PANDA MITI KIBIASHARA
PRIVATE FORESTRY PROGRAMME

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FINAL PLANTATION SURVEY

Final Report

March 2019

United Republic of Tanzania
MINISTRY OF NATURAL RESOURCES AND TOURISM
Forestry and Beekeeping

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ABBREVIATIONS

EODS	End-of-dry-season survey
FPS	Final plantation survey
KVTC	Kilombero Valley Teak Company
NFC	New Forests Company
OSP	Out-grower support programme
PFP	Private Forestry Programme
TGIS	Tree Growing Incentive Scheme

EXECUTIVE SUMMARY

This report describes the methodology and the findings of the final plantation survey (FPS) of the first phase of the Private Forestry Programme (PFP). The objective of the survey was to provide a final assessment of the status and the performance of the plantations established through the smallholder tree-planting support schemes implemented during the first phase. The survey considered the PFP's three largest support schemes: the PFP's standard Tree-Growing Incentive Scheme (TGIS) as well as two of its out-grower support programmes (OSPs), one for the Kilombero Valley Teak Company (KVTC) and one for the New Forests Company (NFC).

A total of 1,088 pre-positioned sample plots, 1,024 of which included trees, were surveyed in the field during the survey. The study area covered almost all of the villages involved in the TGIS, but only a sample of the tree planting communities under OSPs. The mean results for the central variables recorded in the study are compiled in the table below:

Support scheme	Variable	Unit or scale	Planting season			
			2014/15	2015/16	2016/17	2017/18
Standard TGIS	Stand density	trees/ha	966	858	905	983
	Survival rate	%	97%	93%	87%	80%
	Dominant height	metres	4.89	2.72	1.39	0.48
	Level of weeding	0/1/2	0.37	0.38	0.60	0.82
KVTC-OSP	Stand density	trees/ha	903	774	863	641
	Survival rate	%	100%	100%	94%	95%
	Dominant height	metres	6.90	3.70	2.67	0.98
	Level of weeding	0/1/2	1.13	1.31	1.74	1.41
NFC-OSP	Stand density	trees/ha	-	1,068	1,094	930
	Survival rate	%	-	100%	98%	81%
	Dominant height	metres	-	3.59	1.31	0.39
	Level of weeding	0/1/2	-	0.89	0.81	0.62

Note: Note: The level of weeding comprises the combined results of both circle and slash weeding.

The performances of the established plantations varied greatly from woodlot to woodlot but were largely satisfactory.

While the growth in height did not meet the specific targets of Phase 1, the figures were nonetheless good.

The survival rates of most one-year-old plantations were acceptable (though those of the KVTC-OSP were excellent), and the survival rates of older plantations were markedly better. The timing of the mortality observed on older plantations, however, cannot be disaggregated among different seasons, making it hard to account for these survival rates.

Stand densities (including both live and dead trees) were slightly lower than expected, given the initial planting density of 1,111 trees/ha promoted by the PFP. When looked at in conjunction with survival rates, this implies that the densities of live trees are somewhat on the low side.

The average level of weeding, including both circle and slash weeding, was on the low side in the TGIS and in the NFC-OSP, but not in the KVTC-OSP, which has mandatory weeding built into its support model. A comparison of the present weeding levels with those of a survey conducted two years earlier showed some improvement, possibly because the PFP scaled up its pilot for a cash-for-weeding support mechanism.

Previous PFP studies found that there was a positive correlation between the level of weeding and plantation performance as measured in terms of growth in height and tree survival rates. This study found similar results. The connection between the level of weeding and plantation performance was particularly strong in juvenile eucalyptus woodlots.

1. INTRODUCTION

1.1 Background

The Private Forestry Programme (PFP) is a bilateral development programme implemented by the governments of Tanzania and Finland. Its aim is to increase rural income in the Southern Highlands and Kilombero Valley of Tanzania by strengthening smallholder commercial forestry and wood-processing industries. Phase 1 of the programme started in January 2014.

Specific interventions carried out during Phase 1 included preparing village land-use plans for selected communities and helping the smallholder tree growers in these communities to form well-governed tree growers' associations and to establish high-quality plantations.

In terms of the number of participants and the area planted, the majority of the PFP's support for smallholder tree planting was delivered through three different support schemes, presented below.

In terms resource usage and total planting area, most of the project's support was delivered through the programme's standard Tree-Growing Incentive Scheme (TGIS), which was updated twice during Phase 1. In all three versions of the TGIS, high-quality tree seedlings were delivered free of cost (up to a certain limit) to those members of the beneficiary communities who fulfilled certain criteria. Under TGIS, plantations were established during four planting seasons.

Phase 1 of the PFP also supported the out-grower support programmes (OSPs) of two forest companies, Kilombero Valley Teak Company (KVTC) and New Forests Company (NFC). While these OSPs, like TGIS, were designed to support smallholder tree growers in establishing plantations, they were different from each other and from the TGIS. The KVTC-OSP was implemented before the PFP was even established, but the PFP supported its expansion over four planting seasons. The NFC-OSP, in contrast, was established as a joint intervention by NFC and PFP and received support from the PFP during three planting seasons.

Each supported plantation owner planted either selected species of pine, selected species of eucalyptus, or teak (*Tectona grandis*).

Table 1 shows the active planting seasons and the areas planted under the TGIS, KVTC-OSP and NFC-OSP, while Table 2 compares various components of these schemes.

Table 1 Active seasons and areas planted under the main tree-planting support schemes implemented by the PFP during Phase 1

Support scheme	Active seasons				Area planted (ha)			
	14/15	15/16	16/17	17/18	Pine	Euca	Teak	Total
Standard TGIS	x	x	x	x	6,660	1,755	214	8,629
KVTC-OSP	x	x	x	x	-	-	1,069	1,069
NFC-OSP		x	x	x	1,097	255	-	1,352

Note: The district forest reserves planted in season 2017/18 are counted under the standard TGIS herein.

During Phase I the PFP also supported several smaller tree-planting schemes, each with a special focus. These included demonstration plots, seed orchards and plantations for vulnerable groups. More information on all of the support schemes implemented during Phase 1 is included in the periodic progress reports of the PFP, all of which are available through the programme website.[1]

For simplicity's sake, this report refers to plantations established in 2017/18 as one-year-old plantations, those established in 2016/17 as two-year-old, and so forth. In actual fact, at the time of the measurements described in this report (October-December 2018) the plantations fell some months short of the stated ages.

[1] www.privateforestry.or.tz/en/resources

Table 2 Components of the main tree-planting support schemes implemented by the PFP during Phase 1

Category	Description of the support provided to beneficiaries	Support scheme		
		Standard TGIS[a]	KVTC-OSP	NFC-OSP
Capacity building	Village land use plan preparation	x		
	Assistance in the establishment and official registration of tree growers' associations or out-grower groups	x		x
	Training in administration	x		x
	Training in silviculture	x		x
Technical support	Extension support person made available	x	x	x
In-kind support	Provision of herbicides		x	
	Provision of fertilisers		x	x
	Free distribution of improved seedlings for planting	(x)[b]	x[c]	x
	Free distribution of improved seedlings for blanking upon need	x	x	x
	Fire-fighting equipment delivered	x		x
Support for labour costs	Tree growers paid full standard unit rates weeding their 1–2 year- old woodlots up to the PFP's technical standard (*pilot of the TGIS cash incentive scheme*)	x		
	Tree growers paid 50% of standard unit rates for conducting silvicultural activities on their woodlots as called for in the management regime		x	
End product market	Guaranteed market provided for the end product (assuming quality standards met)		x	x
	Right reserved by the company to 25% of the end product and the first right of refusal to the remaining 75%		x	

[a] *The PFP TGIS after the latest revision, which was implemented during the FY 2017/18*
[b] *Progressive model includes free seedlings for each beneficiary to plant for up to 0.8 ha*
[c] *Maximum limit of seedlings for each beneficiary to plant for up to 50 ha*

1.2 Rationale and scope of the survey

As Phase 1 of the PFP approached completion, a final plantation survey (FPS) was conducted in late 2018 to assess the outcomes of the support delivered for the establishment of smallholder plantations. This survey would enable further assessment of the success of the applied support schemes and carrying out possible improvements in any future support delivery. This final survey was also designed to measure data for specific indicators included in the programme monitoring framework.

The three main support schemes described above were included in the scope of the survey. The afforestation of district forest reserves undertaken in 2017/18, which has often been treated as a support scheme of its own was included under the TGIS in this survey and report.

The last major survey of PFP-supported plantations was the end-of-dry-season survey (EODS) conducted between December 2016 and January 2017. It covered plantations established with PFP support during the first two planting seasons of Phase 1. Where possible, the FPS replicated the measurements done in the EODS.

1.3 Objective of the survey

The objective of the survey was to assess the status and the performance of the woodlots established under the three main tree-planting support schemes implemented by the PFP during Phase 1.

2. METHODOLOGY

2.1 Sampling

2.1.1 Selection of villages

The experience from Phase 1 shows that individual villages, even neighbouring ones, vary greatly in terms of the performances and the outcomes of the plantation forestry and related activities that they implement. To capture these differences and consider as many Phase 1 beneficiary communities as possible, the survey team decided to investigate a few sample plots in each of many villages rather than many sample plots in each of few villages. It set a target to cover all the villages in which the PFP had implemented TGIS to establish plantations.

In addition, it surveyed six of the 16 villages in Kilolo District involved in NFC-OSP in or before the 2017/18 planting season. These villages included Barabara mbili, Kidabaga, Kising'a, Makungu, Ng'ang'ange and Ukwega. Three of them were among the first four villages where NFC-OSP was originally started, in 2015/16.

Sampling for the KVTC-OSP did not involve villages as this scheme does not use the village as its unit of operation. Instead, the KVTC-OSP woodlots established during the PFP support were divided into four clusters based on their spatial distribution: two clusters were located in Kilombero District and two in Ulanga District. Sampling was conducted within these clusters.

2.1.2 Sample sizes

In consideration of the time and the resources available, the survey team decided to set a target of 1,000 woodlots.

In each TGIS village the sample size was 15% of the total PFP-supported woodlots but two limitations were also imposed:

- Minimum number of sample plots per village: 5
- Maximum number of sample plots per village: 20

In addition, the total number of sample plots for each village was allocated across the four planting seasons on a pro rata basis. The final sample was randomly selected within the woodlots of these strata.

The target for each NFC-OSP village was 10 woodlots. The proportional sample size of woodlots from the first NFC-OSP planting season (2015/16) was doubled in order to secure enough observations, but the rest of the sample plots were allocated across the woodlots from 2016/17 and 2017/18 on a pro rata basis. The final sample was randomly selected within the woodlots of these strata.

KVTC-OSP sampling applied a total indicative target of 100 woodlots manually distributed across four planting seasons as, from the perspective of data analysis, distributing them on a pro rata basis would have resulted in overly high share of woodlots established in 2016/17. The resulting samples were then distributed across the four clusters mentioned above on a pro rata basis and the final samples were randomly selected among the woodlots of the resultant strata.

The woodlots actually surveyed deviated slightly from the theoretically selected sample due to a few practical limitations encountered in the field. The most typical reason for selecting an alternative was that the sample woodlot was too far away and too difficult to access within the given time. The substituted samples were, for the most part, woodlots within the same village and, if possible, woodlots planted during the same season as the original sample. The final realised sample is presented in Table 6.

2.1.3 Sample plot design

Multiple variables included in the survey required that sample plots were measured. A circular sample plot with a radius of 7.57 m was chosen. A sample plot with this size would hold 20 trees as long as the PFP's recommended planting density of 3 x 3 m was used.

Sample plots were positioned on the selected woodlots in one of the following two ways, depending on the year in which the woodlot was established:

– For each woodlot established in the planting seasons of 2016/17 and 2017/18, the sample plots were located in the calculated centroid of the woodlot

– For each woodlot established in the planting seasons of 2014/15 and 2015/16, the sample plot was located using the sample plot centre coordinates recorded in the EODS of 2016/17

Sample plots of compensatory woodlots selected in the field on an ad-hoc basis presented a special case. They were placed randomly by the field team around the central area of the woodlot.

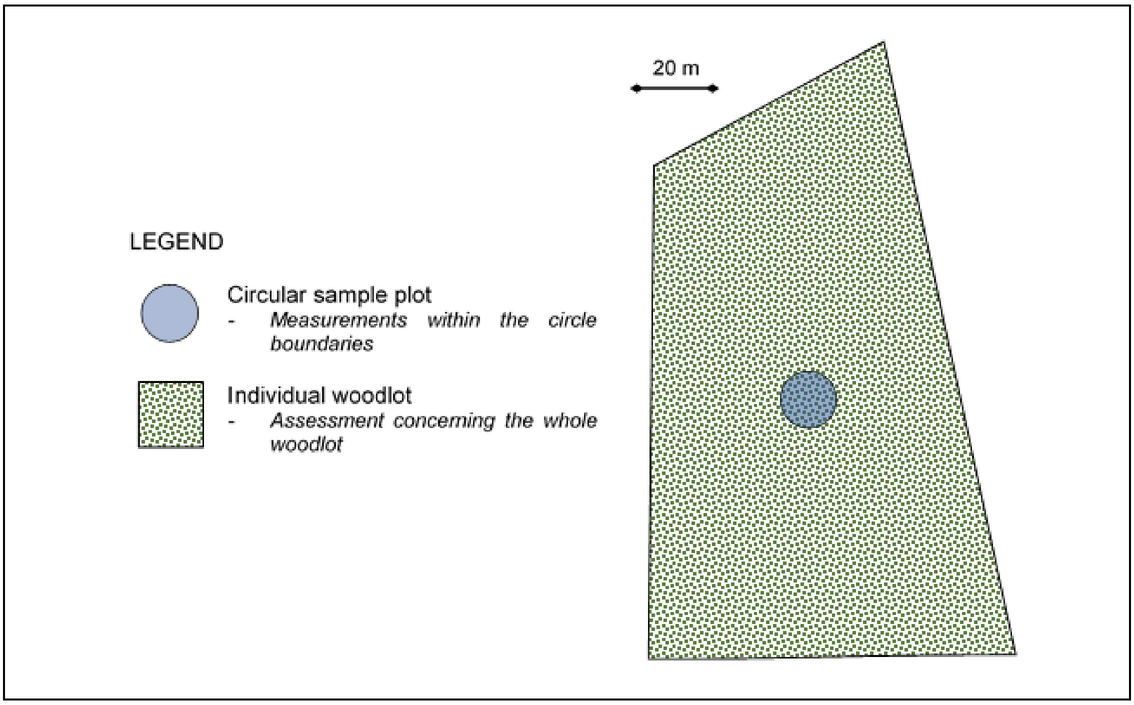
2.2 Variables recorded in the survey

Table 3 lists the variables recorded for each sampled woodlot. Depending of the variable involved, either the whole woodlot was assessed or the sample plot was used to derive a representative measurement. The set-up of the survey plot is illustrated in Figure 1.

Table 3 Variables recorded for each sampled woodlot

No.	Variable	Scope of determination
1	Year of woodlot establishment	Whole woodlot
2	Tree species group	Whole woodlot
3	GPS coordinates of the centre of the sample plot	Sample plot
4	Number of live trees	Sample plot
5	Number of dead trees	Sample plot
6	Height of the two tallest trees in the sample plot	Sample plot
7	Main cause of seedling death *(if applicable)*	Whole woodlot
8	Level of circular weeding	Whole woodlot
9	Level of slash weeding	Whole woodlot
10	Quality of pruning *(if applicable)*	Whole woodlot
11	Woodlot health	Whole woodlot
12	Woodlot accessibility	Whole woodlot

Figure 1 Survey set-up of a woodlot



Heights of the two tallest trees in the sample plot were recorded in order to estimate the dominant height of the woodlot.

The variables that were assessed subjectively by the surveyors instead of being measured were scored as presented in Table 4.

Table 4 Scoring of variables requiring assessment by a surveyor

Variable	Score	Label	Description
Weeding (assessed individually for circle and slash weeding)	0	No weeding	No sign of weeding done in the woodlot
	1	Some weeding	Some weeding activities done, but not up to the standard required by the TGIS cash support incentive
	2	Approved weeding	Weeding activities done up to the standard required by the TGIS cash support incentive
Quality of pruning	1	Good	Branches cut cleanly along the surface of the stem and no damage done to the bark of the tree
	2	Mediocre	Features from both the good and the poor pruning quality categories
	3	Poor	Significant stumps left across the pruned stems and/or notable damage done to the bark
Woodlot health	1	Good	No visible, or only minor health issues that are not expected to cause a notable reduction in timber yield
	2	Mediocre	Visible health issues such as yellow or yellowish leaves and dead or dying trees which will likely reduce timber yield
	3	Poor	Major health issues and a considerable share of dead or dying trees, which are expected to cause a significant reduction in timber yield
Woodlot accessibility	1	Easy	Can use motorised transportation to get close to the woodlot
	2	Medium	Requires some time and energy to access the woodlot due to either its distance from a road head or to the condition of its terrain, or both
	3	Hard	Requires so much time and energy to access the woodlot that standard management activities may be disincentivised

The level of weeding was assessed using the same methodology the PFP used in 2016/17 and 2017/18 to verify which beneficiaries should get TGIS cash support for weeding. The period in which the survey was conducted, October to December, is the late dry season in most of the PFP's area of operation and was thereby not the optimal time to assess the level of weeding activities, which are meant to be carried out mainly during rainy season. That said, in earlier field surveys, the PFP has established that in most cases the level of weeding could be reasonably well assessed during the dry season as well.

The weeding scores obtained by this survey were compared to the weeding scores recorded two years earlier during the EODS of 2016/17. It was not possible to compare the scores directly, however, as they used different scoring systems. Instead, the results from the EODS 2016/17 were calibrated to match the updated system applied in this survey by combining the two "approved" categories of the EODS 2016/17 (scored 2 and 3) into a single category (scored 2), as shown in Table 5.

Table 5 Weeding scores used in the FPS matched with those used by the EODS of 2016/17

Weeding scores applied in FPS		Weeding scores applied in EODS 2016/17	
Score	Label	Score	Label
0	No weeding	0	No weeding done
1	Some weeding	1	Some weeding done, but not acceptably
2	Approved weeding	2	Weeding activities done acceptably
		3	Weeding activities done completely

2.3 Survey tools

The survey utilised the smartphone application ODK Collect to record the collected data. External GPS units were used with the smartphones to improve the accuracy of the spatial data.

Tree height was mainly determined using measurement poles. In the best-growing woodlots established in 2014/15 and 2015/16, hypsometers were used instead.

Sample plot boundaries were determined using ropes cut to the length of the radius (7.57 m) and GPS units (both stand-alone units and smartphone-external unit combinations) were used to navigate the sample plots.

While conducting the EODS of 2016/17, the survey team buried metal bars underground to mark the centres of the sample plots in most of the surveyed 2015/16 woodlots. The FPS piloted the use of metal detectors to detect these bars and thereby place the centres of the new sample plots in exactly the same place. This approach was not feasible, however, so it was abandoned. See section 4.3 for more information about the metal bars.

2.4 Timing of the survey

The field work for the survey of TGIS and NFC-OSP plantations was carried out during October and November 2018, while that for the KVTC-OSP plantations was carried out in December 2018.

3. RESULTS

3.1 Number of woodlots surveyed

A total of 1,088 sample plots were surveyed: 943 under the TGIS, 85 under the KVTC-OSP and 60 under the NFC-OSP. The numbers of surveyed sample plots disaggregated by support scheme, species group and planting season are shown in Table 6.

Sample plots were measured in 61 of the total of 65 villages that established plantations through TGIS. Summary tables for the results by village are included as annexes to this report though sample sizes should be considered prior to drawing strong conclusions about village-level results.

Table 6 Number of sample plots surveyed by support scheme, species group and planting season

Support scheme	Species group	No. of surveyed sample plots						
		Non-empty plots, by season					Empty plots	Grand total
		2014/15	2015/16	2016/17	2017/18	Sub-total		
Standard TGIS	Pine	49	71	295	298	713	15	728
	Eucalyptus	17	21	45	72	155	15	170
	Teak	-	-	-	30	30	15	45
	Overall	66	93	339	400	898	45	943
KVTC-OSP	Teak	16	16	30	11	73	12	85
	Overall	16	16	30	11	73	12	85
NFC-OSP	Pine	-	9	26	16	51	5	56
	Eucalyptus	-	-	1	1	2	2	4
	Overall	-	9	27	17	53	7	60
Grand total		82	118	396	428	1,024	64	1,088

Note: Non-empty plots include sample plots with at least one live or dead tree present. The species data of woodlots which were completely empty is based on information available before the survey.

A total of 60 sample plots were found to include no trees, neither live nor dead. TGIS woodlots meant to be planted with teak had the highest proportion of empty woodlots, one third.

Empty sample plots fell into two categories, but these were not systematically distinguished during the survey. In the first category, sample plots fell on empty woodlots. These woodlots either had lost all their trees or had not been planted at all (despite there being a record of plantation in the database). In the second category, sample plots fell on woodlots that did have trees, but not in the sample plot area. The latter category presented a problem for analysis since a woodlot was confirmed to exist but no performance data for its trees could be obtained.

To simplify the presentation and analysis of the results that follows, all empty sample plots, both those on empty and those on planted woodlots, were excluded. The two eucalyptus sample plots planted with trees under the NFC-OSP were also excluded since any conclusions based on them would not be representative.

3.2 Stand densities and the survival rates of trees

3.2.1 Stand densities and survival rates in general

The PFP instructed TGIS beneficiaries to plant seedlings at 3 x 3 m intervals, which corresponds to a stand density (stocking) of 1,111 trees/ha. The same spacing was recommended to beneficiaries of the KVTC and NFC OSPs.

Since the figures on stand density reported below include both live and dead trees, they should be interpreted with their respective tree survival rates in mind. The mean stand density and survival rates observed in the survey are summarised in Table 7 and Table 8 respectively.

The mean (and median) stand densities fell below the targeted figure of 1,111 trees/ha. With plantations older than one year of age, lower than targeted densities are partially explained by tree mortality as, over time, all traces of dead trees disappear and the fact that they were planted will not be accounted for in the stocking figures which later surveys record. As less resilient species, eucalyptus plantations suffered higher losses of stand density over time as compared to pine plantations (Figure 2).

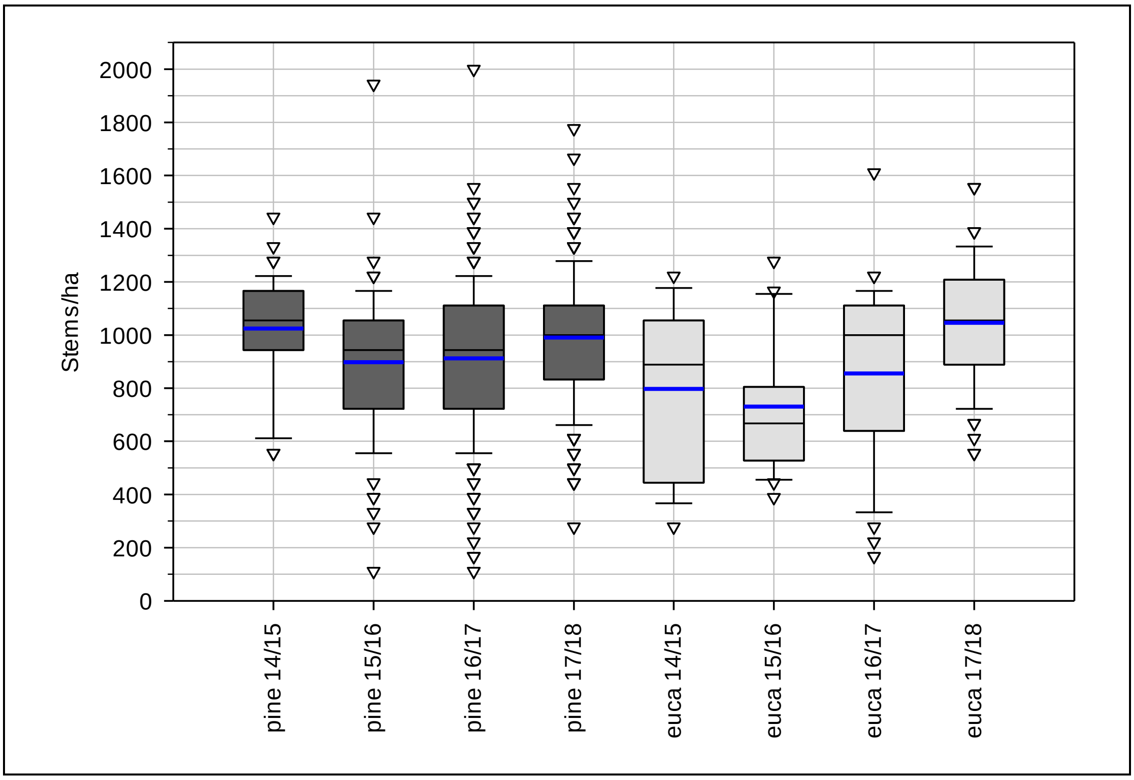
Table 7 Mean stand density by support scheme, species group and planting season

Support scheme	Species group	Stand density (trees/ha)			
		2014/15	2015/16	2016/17	2017/18
Standard TGIS	Pine	1,025	902	911	991
	Eucalyptus	797	733	851	1,046
	Teak	-	-	-	754
	Overall	966	865	903	983
KVTC-OSP	Teak	903	774	863	641
NFC-OSP	Pine	-	1,068	1,094	930

Table 8 Mean survival rate by support scheme, species group and planting season

Support scheme	Species group	Survival-%			
		2014/15	2015/16	2016/17	2017/18
Standard TGIS	Pine	96%	92%	89%	80%
	Eucalyptus	98%	96%	79%	86%
	Teak	-	-	-	67%
	Overall	97%	93%	88%	80%
KVTC-OSP	Teak	100%	100%	94%	95%
NFC-OSP	Pine	-	100%	98%	81%

Figure 2 Distribution of stand densities for TGIS pine (left) and eucalyptus (right) plantations with different year of establishment

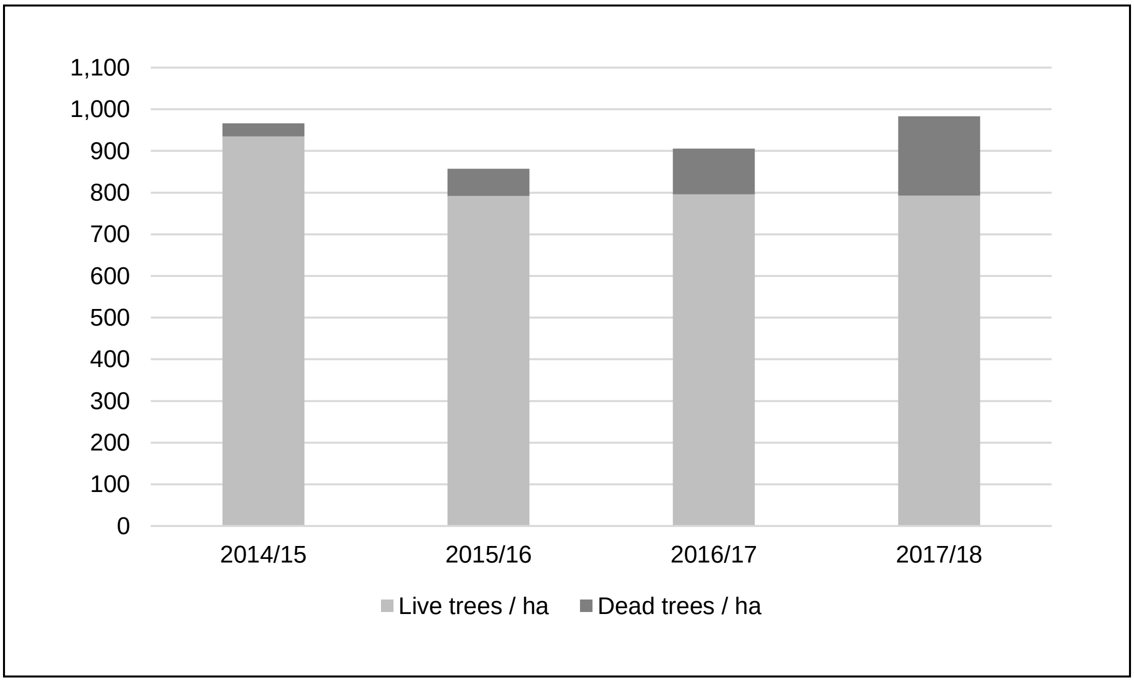


Note: The boxes represent observations between the 25th and 75th percentiles, and the whiskers represent observations between the 10th and 90th percentiles. Additional bars show medians (black bars) and arithmetic means (blue bars).

The NFC-OSP plantations from 2015/16 and 2016/17 stand out with their good stocking and survival figures, which may be attributable to well-conducted blanking efforts. The same applies to TGIS pine woodlots planted in 2014/15. Besides successful blanking, the high figures may be due to the fact that only a moderate area was targeted for planting that season. TGIS teak planting, in contrast, had poor stocking figures and poor survival rates. The lowness of the figures is due to several reasons, including widespread wildfires, poor site preparation and planting, and poor woodlot management. The final result, however, is expected to be better as new growth emerges as coppices from teak stumps that were categorised as dead during the survey.

The results generally show that the most significant tree mortality occurs during the first two years after planting, as expected, and that the rate is especially high during the first year. When plantations grow older, the effect of this early mortality is reflected in lower stand densities. Figure 3 illustrates this phenomenon by disaggregating the total stocking of TGIS plantations into live and dead trees. Notably, the planting season of 2014/15 stands out for its high total stocking though the ratio between live and dead trees over the four age categories follows the general pattern: the most trees die in the youngest plantations.

Figure 3 Mean stand density (trees/ha) disaggregated by live and dead trees of all species on TGIS woodlots by planting season



A comparison of the mean stockings of live trees on plantations found by the EODS of 2016/17 and this survey reveals that no additional trees died in the two years between the two surveys (Table 9). In fact, the mean stockings seem to have marginally increased between the surveys, an increase which is likely due to sampling error.

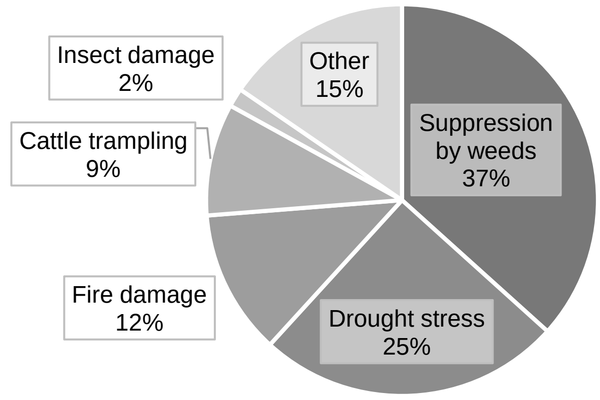
Table 9 Comparison between results for live tree stocking on TGIS plantations in EODS 2016/17 and FPS

Planting season	EODS 2016/17			FPS	Difference in observed stocking of live trees (trees/ha)
	Total stand density (trees/ha)	Survival-%	Stocking of live trees (trees/ha)	Stocking of live trees (trees/ha)	
2014/15	1,041	87.7%	913	937	+24
2015/16	1,078	74.1%	799	798	+1

3.2.2 Assessed causes of mortality

A total of 496 of the measured 1,024 sample plots (48%) included dead trees. The likely main cause of mortality was assessed for 259 of them. The most common reason for mortality was suppression by weeds, followed by drought stress, fire damage and cattle trampling (Figure 4).

Figure 4 Distribution of assessed causes of tree mortality



3.3 Plantation height

Table 10 presents the observed mean dominant height by species group, planting season and support scheme. NFC-OSP pine woodlots planted in 2015/16 had notably higher growth rates than the respective average TGIS plantations, but this might have been affected by the limited sample size (n=9) of the NFC-OSP pine woodlots of that season.

Figure 5 shows the distribution of the observed dominant heights within TGIS plantations of pine and eucalyptus. The results omit four sample plots in which both of the measured trees (the two tallest) were reported as over 12 m tall because these results could not be verified.

Table 10 Mean dominant height by support scheme, species group and planting season

Support scheme	Species group	Mean dominant height (m)			
		2014/15	2015/16	2016/17	2017/18
Standard TGIS	Pine	4.37	2.29	1.41	0.49
	Eucalyptus	6.60	4.35	1.32	0.53
	Teak	-	-	-	0.19
KVTC-OSP	Teak	6.90	3.70	2.67	0.98
NFC-OSP	Pine	-	3.59	1.31	0.39

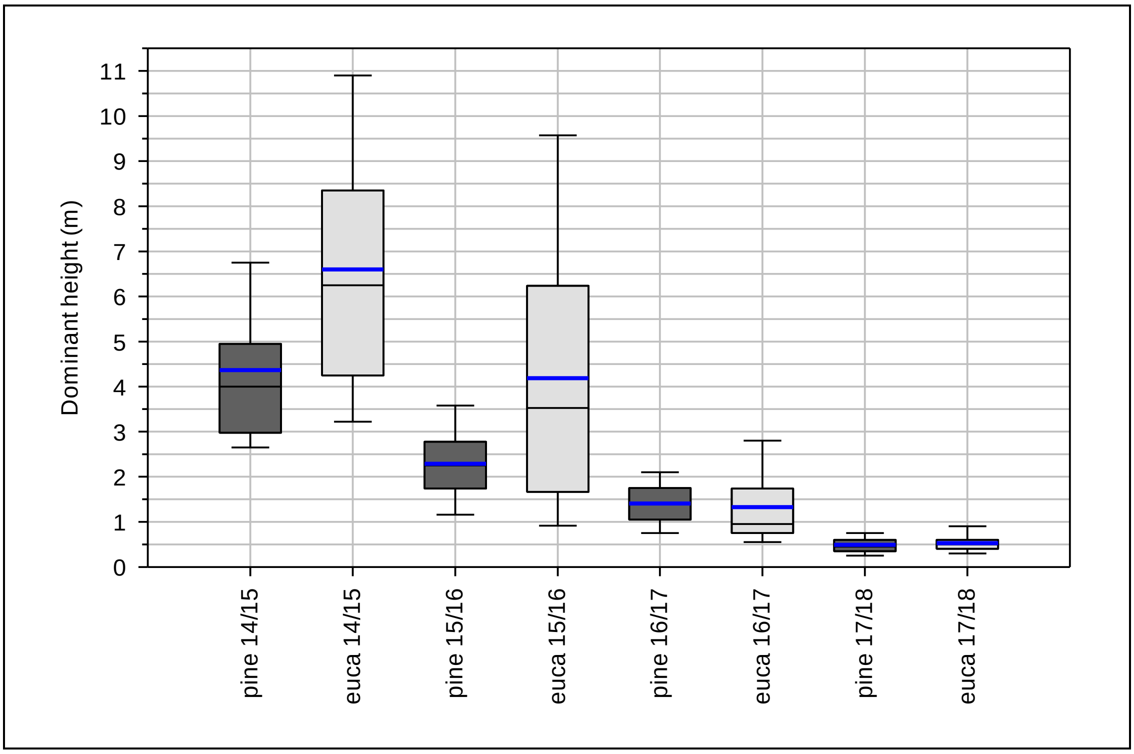
The results show that average height growth rates of pine and eucalyptus trees is limited in the first year after planting but that it increases considerably from the second year onwards. Eucalyptus trees, in particular, have the potential for rapid height growth (Figure 5).

The rate of height growth in TGIS pine plantations was included as one of the indicators in the PFP's monitoring framework to measure programme performance. The set target of one metre of growth per year during the first three years after planting was not achieved except on some individual woodlots. One reason the target was not met, however, is that the plantations were not fully one, two or three years of age at the time of measurement. In any case, as the end of the fourth year approached, half of the TGIS pine plantations had reached a dominant height of four metres or above (Figure 5).

The height growth rates for one- and two-year-old TGIS plantations that this FPS found were relatively similar to those recorded by the EODS in 2016/17.

NFC-OSP pine woodlots planted in 2015/16 had notably higher growth rates than the respective average TGIS plantations, but this might have been affected by the limited sample size (n=9) of the NFC-OSP pine woodlots of that season.

Figure 5 **Distribution of the dominant heights of TGIS pine and eucalyptus plantations by planting season**



Note: The boxes represent observations between the 25th and 75th percentiles, and the whiskers represent observations between the 10th and 90th percentiles. Additional bars show medians (black bars) and arithmetic means (blue bars).

3.4 Weeding

3.4.1 Level of weeding observed in the survey

The mean scores for circle and slash weeding assessed using a three-tier classification (no weeding, some weeding, approved weeding) scored 0, 1 and 2 respectively are compiled in Table 11 and Table 12 respectively.

Table 11 **Mean circle weeding score by support scheme, species group and planting season**

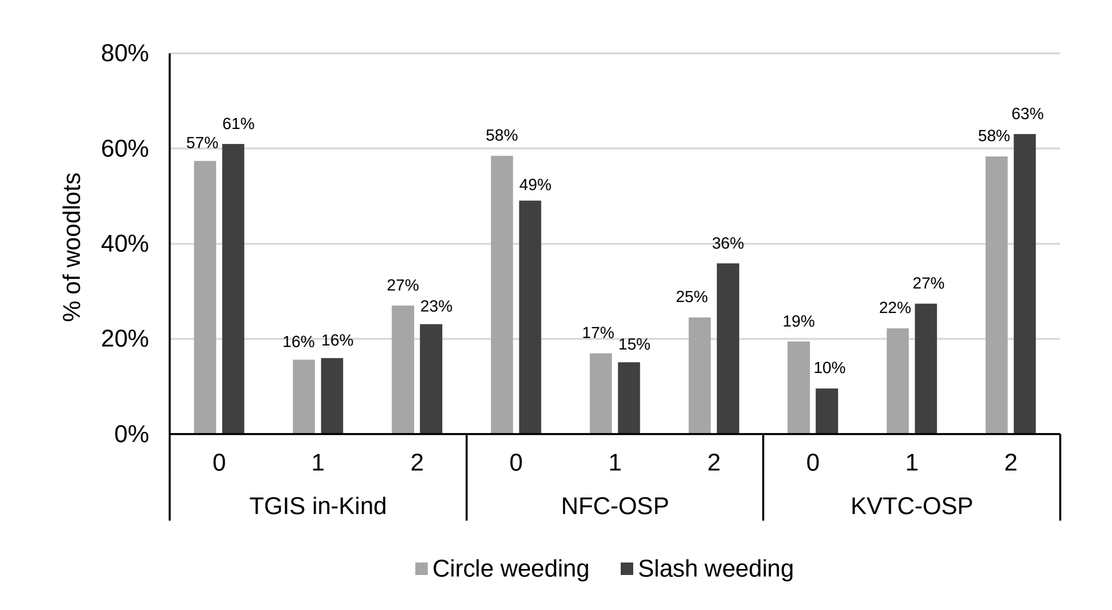
Support scheme	Species group	Mean circle weeding score (0/1/2)			
		2014/15	2015/16	2016/17	2017/18
Standard TGIS	Pine	0.37	0.47	0.58	0.87
	Eucalyptus	0.00	0.21	0.70	1.13
	Teak	-	-	-	0.80
	Overall	0.28	0.42	0.60	0.91
KVTC-OSP	Teak	1.00	1.19	1.72	1.27
NFC-OSP	Pine	-	0.67	0.77	0.56

Table 12 **Mean slash weeding score by support scheme, species group and planting season**

Support scheme	Species group	Mean slash weeding score (0/1/2)			
		2014/15	2015/16	2016/17	2017/18
Standard TGIS	Pine	0.51	0.39	0.58	0.71
	Eucalyptus	0.35	0.32	0.63	0.99
	Teak	-	-	-	0.34
	Overall	0.47	0.37	0.59	0.73
KVTC-OSP	Teak	1.13	1.44	1.77	1.55
NFC-OSP	Pine	-	1.11	0.92	0.75

The distribution of different weeding scores is presented in Figure 6. It shows that the frequencies for the two different weeding scores (one for circle weeding and one for slash weeding) are similar to each other (though not necessarily on the same individual plantations). KVTC-OSP stands out from the other two support schemes due to the high average levels of both circle and slash weeding.

Figure 6 **Distribution of assessed circle weeding and slash weeding scores of all species by support scheme**



3.4.2 Changes in the level of weeding under TGIS between 2016 and 2018

The method through which the weeding scores of the EODS 2016/17 were calibrated to match the scoring system of this survey is shown in Table 5 in section 2.2.

For the most part, the level of weeding on one- and two-year-old TGIS woodlots improved in the two years between EODS 2016/17 and this survey (Table 13). The results show that within one- and two-year-old TGIS woodlots, the average level of weeding (both circle and slash) had improved on i) all eucalyptus woodlots and ii) on all one-year-old woodlots. This improvement is encouraging in that sense that tree growth and survival rates within both groups are especially sensitive to the level of weeding, as shown below in 3.4.3.

In contrast, the average level of weeding on two-year-old pine woodlots had decreased slightly since it was last measured by the EODS of 2016/17. While this result is not positive, it is not particularly alarming since two-year-old pines, on average, are less affected by the lack of weeding than one-year-old pines, as also shown below in section 3.4.3.

Table 13 **Comparison between the average level of weeding observed on one- and two-year-old TGIS woodlots during FPS and EODS of 2016/17**

Type of weeding	Species group	Mean weeding score (0/1/2)			
		One-year-old woodlots		Two-year-old woodlots	
		EODS 16/17	FPS	EODS 16/17	FPS
Circle weeding	Pine	0.51	0.87	0.66	0.58
	Eucalyptus	0.45	1.13	0.27	0.73
	Total	0.50	0.92	0.58	0.60
Slash weeding	Pine	0.39	0.71	0.72	0.58
	Eucalyptus	0.39	0.99	0.21	0.66
	Total	0.39	0.76	0.62	0.59

3.4.3 Effect of weeding on the survival and height growth of trees

The effect of weeding on survival and height growth of trees was addressed through two different comparisons, depending on the age of the surveyed woodlot:

1. The survival and the height growth of one- and two-year-old plantations (those planted in 2017/18 and 2016/17 respectively) were cross-checked with their respective weeding scores recorded by the FPS.
2. The stocking of live trees and the height growth of three- and four-year-old plantations (those planted in 2015/16 and 2014/15 respectively) were cross-checked with their respective weeding scores recorded by the EODS of 2016/17.

The reason for carrying out this cross-check was that recent weeding activities were, as expected, found to have little effect on plantations of three or four years of age in terms of survival and height growth. By the age of three, most trees had grown taller than the surrounding weeds and, as a result, were no longer greatly affected by competition. The performance of older plantations could, nevertheless, be compared with their respective weeding scores recorded by the EODS two years earlier, in 2016/17, when they were in a much more juvenile stage.

Plantations established in the planting seasons of 2016/17 and 2017/18

Recent weeding activities were found to have a considerable effect on the performances of one- and two-year-old TGIS plantations, as shown in Table 14 and Table 15. Weeding, whether it is circle or slash, results in improvements in both survival and height growth rates.

The effect of weeding on height growth rates was especially strong in the second year after the plantation of eucalyptus trees. High-standard circle or slash weeding doubled the mean dominant height of eucalyptus woodlots from the one meter height found on unweeded plantations to two metres (Table 14). In contrast, the level of weeding did not show much correlation with plantation performance on TGIS teak woodlots. However, the results for teak woodlots are not reliable because the number of observations of each weeding subcategory (no weeding, some weeding, approved weeding) is very few. The survival of TGIS teak was also significantly affected by other factors such as widespread wildfires.

Table 14 Mean survival rates of one- and two-year-old TGIS plantations by species group and FPS weeding score

Type of weeding	Weeding score recorded by the FPS	Mean survival rate in FPS (%)				
		2016/17		2017/18		
		pine	euca	pine	euca	teak
Circle weeding	0 (no weeding)	86%	72%	74%	80%	52%
	1 (some weeding)	93%	85%	85%	94%	79%
	2 (approved weeding)	95%	91%	86%	90%	80%
Slash weeding	0 (no weeding)	87%	70%	78%	80%	66%
	1 (some weeding)	91%	89%	80%	90%	93%
	2 (approved weeding)	95%	94%	86%	91%	75%

Table 15 Mean dominant height of one- and two-year-old TGIS plantations by species group and FPS weeding score

Type of weeding	Weeding score recorded by the FPS	Mean dominant height in FPS (m)				
		2016/17		2017/18		
		pine	euca	pine	euca	teak
Circle weeding	0 (no weeding)	1.32	1.04	0.46	0.45	0.19
	1 (some weeding)	1.54	1.14	0.48	0.49	0.22
	2 (approved weeding)	1.58	2.03	0.54	0.59	0.18
Slash weeding	0 (no weeding)	1.33	1.10	0.46	0.47	0.20
	1 (some weeding)	1.32	1.14	0.52	0.55	0.15
	2 (approved weeding)	1.68	2.04	0.53	0.58	0.16

The following two additional issues should be noted in relation to the interpretation of the above results:

i. High levels of circle weeding and slash weeding often, but not always, appear together. Hence, part of the observed performance improvement results from the combined effect of the two weeding activities.

ii. The effects of weeding accumulate from one growing season to the next. The good performance of a two-year-old woodlot may hence be affected by a high level of weeding done the previous year by the same active tree grower.

Plantations established in the planting seasons of 2014/15 and 2015/16

As shown above in Table 11 and Table 12, some weeding was conducted on three- and four-year-old plantations, but that level had no observable effect on the survival and height growth rates recorded. Thus, the observed survival and height growth rates of these older plantations were compared with their older weeding scores, those recorded by the EODS in 2016/17, to see what effect the weeding done during a juvenile stage had on the performances of plantations two years later.

Herein the density of live trees was used rather than the survival rate since the former is a better indicator of tree survival in older plantations. As discussed above, most tree mortality on average occurs within the first and second years after planting, and trees that die then have largely disappeared a few years afterwards. With the dead trees no longer present, the density of live trees acts as a proxy for the survival rate if the general target stand density of 1,111 trees/ha is kept in mind.

Herein density of live trees was applied instead of survival rate since it was considered as a better indicator of tree survival at older plantations. As discussed above, most of the tree mortality on average occurs during the first and second year after planting, and these dead trees have largely disappeared a few years after. With the dead trees not present, the density of live trees acts as a proxy for the survival rate, keeping in mind the general target stand density of 1,111 trees/ha.

Table 16 shows the weeding scores recorded by EODS of 2016/17 and the recent performance of the same plantations recorded by FPS. The old weeding scores of 2 and 3 were combined into a single category, 2, as is shown in Table 5.

Table 16 Densities of live trees and mean dominant heights on 2014/15 and 2016/16 TGIS plantations by weeding scores assessed by EODS of 2016/17

Type of weeding	Weeding score recorded in EODS (2016/17)	Density of live trees in FPS (trees/ha)		Mean dominant height in FPS (m)	
		2014/15	2015/16	2014/15	2015/16
Circle weeding	0 (no weeding)	899	772	5.17	2.53
	1 (some weeding)	898	760	4.62	2.54
	2 or 3 (approved weeding)	1,087	844	4.06	3.33
Slash weeding	0 (no weeding)	918	785	4.79	2.54
	1 (some weeding)	858	803	5.67	2.62
	2 or 3 (approved weeding)	1,083	759	4.19	3.69

It should be noted that results from 2014/15 were affected by a low number of observations in the category of approved weeding (n=7 and n=4 for circle weeding and slash weeding respectively). For this reason, the data was not disaggregated by species group.

The comparison produced mixed results. The average stocking of live trees on 2014/15 plantations was notably higher in FPS on those woodlots that had been weeded well by the time of EODS 2016/17 as opposed to those woodlots that had not been weeded at all. The same effect could not be seen in the 2015/16 plantations. Then again, the height growth recorded by FPS on the 2015/16 plantations correlated well with the EODS 2016/17 weeding scores. This effect, however, could not be seen in the 2014/15 plantations.

3.5 Pruning

52 of the 1,024 woodlots sampled during the survey were found to have been pruned. Of them, the majority, 36, fell under the KVTC-OSP, which carries out an intensive pruning scheme. Another 15 pruned woodlots (14 pine and 1 eucalyptus) fell under the PFP's standard TGIS, and there was one pruned pine woodlot under the NFC-OSP.

All 15 of the pruned woodlots under the TGIS were planted in 2014/15. Together they represented 23% of the total sample of 2014/15 plantations. Four of the pruned TGIS woodlots were well pruned but the other 11 were just moderately pruned. No poorly pruned woodlots were encountered. The disaggregated results on pruning under KVTC-OSP are included in Table 17.

Table 17 Prevalence and assessed quality of pruning in KVTC-OSP woodlots by planting season

	No. of woodlots				% of woodlots			
	14/15	15/16	16/17	17/18	14/15	15/16	16/17	17/18
Good quality	8	8	9	2	50%	50%	30%	18%
Mediocre quality	3	4	1	-	19%	25%	3%	-
Poor quality	-	-	-	-	-	-	-	-
Not pruned	5	4	20	9	31%	25%	67%	82%
Total	16	16	30	11	100%	100%	100%	100%

3.6 Health

The distribution of the health statuses of the assessed plantations is presented in Figure 7 for TGIS plantations and in Figure 8 for OSP plantations.

Figure 7 Distribution of the health statuses of TGIS pine (left) and eucalyptus (right) woodlots

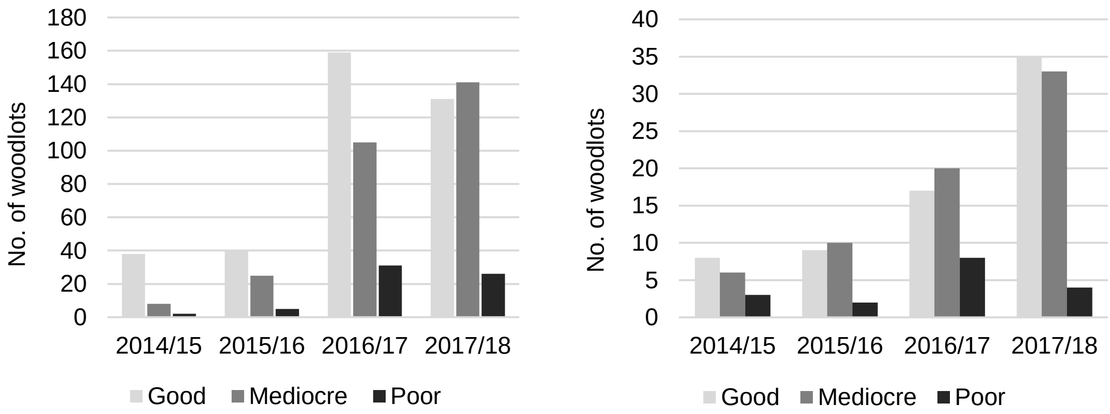
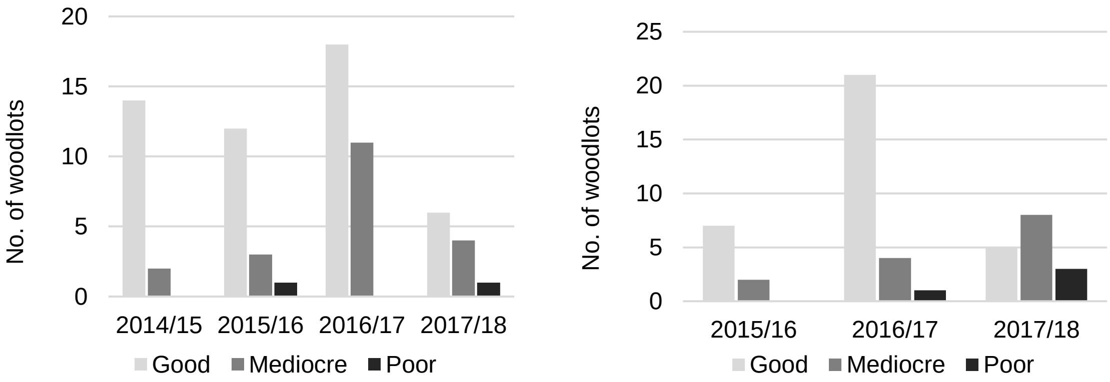


Figure 8 Distribution of the health statuses of KVTC-OSP teak woodlots (left) and NFC-OSP pine woodlots (right)



The assessed health status of the TGIS pine and eucalyptus plantations was mostly satisfactory, while there was evidence of some health issues as well. The one-year-old pine and eucalyptus plantations only demonstrated negligible differences in their assessed health, but the differences between the two species groups become evident in the plantations older than that with pine showing notably better results than eucalyptus. Both OSPs showed mostly good health results, apart from the latest planting season under NFC-OSP.

The health statuses of the assessed TGIS pine and eucalyptus plantations were mostly satisfactory, but there was evidence of some health issues. The health statuses of one-year-old pine and eucalyptus plantations showed only negligible differences, but differences in the health statuses of more mature plantations were marked, with pine plantations notably healthier than eucalyptus plantations. Most of the surveyed plantations under the two OSPs, with the exception of the NFC-OSP 2017/18 woodlots, had good health.

Though not shown graphically, 10%, 67% and 23% of TGIS teak plantations were rated as having good, mediocre and poor health respectively.

3.7 Accessibility

Table 18 summarises the accessibility of the woodlots surveyed in this study. The effort required to get the nearest road head was not considered as a part of this assessment.

Table 18 Distribution of assessed woodlot accessibility categories by support scheme

Support scheme	Season	Accessibility category		
		Easy	Medium	Hard
Standard TGIS	2014/15	55%	35%	11%
	2015/16	61%	34%	5%
	2016/17	38%	45%	17%
	2017/18	25%	62%	12%
	Overall	36%	51%	13%
KVTC-OSP	Overall	93%	7%	-
NFC-OSP	Overall	66%	34%	-

Among the TGIS woodlots, a shift in accessibility can be seen between the two first and the two last planting seasons, when the share of easily accessible plantations decreased considerably and the share of plantations with medium accessibility increased. The change coincide with a change in the TGIS model espoused by the programme from season 2016/17 onwards: it began to promote village common tree-planting zones over woodlots planted on private land.

4. CONCLUSIONS

4.1 General performance of PFP-supported plantations

While the height growths of TGIS pine plantations fell below the targets set for the first three years after planting, the overall growth rate can still be considered satisfactory given that the heights observed after the fourth year exceed 4 m. The mean height growth results for three- and four-year-old eucalyptus trees were even better than those for pine trees, though results were wide-ranging and including both highly impressive as well as underperforming height growth. The results also indicate that average height growth figures could be improved by applying a higher standard of weeding on plantations.

The PFP often used 80% as the lower limit for an acceptable survival rate on new plantations (one-and two-year-old), and, as stand-alone variables, survival rates within different species and planting seasons were by and large above this limit. With this rate in mind, and assuming a planting density of 1,111 trees/ha, the resulting density of live trees should be roughly 900 live trees per hectare by year three. However, due to lower initial stocking, the TGIS plantations, on average, did not reach this figure; instead, the average density was only around 800 live trees per hectare.

Some individual woodlots planted with different species in different planting seasons deviated from this average, whether for better or for worse. The highest densities were found on the oldest plantations, those planted in the very first planting season of the programme, and on TGIS eucalyptus woodlots planted in 2017/2018, though the latter may still experience more mortality in the second or subsequent years. While the height growth rates of three- and four-year-old eucalyptus trees are impressive, they are somewhat countered by the fact that the stocking of lives trees on eucalyptus plantations is generally lower than that of pines.

Improvements in the level of weeding have a direct effect on survival rates. The results indicate that the average stocking of live trees could be maintained as high as around 1,000 trees/ha if weeding during the first two years after plantation were of a sufficiently high standard. Since this figure already includes the effect of an early blanking campaign, it is unlikely that higher average live stockings could be achieved on a large number of smallholder plantations without adjusting the initial planting density as well.

4.2 Potential effect of a cash incentive for weeding

The results indicate that, in general, the level of weeding improved moderately in the two years between the EODS of 2017/18 and FPS. Importantly, improvements were seen in the level of weeding in the most sensitive of plantations, one-year-old woodlots and eucalyptus stands. These results strengthen the independently derived conclusion that high-standard weeding during the first two years after planting has a significant positive effect on the immediate performance of all plantations, but especially eucalyptus plantations. It is less clear, however, how strongly this effect will be echoed in the later performances of well-weeded plantations.

One measure that encouraged more beneficiaries to carry out high-standard weeding during the first two years was the expansion of the cash incentive for weeding from two pilot villages to all TGIS-supported villages. Since multiple other factors may have affected weeding practices, including the expansion of the PFP’s area of operations, it cannot, however, be established with certainty that the observed improvement resulted solely from the cash incentive. That said, the result is promising and suggests that this mechanism did have a positive effect.

4.3 Metal bars and permanent sample plots

Metal bars were buried underground at the centres of the sample plots measured by the EODS in 2016/17 with the intention of creating a pool of permanent sample plots. The same practice was carried out in the one- and-two-year-old woodlots sampled in this survey. This survey also piloted finding the previous metal bars using a metal detector. This task was found to be impractical, however, as there were extremely few hits despite the great effort put into discovering the bars.

The likely two main reasons for the difficulty experienced were that the metal bars were too small to be easily detected and that their GPS positions were not recorded with sufficient precision. A different metal detector model might have also had better results, but would not have solved the problem alone. There were also rumours that woodlot owners had removed some metal bars despite the fact that representatives of tree growers' associations had agreed to the procedure. It was not possible to take corrective action during this survey, so it is unlikely that even the recently buried metal bars will be found with ease even though their positions were recorded with greater precision in this survey than those of the EODS of 2016/17.

The following points should be considered if establishing a permanent sample plot system again becomes relevant for PFP-supported smallholder plantations, or for any corresponding intervention:

- Bury sizeable pieces of metal that are easily discoverable by a metal detector and not easily removed during woodlot management activities like circle weeding. J-shaped bars longer than 30 cm and thicker than 1 cm thick, for example, could be buried hook-end upwards. Also, prepare to use digging tools.
- Record the position of the bars with a precision GPS and use the same device when relocating them. Weed cover is often present on smallholder plantations, especially on those that are never weeded, which slows the detection process considerably. Hence it is very important to minimise the search area by being precise.
- Come to an agreement individually with each woodlot owner to establish a permanent sample plot as the sort of cooperation required for successful measurements in the future depends on ensuring that each owner understands the role of permanent sample plots and develops a sense of ownership for them.
- Select a moderate number of permanent sample plots as surveying them consumes much time and many resources.

Annex 1 Number of sample plots surveyed by village and species group

District	Village	2014/15		2015/16		2016/17		2017/18			Empty plots
		pine	euca	pine	euca	pine	euca	pine	euca	teak	
Kilolo	Lyamko					12	2	5			1
Kilombero	Kitete					7	3	1	2		
	Uchindile						10	1	4		4
Ludewa	Amani				6	4	2	6			1
	Ibumi					15		4			2
	Kitewele					15		3	2		
	Kiwe					10	2	4	1		2
	Ludende					7	7				
	Lusala	15		2		4					
	Madope			6	1	9		3			1
	Maholong'wa					6	2				1
	Masimbwe				2	4	3	1			
	Mavanga	7		5		4		4			
	Mundindi					10		8			2
	Njelela					8	1	7			
	Utilili			4		11		2			2
Madaba DC	Ifinga					8		8			4
	Lilondo							6	9		
	Maweso					14		3	3		
	Mkongotema					9	1	6	1		5
	Wino					8	6	4	2		
Makete	Igumbiro					18		2			
	Ihanga					12		8			1
	Ihela							16			
	Ilindiwe							10			
	Kijyombo					16		2			1
	Lupila					17		3			
	Makangalawe					8		10			1
	Masisiwe							10			
	Ukwama			8		5					
	Usagatikwa	2		4				6			
	Utweve					14					
Mbinga DC	Kihangi mahuka							20			
	Ndembo							8			
	Silo							9			
Mbinga TC	Lipilipili							11	8		
	Ukimo							12	8		
Mufindi	Holo					1	2				2
	Idete					3		10			
	Ipilimo					11		9			
	Kiyowela			5							
	Lugema			3		1		4			
	Lugolofu			12		6		2			
	Magunguli			5	2						
Njombe DC	Ikang'asi	3	6		3			1	2		
	Itambo		4		3				6		
	Madeke								11		
	Mfriga							6			
Njombe TC	Iboya	2	3	5	1	5	2	2			
	Kifanya	9	1	4		1	2	2			
	Mgala	2	1	2		7		3	1		
	Ngalanga	5	1	4	2	5					
	Ng'elamo	4	1	2	1						
Nyasa DC	Kigongo							6			
	Lipingo									13	3
	Litindo asili							16	5		
	Liuli									15	5
	Mapato							12	1		
	Mbanga							13	2		
	Mkali A									2	7
	Upolo							9	4		

Annex 2 Mean stand densities (trees/ha) by village and species group

District	Village	2014/15		2015/16		2016/17		2017/18		
		pine	euca	pine	euca	pine	euca	pine	euca	teak
Kilolo	Lyamko					1,125	972	1,033		
Kilombero	Kitete					666	537	1,000	889	
	Uchindile						905	1,111	1,028	
Ludewa	Amani				741	944	861	1,074		
	Ibumi					733		833		
	Kitewele					918		796	806	
	Kiwe					833	833	1,083	611	
	Ludende					881	801			
	Lusala	992		889		958				
	Madope			1,129	667	1,185		981		
	Maholong'wa					750	306			
	Masimbwe				584	820	1,241	944		
	Mavanga	1103		744		1,014		764		
	Mundindi					1,011		965		
	Njelela					1,090	389	936		
	Utilili			833		884		750		
Madaba DC	Ifinga					792		951		
	Lilondo							1,074	1,160	
	Maweso					984		1,037	1,222	
	Mkongotema					969	444	1,194	667	
	Wino					1,083	1,028	1,167	1,056	
Makete	Igumbiro					790		778		
	Ihanga					912		896		
	Ihela							1,108		
	Ilindiwe							1,039		
	Kijyombo					892		556		
	Lupila					758		667		
	Makangalawe					597		861		
	Masisiwe							1,111		
	Ukwama			875		811				
	Usagatikwa	1056		1,125				1,028		
	Utweve					1,004				
Mbinga DC	Kihangi mahuka							989		
	Ndembo							1,007		
	Silo							1,222		
Mbinga TC	Lipilipili							1,111	1,173	
	Ukimo							1,153	1,049	
Mufindi	Holo					889	1,000			
	Idete					944		1,000		
	Ipilimo					1,035		1,092		
	Kiyowela			789						
	Lugema			611		889		819		
	Lugolofu			990		981		1,000		
	Magunguli			878	750					
Njombe DC	Ikang'asi	592	778		648			500	667	
	Itambo		903		667				1,324	
	Madeke								1,040	
	Mfriga							916		
Njombe TC	Iboya	1,028	537	889	1,278	1,133	667	1,083		
	Kifanya	1,142	1,000	889		1,111	1,111	889		
	Mgala	1,000	389	361		1,016		907	1,000	
	Ngalanga	1,055	1,166	930	584	922				
	Ng'elamo	1,028	1,111	1,083	1,166					
Nyasa DC	Kigongo							1,019		
	Lipingo									714
	Litindo asili							910	733	
	Liuli									770
	Mapato							875	667	
	Mbanga							880	1,000	
	Mkali A									889
	Upolo							969	1,125	

Annex 3 Mean survival rates of trees by village and species group

District	Village	2014/15		2015/16		2016/17		2017/18		
		pine	euca	pine	euca	pine	euca	pine	euca	teak
Kilolo	Lyamko					98%	100%	76%		
Kilombero	Kitete					100%	100%	83%	100%	
	Uchindile						79%	80%	97%	
Ludewa	Amani				96%	100%	100%	77%		
	Ibumi					89%		86%		
	Kitewele					99%		83%	80%	
	Kiwe					60%	68%	31%	18%	
	Ludende					98%	91%			
	Lusala	100%		100%		94%				
	Madope			98%	100%	98%		57%		
	Maholong'wa					100%	100%			
	Masimbwe				82%	74%	89%	94%		
	Mavanga	97%		100%		93%		94%		
	Mundindi					84%		86%		
	Njelela					99%	0%	89%		
	Utilili			90%		95%		47%		
Madaba DC	Ifinga					98%		77%		
	Lilondo							81%	78%	
	Maweso					94%		81%	100%	
	Mkongotema					60%	0%	52%	33%	
	Wino					86%	72%	95%	98%	
Makete	Igumbiro					82%		71%		
	Ihanga					86%		93%		
	Ihela							96%		
	Ilindiwe							64%		
	Kijyombo					91%		67%		
	Lupila					92%		35%		
	Makangalawe					93%		70%		
	Masisiwe							83%		
	Ukwama			96%		78%				
	Usagatikwa	100%		100%				70%		
	Utweve					91%				
Mbinga DC	Kihangi mahuka							75%		
	Ndembo							51%		
	Silo							72%		
Mbinga TC	Lipilipili							79%	86%	
	Ukimo							79%	92%	
Mufindi	Holo					19%	42%			
	Idete					33%		79%		
	Ipilimo					98%		94%		
	Kiyowela			94%						
	Lugema			92%		100%		100%		
	Lugolofu			88%		75%		98%		
	Magunguli			89%	100%					
Njombe DC	Ikang'asi	100%	100%		100%			100%	95%	
	Itambo		100%		100%				89%	
	Madeke								83%	
	Mfriga							79%		
Njombe TC	Iboya	100%	100%	87%	100%	95%	84%	100%		
	Kifanya	86%	78%	75%		45%	86%	94%		
	Mgala	100%	100%	100%		98%		94%	78%	
	Ngalanga	100%	100%	100%	79%	95%				
	Ng'elamo	93%	95%	24%	71%					
Nyasa DC	Kigongo							89%		
	Lipingo									60%
	Litindo asili							88%	85%	
	Liuli									74%
	Mapato							86%	92%	
	Mbanga							92%	95%	
	Mkali A									57%
	Upolo							95%	98%	

Annex 4 Mean dominant heights (m) by village and species group

District	Village	2014/15		2015/16		2016/17		2017/18		
		pine	euca	pine	euca	pine	euca	pine	euca	teak
Kilolo	Lyamko					1.41	2.08	0.36		
Kilombero	Kitete					1.58	2.00	0.55	0.93	
	Uchindile						0.88	0.75	0.60	
Ludewa	Amani				9.13	2.04	2.30	0.52		
	Ibumi					1.25		0.54		
	Kitewele					1.60		0.88	0.50	
	Kiwe					0.89	0.70	0.30	0.40	
	Ludende					1.27	2.09			
	Lusala	5.13		1.80		1.40				
	Madope			1.57	2.00	1.62		0.52		
	Maholong'wa					1.17	1.00			
	Masimbwe				0.78	0.63	1.10	0.40		
	Mavanga	4.99		2.72		2.13		0.43		
	Mundindi					1.43		0.51		
	Njelela					1.90		0.53		
	Utilili			2.20		1.35		0.35		
Madaba DC	Ifinga					1.58		0.55		
	Lilondo							0.76	0.58	
	Maweso					1.59		0.38	1.00	
	Mkongotema					0.91	0.75	0.56	0.25	
	Wino					1.23	0.85	0.78	0.40	
Makete	Igumbiro					1.37		0.70		
	Ihanga					1.79		0.44		
	Ihela							0.42		
	Ilindiwe							0.30		
	Kijyombo					1.11		0.25		
	Lupila					1.34		0.25		
	Makangalawe					0.79		0.36		
	Masisiwe							0.41		
	Ukwama			2.76		1.05				
	Usagatikwa	2.80		3.10				0.39		
	Utweve					1.81				
Mbinga DC	Kihangi mahuka							0.37		
	Ndembo							0.20		
	Silo							0.43		
Mbinga TC	Lipilipili							0.65	0.58	
	Ukimo							0.53	0.54	
Mufindi	Holo					0.70	0.85			
	Idete					2.35		0.52		
	Ipilimo					1.48		0.62		
	Kiyowela			2.15						
	Lugema			1.83		1.65		0.40		
	Lugolofu			2.55		1.45		0.33		
	Magunguli			2.60	5.70					
Njombe DC	Ikang'asi	2.92	7.63		2.58			2.60	0.43	
	Itambo		6.44		4.23				0.27	
	Madeke								0.40	
	Mfriga							0.40		
Njombe TC	Iboya	3.03	9.74	2.19	3.15	1.40	2.10	0.45		
	Kifanya	4.19	6.60	2.53		0.40	0.85	0.63		
	Mgala	6.73	3.53	1.05		1.92		0.49	0.40	
	Ngalanga	3.71	17.50	2.06	1.73	1.15				
	Ng'elamo	3.01	2.75	0.78	1.50					
Nyasa DC	Kigongo							0.46		
	Lipingo									0.22
	Litindo asili							0.59	0.46	
	Liuli									0.18
	Mapato							0.54	0.45	
	Mbanga							0.55	0.88	
	Mkali A									0.15
	Upolo							0.51	0.64	

Annex 5 Mean circle weeding scores (0/1/2) by village and species group

District	Village	2014/15		2015/16		2016/17		2017/18		
		pine	euca	pine	euca	pine	euca	pine	euca	teak
Kilolo	Lyamko					1.42	1.00	0.80		
Kilombero	Kitete					0.00	0.33	2.00	2.00	
	Uchindile						0.90	1.00	1.25	
Ludewa	Amani				0.33	0.75	2.00	0.17		
	Ibumi					0.33		1.00		
	Kitewele					0.67		0.67	0.00	
	Kiwe					0.10	0.00	0.50	0.00	
	Ludende					0.43	1.14			
	Lusala	0.27		0.00		0.00				
	Madope			0.50	0.00	0.22		0.00		
	Maholong'wa					0.50	0.00			
	Masimbwe				0.00	0.50	0.00	0.00		
	Mavanga	0.00		0.40		1.00		0.75		
	Mundindi					1.30		1.13		
	Njelela					1.75	0.00	1.29		
	Utilili			0.25		0.64		0.00		
Madaba DC	Ifinga					0.13		0.50		
	Lilondo							2.00	1.33	
	Maweso					1.50		0.33	1.67	
	Mkongotema					0.22	0.00	1.33	0.00	
	Wino					0.75	0.50	1.00	2.00	
Makete	Igumbiro					0.22		0.00		
	Ihanga					0.00		0.25		
	Ihela							0.50		
	Ilindiwe							0.20		
	Kijyombo					0.38		0.00		
	Lupila					0.24		0.00		
	Makangalawe					0.00		1.10		
	Masisiwe							1.80		
	Ukwama			0.25		0.20				
	Usagatikwa	1.50		1.75		1.33				
	Utweve					0.57				
Mbinga DC	Kihangi mahuka							0.45		
	Ndembo							0.88		
	Silo							0.67		
Mbinga TC	Lipilipili							0.91	1.25	
	Ukimo							0.33	0.25	
Mufindi	Holo					0.00	1.50			
	Idete					1.33		1.00		
	Ipilimo					1.36		1.89		
	Kiyowela			1.00						
	Lugema			0.00		2.00		1.75		
	Lugolofu			0.17		0.50		1.00		
	Magunguli			0.00	0.00					
Njombe DC	Ikang'asi	0.00	0.00		0.00			0.00	0.00	
	Itambo		0.00		0.00				0.50	
	Madeke								2.00	
	Mfriga							0.33		
Njombe TC	Iboya	1.00	0.00	0.60	2.00	1.20	1.00	1.00		
	Kifanya	0.67	0.00	1.33		0.00	0.00	0.50		
	Mgala	0.00	0.00	0.71				0.00	0.00	
	Ngalanga	0.00	0.00	0.50	0.00	0.00				
	Ng'elamo	0.75	0.00	0.00	0.00					
Nyasa DC	Kigongo							1.00		
	Lipingo									0.54
	Litindo asili							1.25	0.40	
	Liuli									1.00
	Mapato							0.83	2.00	
	Mbanga							1.46	2.00	
	Mkali A									1.00
	Upolo							1.44	1.50	

Annex 6 Mean slash weeding scores (0/1/2) by village and species group

District	Village	2014/15		2015/16		2016/17		2017/18		
		pine	euca	pine	euca	pine	euca	pine	euca	teak
Kilolo	Lyamko					1.08	0.50	0.20		
Kilombero	Kitete					0.00	0.00	2.00	2.00	
	Uchindile						0.50	0.00	1.25	
Ludewa	Amani				0.33	1.75	1.50	0.33		
	Ibumi					0.33		1.00		
	Kitewele					0.47		0.67	0.00	
	Kiwe					0.10	0.50	1.25	0.00	
	Ludende					1.00	1.14			
	Lusala	0.60		0.00		0.00				
	Madope			0.33	0.00	0.22		0.00		
	Maholong'wa					0.67	1.00			
	Masimbwe				0.50	0.75	0.67	1.00		
	Mavanga	0.29		0.40		1.00		0.75		
	Mundindi					1.60		1.88		
	Njelela					2.00	0.00	1.43		
	Utilili			0.25		0.82		0.00		
Madaba DC	Ifinga					0.38		0.75		
	Lilondo							1.67	1.56	
	Maweso					1.14		0.33	1.67	
	Mkongotema					0.11	0.00	0.50	0.00	
	Wino					0.75	0.50	0.75	1.00	
Makete	Igumbiro					0.28		0.00		
	Ihanga					0.08		0.00		
	Ihela							0.13		
	Ilindiwe							0.30		
	Kijyombo					0.19		0.00		
	Lupila					0.12		0.00		
	Makangalawe					0.00		0.40		
	Masisiwe							1.20		
	Ukwama			0.13		0.60				
	Usagatikwa	0.00		0.00				0.50		
	Utweve					0.50				
Mbinga DC	Kihangi mahuka							0.80		
	Ndembo							0.63		
	Silo							0.89		
Mbinga TC	Lipilipili							0.45	0.25	
	Ukimo							0.33	0.25	
Mufindi	Holo					0.00	1.00			
	Idete					1.33		0.50		
	Ipilimo					0.91		1.89		
	Kiyowela			1.80						
	Lugema			0.00		2.00		1.75		
	Lugolofu			0.17		0.33		0.00		
	Magunguli			0.00	0.00					
Njombe DC	Ikang'asi	0.00	0.50		0.00			1.00	0.00	
	Itambo		0.00		0.00				2.00	
	Madeke								2.00	
	Mfriga							0.83		
Njombe TC	Iboya	0.50	0.00	0.40	1.00	0.60	1.00	1.00		
	Kifanya	0.33	0.00	0.67		0.00	0.00	0.00		
	Mgala	0.00	0.00	0.50		1.14		0.67	0.00	
	Ngalanga	0.40	1.00	0.50	0.00	0.20				
	Ng'elamo	2.00	2.00	1.50	2.00					
Nyasa DC	Kigongo							1.00		
	Lipingo									0.15
	Litindo asili							0.81	0.60	
	Liuli									0.57
	Mapato							0.33	1.00	
	Mbanga							0.92	1.50	
	Mkali A									0.00
	Upolo							0.89	1.00	

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