chains Programme (FORVAC) is a six-year programme (2018-2024), funded by the Ministry for Foreign Affairs of Finland and implemented under the Ministry of Natural Resources and Tourism of Tanzania, to support VLFRs in Tanzania. FORVAC has operated under the hypothesis that “the forest that pays is the forest that stays”, and contributes to increasing economic, social and environmental benefits from forests and woodlands by supporting the commercialisation and improvement of forest value chains (FORVAC, 2022).

This study aimed to test the hypothesis that “the forest that pays is the forest that stays” by analysing forest loss in the VLFRs supported by FORVAC in Liwale and Nachingwea between 2018 and 2022. Remotely sensed deforestation data was provided by Professor Mbilinyi and Professor Zahabu of Sokoine University of Agriculture and the National Carbon Monitoring Centre. I used ‘statistical matching’ to reduce the bias in the dataset between VLFRs, Tanzanian Forest Service (TFS) managed forest reserves and outside forests to provide a robust assessment of forest loss.

I found that VLFRs were effective at reducing deforestation compared to matched outside forests, reducing deforestation by 85 %, 5 % more effective than TFS-managed forest reserves. Additionally, VLFRs that achieved higher timber revenues had the lowest deforestation rates. On average, the VLFRs that achieved timber revenues of over 200,000,000 TZS were 97 % effective at reducing deforestation relative to matched outside forests, which was 46 % more effective than VLFRs that were unable to attain any timber revenues. These results provide evidence for the argument that “the forest that pays is the forest that stays”, showing that the VLFRs, particularly the high-income VLFRs supported by FORVAC were effective at reducing deforestation in Liwale and Nachingwea between 2018 and 2022. Where VLFRs have achieved higher incomes, it is likely that the FORVAC programme has been successful at developing conditions required for the success of CBFM.

Continued decentralisation of forest management could provide a pathway to reduce forest loss in Tanzania that produces synergistic outcomes for communities and forest cover. To achieve this, policymakers and donors may consider continuing to support CBFM programmes that enhance the conditions necessary for successful CBFM and reduce policy and institutional barriers to the commercial and sustainable use of forest resources by communities.

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Contents

Aims

This study analyses the effectiveness of the Village Land Forest Reserves (VLFRs) supported by the Forestry and Value Chains Programme (FORVAC) in achieving avoided deforestation in Liwale and Nachingwea districts in the Lindi region of Tanzania. This analysis aims to identify the credibility of the notion that "the forest that pays is the forest that stays" in relation to the community-based forest management (CBFM) approach of FORVAC. The research questions are as follows. (1) Do VLFRs have a lower deforestation rate compared to matched outside forests? (2) Are VLFRs more or less effective at reducing deforestation than TFS-managed forest reserves? (3) Have VLFRs that have achieved higher timber revenues been more effective at reducing deforestation rates?

Methods

Study area

This study focuses on the forests and woodlands within Liwale and Nachingwea districts, in the Lindi region of Tanzania (Figure 1). These districts were chosen as there is a relatively high number of VLFRs, and a large proportion of them have achieved an income of over 200,000,000 TZS. Miombo woodland is the dominant vegetation type in these districts, typically dominated by *Brachystegia, Julbernadia*, or *Isoberlinia* and often contains valuable timber species such as *Pterocarpus angolensis* (Frost, 1996; Ribeiro et al., 2020). Miombo woodland also offers a diverse range of provisioning ecosystem services which people may rely on as a safety net during droughts or other household income shocks (Kalaba et al., 2013; Ryan et al., 2016).

The Lindi rural district is one of the poorest districts in Tanzania, with little infrastructural development, chronic poverty and food insecurity (Scheba and Rakotonarivo, 2016). Agriculture is the main employer in the Lindi region, with 91 % of households the labour force engaged in agriculture to some capacity in 2012 (Ochieng and Hepelwa, 2018). The population of Liwale district as of the 2022 census was 136,505 (4 people km^{-2}), Nachingwea district was 233,655 (39 people km^{-2}) (URT, 2022).

VLFRs and TFS Forest Reserves

Figure 1 shows the VLFRs covered in this study (n = 33). Geospatial and timber revenue data was provided by the FORVAC programme and its partners. Timber revenue was categorised as none (no income), low (< 50,000,000 TZS), medium (50,000,000 – 200,000,000 TZS) or high (> 200,000,000 TZS). The area covered by forest management plans in Liwale is 235,405 ha, and 48,313 ha in Nachingwea. However, due to missing or erroneous geospatial data, ~31,000 ha of woodland was excluded from this analysis (see Appendix Table 1 for the list of excluded VLFRs).

Data for protected areas and woodlands managed by the Tanzanian Forest Service (TFS) was taken from the World Database on Protected Areas (WDPA) (UNEP-WCMC and IUCN, 2024) (n = 2). The analysis excluded mangroves and the Lionja forest reserve as it overlaps with the Msanjesi game reserve. Therefore, it was unclear whether this area was managed as a TFS forest reserve or not. Geospatial data for Machang'anja forest reserve was also missing in the WDPA data.

Remote Sensing of Deforestation

Professor Mbilinyi and Professor Zahabu of Sokoine University of Agriculture and the National Carbon Monitoring Centre produced the deforestation data for this analysis. They used Sentinel-1 C-band radar data from the European Space Agency and ALOS 2 L-band radar data from the Japanese Space Agency (see their report for the FORVAC programme for details on their methodology).

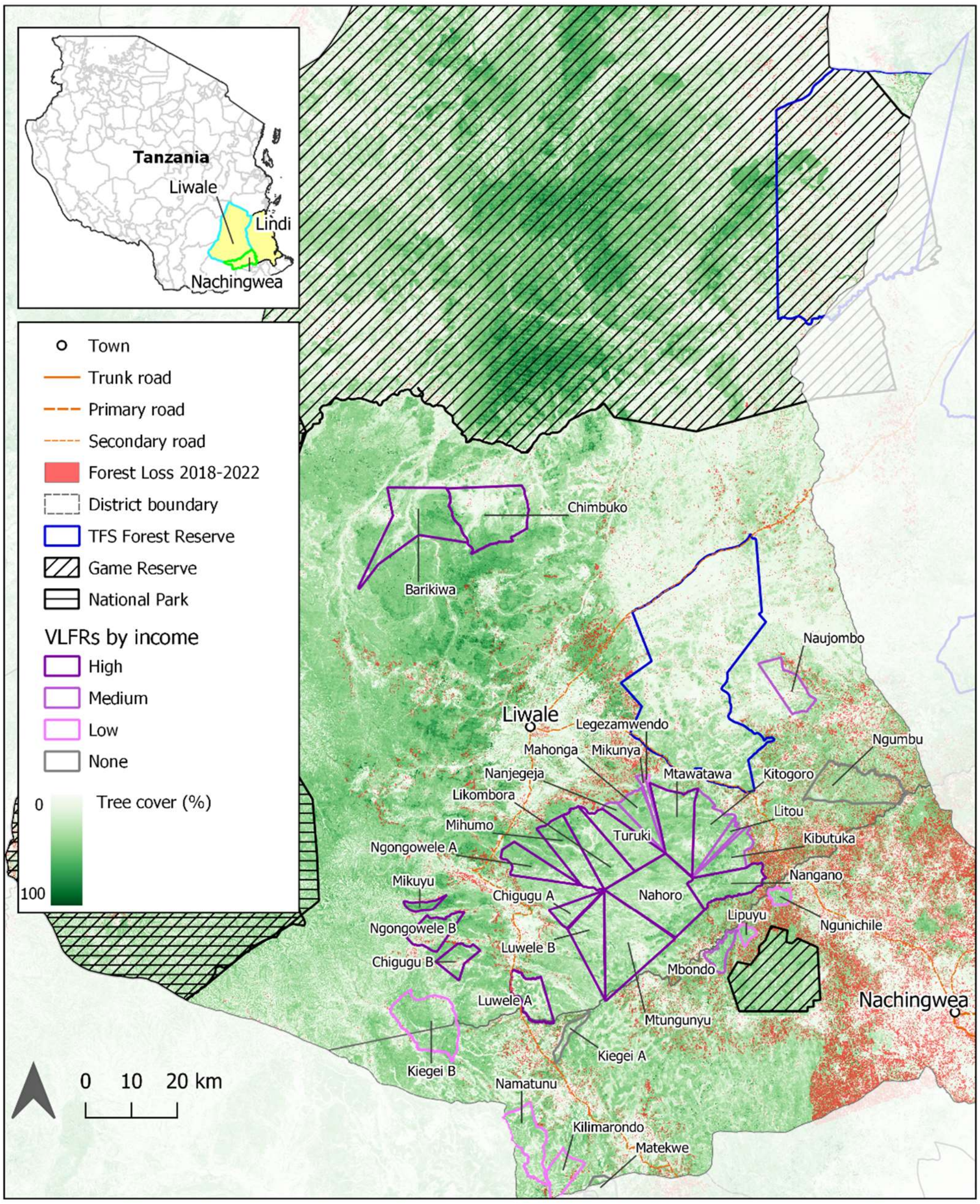

Figure 1 Study area- Liwale and Nachingwea districts in the Lindi region of Tanzania with VLFRs displayed by income level, TFS Forest Reserves, Protected Areas (UNEP-WCMC and IUCN, 2024) and deforestation data provided by Professor Mbilinyi and Professor Zahabu of Sokoine University of Agriculture. Tree cover data from (Hansen et al., 2013).

Assessing VLFR or TFS Forest Reserve Effectiveness

In this analysis effectiveness is considered as the difference in deforestation rates between treatment units (VLFRs or TFS forest reserves) and their matched untreated units (outside forests). Other aspects of VLFR effectiveness are important, such as socio-economic outcomes, but this study focuses on land cover change, specifically avoided deforestation.

Accounting for covariate imbalance – Statistical Matching

An unbiased assessment of any conservation or land management intervention must account for dissimilarities between the areas subject to the intervention and comparison areas. Statistical matching allows analysts to establish such 'counterfactuals' (what would have happened in the absence of interventions) to generate less biased estimates of intervention impacts (Schleicher et al., 2019). Matching aims to identify untreated units (i.e. areas not under any management intervention) that are similar to treated units in terms of potentially confounding covariates at pre-intervention baselines (Brade, 2022; Rasolofoson et al., 2015; Schleicher et al., 2019). The analysis is termed as "balanced" when treated and untreated units, in this case pixels, have similar values of covariates. This approach improves causal inference from non-experimental data as the resulting matched dataset should have similar characteristics to a randomised experiment in terms of balance of confounding covariates.

Here we use Coarsened Exact Matching (CEM) to match untreated pixels (forests outside VLFRs or TFS forest reserves) to treated pixels (forests inside VLFRs or TFS forest reserves). This method requires the analyst to make ex-ante decisions based on knowledge of the selected covariates. This domain knowledge is used to coarsen values of covariates into strata, which are then matched exactly (i.e., treated pixels are matched to untreated pixels in the same strata).

The selection of covariates was guided by peer-reviewed literature aimed at understanding the geography of deforestation in the region and in the broader forested land systems context (Ahrends et al., 2010; Brade, 2022; Rasolofoson et al., 2015; Scheid et al., 2019; Schleicher et al., 2017). This resulted in a set of seven covariates that are likely to influence woody resource use rates and for which spatial data are available (Table 1).

All covariates were formatted as detailed in table 1. When formatting the dataset for analysis, protected areas such as national parks or game reserves were excluded, as were 1km buffers around VLFRs and TFS forest reserves and 3km buffers around protected areas to remove potential 'leakage' effects. The deforestation dataset was resampled and converted into a data frame with the covariates to use in the CEM. All 'non-wooded' pixels were excluded from the analysis based on the >10 tC ha^{-1} threshold outlined in table 1. After the CEM, a new matched dataset was produced which enabled the assessment of deforestation rates within treated units and matched untreated units.

Assessing Effectiveness in Matched Data

After matching treated (VLFR or TFS forest reserve) and non-treated (outside of VLFRs or TFS forest reserve) pixels, deforestation rates were calculated as the mean of the binary deforestation fields for treated and non-treated pixels, as a proportion of woodland extent defined above 10 tC ha^{-1}. A simple effectiveness score, E, was calculated to quantify the relative impact of each given VLFR or TFS forest reserve on deforestation rates relative to similar (matched) non-VLFR or non-TFS forest reserve pixels:

$$Effectiveness\ Score\ (E) = 1 - \left(\frac{Treated\ Unit\ Deforestation\ Rate}{Non-treated\ Unit\ Deforestation\ Rate}\right) \times 100$$

Table 1 Covariates used in matching, rationale for inclusion, data sources, notes on processing steps and coarsening cut points used for Coarsened Exact Matching- from Brade (2022).

Covariate	Inclusion Rationale	Source	Processing	Unit	Cut-points
Travel time to urban centre	Charcoal production is a prominent proximate cause of deforestation, primarily consumed by urban residents. Pressure on woody resources for charcoal production is notably larger closer to large settlements (Ahrends et al., 2010; Doggart et al., 2020).	A global map of travel time to cities to assess inequalities in accessibility in 2015 (Weiss et al., 2018)	Resampled to 25 m (bilinear interpolation).	Minutes	0, 60, 120, 240, 360, 480, 600, MAX (Time in hrs: 0, 1, 2, 4, 6, 8, 10, >10)
Distance to settlement	Local woodlands produce construction materials. Traditionally the extent of the spatial extent of harvesting around settlements <5 km (round trip) but scarcity of resources can result in increasing distances.	Points of populated places including hamlets, villages, towns, cities (HOT, 2024a)	Euclidean distance between populated places and all other pixels. Resampled to 25 m (bilinear interpolation).	Kilometres	0, 10, 24, 50, 100, 200, MAX
Distance to roads	Proximity to roads influences the accessibility and ease of timber extraction. Areas close to roads are preferable to minimise the distance materials are moved via non-mechanised means and over less easily traversed terrain.	Road data exported from Open Street Map (HOT, 2024b)	Euclidean distance between roads and all other pixels. Resampled to 25 m (bilinear interpolation).	Kilometres	0, 5, 10, 20, 50, MAX
Distance to converted land	Conversion for crop cultivation or livestock is responsible for the majority of deforestation in Tanzania (Doggart et al. 2020). Expansion of existing areas of cultivation is the major mode of increase in deforested area.	Land Cover time-series (1992-2020). (ESA, 2022)	**10–Cropland**, Rainfed **20–Cropland**, Irrigated **30–Mosaic** cropland (>50%) / natural vegetation (<50%) **40–Mosaic** cropland (<50%) / natural vegetation (>50%). Resampled to 25 m (nearest neighbour interpolation) Euclidean Distance from selected pixels to all other pixels.	Kilometres	0, 2.5, 5, 7.5, 100, MAX
Distance to the woodland/ forest edge	Edges of forests are more readily exploitable and susceptible to conversion or the effects of fire (Green et al., 2013).	Wooded pixels were defined using Above-ground carbon from the ALOS 1 era (2007-2010) from McNicol et al. (2023)	Euclidean distance between pixels > 10 tC and all other pixels. AGC values from ALOS 1 data from McNicol et al. (2023). Resampled to 25 m (bilinear interpolation).	Kilometres	0, 2.5, 5, 10, 20, MAX
Woodland/ forest structure – antecedent above ground carbon	Woodlands and forests have different resource values attributed to differences in species and woodland structure.	Above-ground carbon from the ALOS 1 era (2007-2010) from McNicol et al. (2023)	All pixels > 10 tC classified as 'wooded' in ALOS 1 data.	$tC\ ha^{-1}$	10, 25, 50, MAX
Maize suitability	The suitability of land for cultivation- affects the likelihood of conversion.	Global Agro-Ecological Zones (FAO, 2012)	Resampled to 25 m (nearest neighbour interpolation).	Index	Equal Interval: 1: Good, 2: Good-Mod, 3: Mod, 4: Mod – Poor, 5: Poor

Results and Discussion

VLFRs have been effective at reducing the deforestation rate compared to matched forests in Liwale and Nachingwea districts (Figure 2). VLFRs had a mean deforestation rate of 1.5 ± 0.4, 6.5 times lower than matched outside forests, and on average, they achieved an 85 % reduction in deforestation compared to matched outside forests. This result shows that VLFRs have been effective at reducing deforestation in the period of 2018 to 2022.

This analysis also provides evidence that VLFRs were more effective than TFS managed forest reserves at reducing deforestation. Whilst TFS-managed forest reserves had a mean deforestation rate of 1.3 ± 0.3, 5 times lower than matched outside forests, they were 5 % less effective than the VLFRs in Liwale and Nachingwea districts at reducing deforestation. Note that in this analysis, Machang'anja (which has a deforestation rate of 47 %) was excluded but would have resulted in a higher mean deforestation rate if included- as can be seen in Appendix Figure 1.

Pressure on resources in TFS-managed forest reserves is likely lower than in VLFRs due to their location and suitability for agriculture, hence the marginally lower deforestation rate shown in Figure 2. This is apparent from the lower deforestation rate of matched non-treated pixels for TFS forests compared to matched non-treated pixels for VLFRs. Evidence from the literature suggests a common trend in several countries where the benefits from high-value resources that face less pressure are captured by local government, leaving communities to manage land that faces more modification or conversion pressure (Anderson et al., 2015).

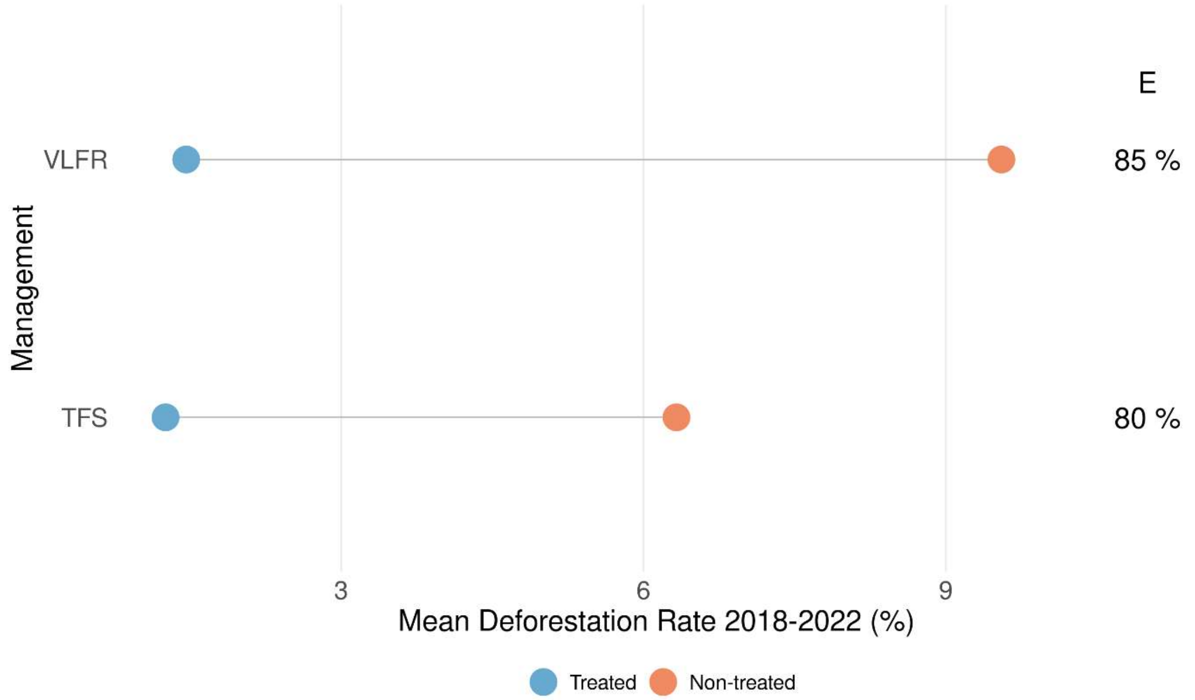

Figure 2 Mean deforestation rates for treated units (VLFRs and TFS forest reserves) and matched non-treated units (matched forests outside of VLFRs, TFS forest reserves or protected areas). Mean deforestation rate shown on the x axis as the mean of all VLFRs or TFS forest reserves for the period 2018-2022 as a proportion of wooded pixels within each treated or matched non-treated unit. The effectiveness score for each management type is also shown where 100% amounts to complete reduction of deforestation, 0 amounts to no difference.

I also found that VLFRs that have attained timber revenues of over 200,000,000 TZS have been the most effective VLFRs at reducing deforestation between 2018 and 2022 in Liwale and Nachingwea districts (Figure 3). Figure 3 (and Appendix Figure 2) shows a clear linear relationship between VLFR income and forest loss. High-income VLFRs achieved an almost complete reduction in deforestation in the study period of 97 % in relation to matched outside forests. In comparison, VLFRs that were unable to generate revenue from timber sales were 46 % less effective at reducing deforestation than the high-income VLFRs.

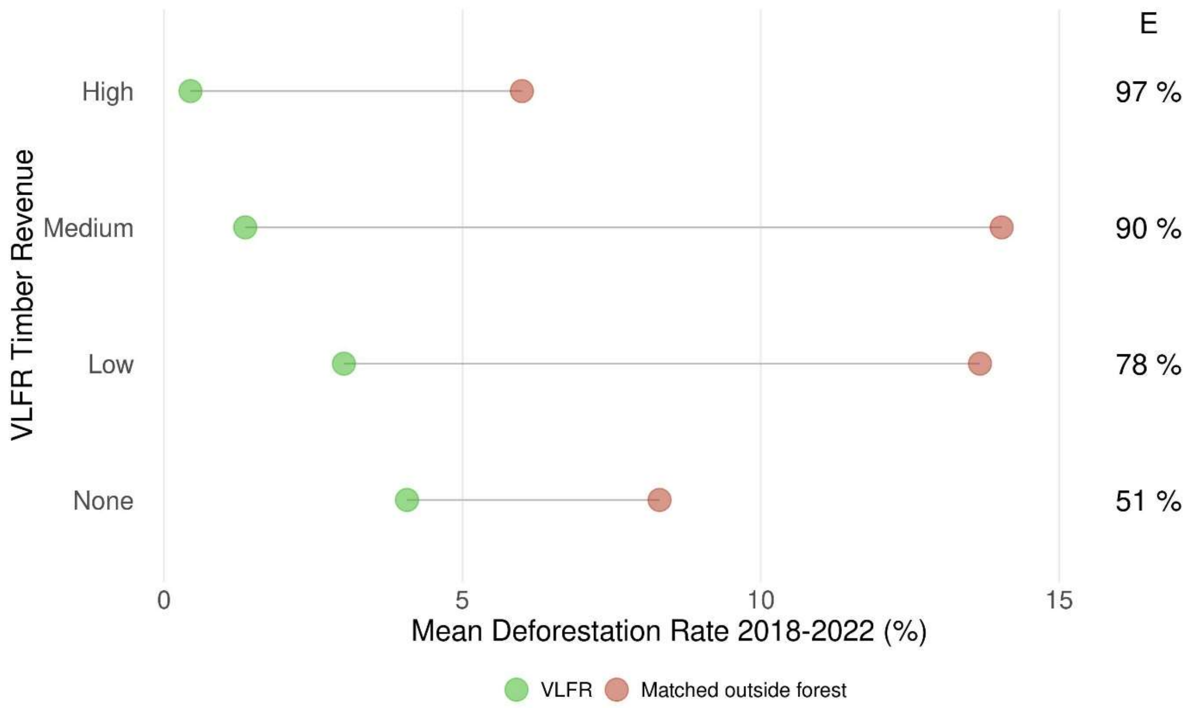

Figure 3 Mean deforestation rates for VLFRs that achieved different levels of timber revenue and matched non-treated units (matched forests outside of VLFRs, TFS forest reserves or protected areas). Mean deforestation rate is shown on the x axis as the mean of all VLFRs of different incomes for the period 2018-2022 as a proportion of wooded pixels in that VLFR or matched non-treated unit. The effectiveness score for each income level is also shown where 100% amounts to complete reduction of deforestation, 0 amounts to no difference.

Evidence from this study shows that from 2018 to 2022, VLFRs have been effective at reducing deforestation compared to outside forests and TFS forest reserves- high-income VLFRs have been the most effective. These findings support the argument that “the forest that pays is the forest that stays”. Where communities have secure tenure and are able to capture benefits from commercial use of forest resources through sustainable forest management, such as in the high-income VLFRs, deforestation is reduced. Similar effects of VLFR establishment on reducing forest loss have been found in other studies in Tanzania (Brade, 2022; Kimaro et al., 2024; Lupala et al., 2015). Although forest gain was not assessed in this study, CBFM was found to promote increased forest cover and, importantly, the persistence of forest regrowth in the VLFRs of the Greater Gombe Ecosystem, highlighting the positive impact that community ownership and decentralised management of natural resources can have on forest cover (Kimaro et al., 2024).

Extensive work on self-governed common-pool resources shows that the factors that facilitate their success and the success of CBFM include: tenure security, clear ownership, effective enforcement of rules and regulations, monitoring, sanctioning, strong leadership with capable local organisation, expectation of benefits and common interests among community members and local authorities (Agrawal, 2001; Ostrom, 1999, 1990; Pagdee et al., 2006). The FORVAC programme aimed to develop and improve CBFM through four outputs that: (1) sought to improve value chains and increase private sector involvement in the forest sector, thereby increasing the expectation of benefits perceived by communities from sustainable forest management; (2) enhance stakeholder capacity to promote and implement CBFM, ensuring strong leadership with capable local organisation, common interests among community members and effective enforcement of rules and regulations; (3) develop extension, communication and monitoring systems, providing communities with monitoring capacity; (4) strengthen legal and policy framework, securing tenure and clear ownership of VLFRs for communities and a favourable policy environment for commercialisation of sustainable forest management (FORVAC, 2022). Therefore, it is likely that the income-generating VLFRs that have been supported by FORVAC have satisfied some of the criteria that enable successful CBFM.

Conclusion

VLFRs in Liwale and Nachingwea were effective at reducing deforestation between 2018 and 2022, particularly those that were able to generate income from timber sales. The success of VLFRs and CBFM relies on factors such as secure tenure, and a favourable institutional and policy environment that enables communities to see the benefits of commercialising sustainable forest management. To achieve synergistic outcomes for forest cover and communities, policymakers and donors may consider continuing the decentralisation of forest management, empowering local communities through supporting the establishment of VLFRs and their self-organisation capacity, and reducing barriers to sustainable forest management and the sale of timber by VLFRs.

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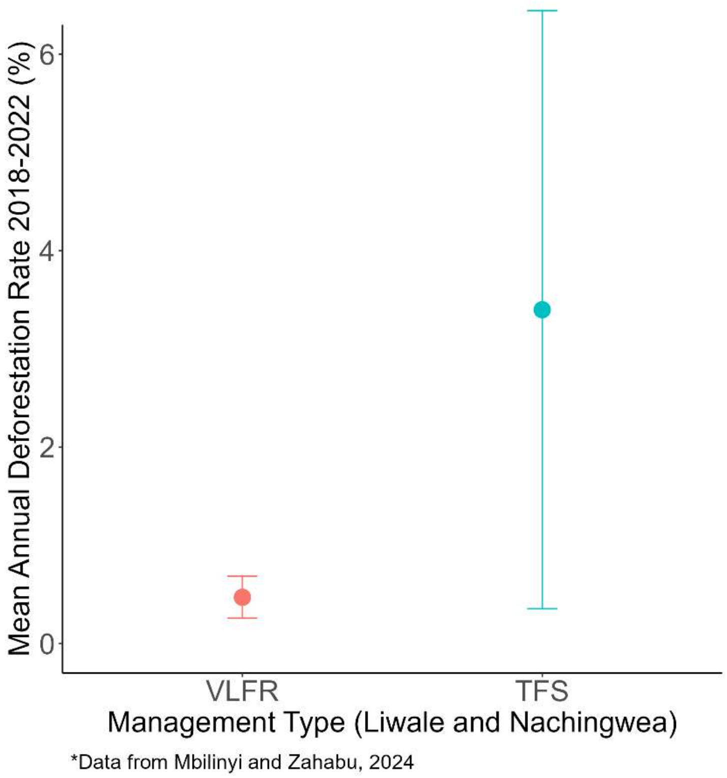
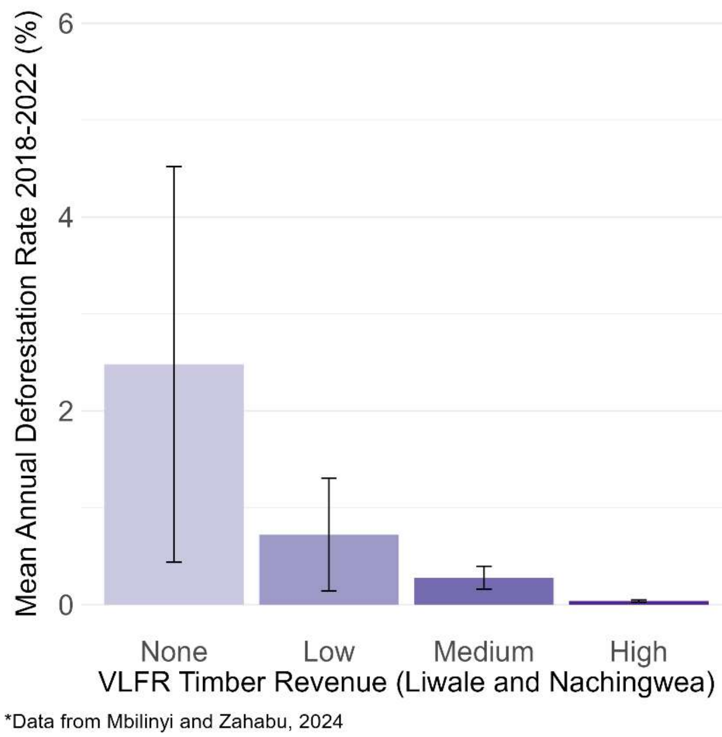
Appendix

Appendix Table 1 VLFRs included in the analysis. VLFRs not included were excluded due to missing or erroneous data.

District	Village	Included
Liwale	Mikunya	Yes
	Mtawatawa	Yes
	Nangano	Yes
	Mtungunyu	Yes
	Nahoro/VLFR 1	Yes
	Nahoro/VLFR 2	No
	Naujombo	Yes
	Chimbuko	Yes
	Barikiwa	Yes
	Darajani	No
	Kitogoro	Yes
	Likombora	Yes
	Turuki	Yes
	Chigugu/VLFR 1	Yes
	Chigugu/VLFR 2	Yes
	Lilombe	No
	Luwele/VLFR 1	Yes
	Luwele/VLFR 2	Yes
	Mikuyu/VLFR1	Yes
	Mikuyu/VLFR2	No
	Mahonga	Yes
	Nanjegeja	Yes
	Ngumbu	Yes
	Legezamwendo	Yes
	Kiangara	No
	Kibutuka	Yes
	Mihumo	Yes
	Ngongowele VLFR1	Yes
	Ngongowele VLFR2	Yes
	Litou	Yes
	Ngunja	No
Nachingwea	Nanjihi	No
	Kilimarondo	Yes
	Matekwe	Yes
	Majengo	No
	Nahimba	No
	Mbondo	Yes
	Kiegei A	Yes
	Kiegei B	Yes
	Namatunu	Yes
	Ngunichile	Yes
	Lipuyu	Yes
	Majonanga	No



Appendix Figure 1 Mean Annual deforestation rates of VLFRs and TFS managed forest reserves in Liwale and Nachingwea. Mean annual deforestation rates here were calculated as the forest loss (2018-2022) as a proportion of stable forest as calculated by Professor Mblinyi and Professor Zahabu. The TFS data also includes Machang'anja.



Appendix Figure 2 Mean annual deforestation rate of VLFRs with different levels of income in Liwale and Nachingwea. Mean annual deforestation rates here were calculated as the forest loss (2018-2022) as a proportion of stable forest as calculated by Professor Mblinyi and Professor Zahabu. Timber revenue was categorised as none (no income), low (< 50,000,000 TZS), medium (50,000,000 – 200,000,000 TZS) or high (> 200,000,000 TZS). Error bars show standard error of mean deforestation rates within the groups.