Restoration of Degraded Land for Food Security and Poverty Reduction in East Africa and the Sahel: Taking Successes in Land Restoration to Scale

Country Report on farmers profiles and assessment of options for land restoration based on tree plantations.

Ethiopia – 2019 Data

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Foreword

This report summarizes main findings from data analysis about land restoration using tree plantations In Ethiopia. Results we present in this report are related to farmers profiles, including socio-demographic characteristics, in addition to tree experiments implemented in different contexts, management options and study areas of Ethiopia. Conclusions about tree survival rates in relation to different contextual factors are also presented and discussed.

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Introduction

This report is elaborated in the framework of the "Restoration of degraded land for food security and poverty reduction in East Africa and the Sahel: taking successes in land restoration to scale" Project. It aims at analyzing 2018-2019 data of the mentioned project, in relation to farmers and farms profiles in addition to an evaluation of the survival rate of different tree plantation options implemented by participant farmers. Tree plantations have been suggested as an option for restoration of degraded land in the study areas. The project team collected and reported relevant and related (2019) data about the survival rate of trees planted in these experiments at the farm level. This report builds on the collected data to provide a more comprehensive overview of the best tree plantation options based on their survival rates and links this indicator to different contextual variables. The report presents a statistical analysis of the relevant data/variables collected during 2019 in Ethiopia.

Statistical analysis of farmers and farms profiles in Ethiopia

Overall Geographical distribution of the sample

Most of farmers considered in the data set are located in East Tigray zone. Farmers of this area represents 34.9% of the total sample. Farmers from Southeastern area represents 30.2% of the total sample and the remaining 18% and 16.9% of farmers were respectively located in East Harerge and East Shoa (figure 1).

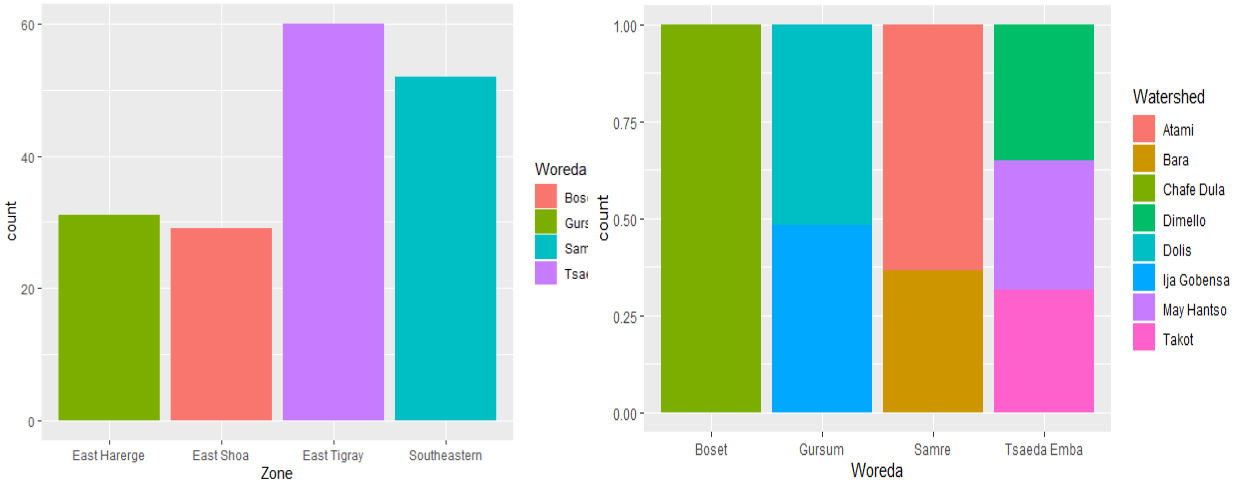

Figure 1. Location of participant farms by zone and Woreda in Ethiopia.

Figure 1 shows the distribution of farmers by Woreda (counts in the figure are reflecting percentages). Woreda, also spelled wereda, is the third level of administrative divisions in Ethiopia. They are further subdivided into several wards (kebele) which are the smallest unit of local governments in Ethiopia.

Farmers profiles

Most of farmers involved in the project in Ethiopia are male (about 76.2%), with the highest rate of male participation in East Harerge zone reaching 90.3 % of the total simple. The highest rate of female participation has been registered in East Shoa where 41.4 % of the farmers are female (Figure 2). Figure 2 provides a gender distribution of the participant farmers to the project in the different zones and watershed.

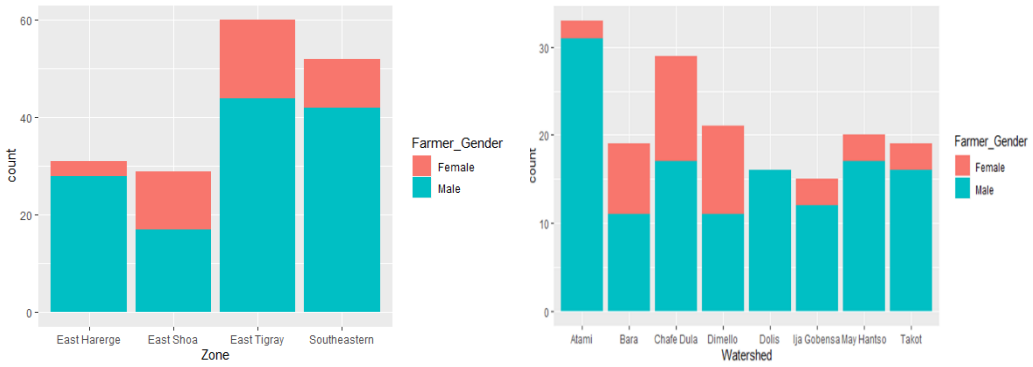

Figure 2. Gender of participating farmers to the tree plantation experiments.

the age of participants in different project sites is represented by a box plot (Figure 3). The medium age of farmers is about 53 years in Atami, 32 years in Bara, 35 years in Chafe Dula and Dolis, 45 years in Dimello, 30 years in Ija Gobensa, 49.5 in May Hantso and 56 in Takot, which is also the highest average age value. The largest range of age is observed in Atami with 60 years difference between the maximum (78 years) and the minimum (18 years) age in the area.

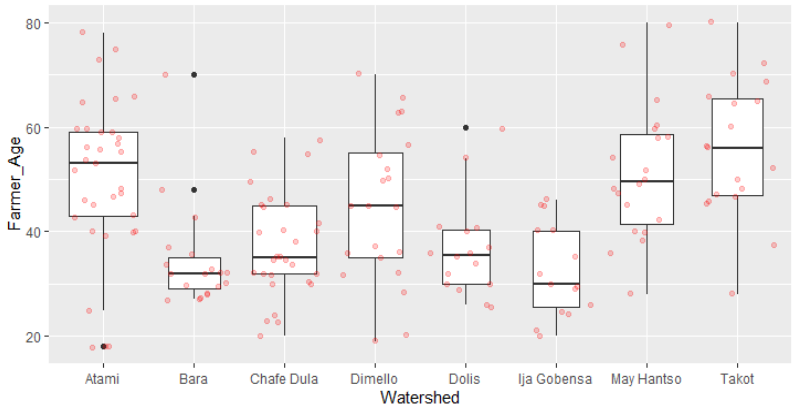

Figure 3. Distribution of farmer age by project site in Ethiopia

In all project sites female famers are younger than male farmers with a median age of female farmers equal to 35 years and a medium age of male farmers equal to 45 years. The least median of the female farmers age has been registered in Ija Gobensa which is 25 years and the highest median female farmers age has been registered in Mwala which is 45 years old. For male farmers the highest median (of 58 years) has been registered in Takot.

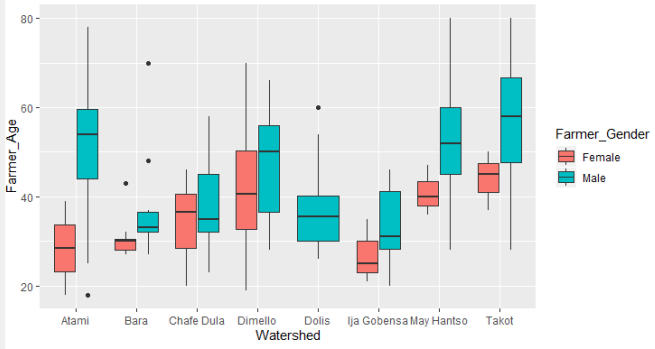

Figure 4. Age of participant farmers by watershed and gender

About 91.2% of the household heads participating to the project are male and only 8.8% of them are female. These proportions are differently distributed in the project sites (Figure5). In Atami, Dimello

and Ija Gobensa all the household heads are male. In Dimello, 31.3% of the household heads are female which is the highest rate among the different project areas/sites.

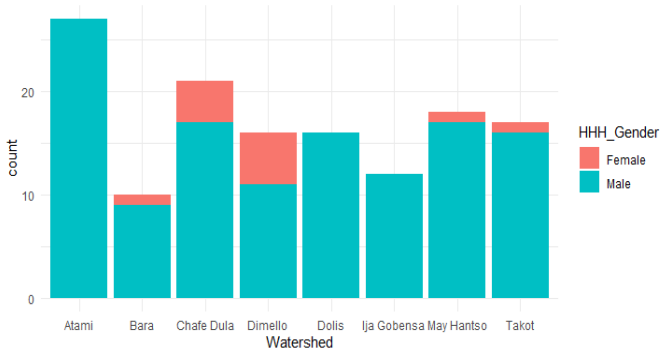

Figure 5. Gender of the household head in the different project site

Most farmers in the different counties of the project have basic education while 41.9% of them have no formal education and 45.9 % having a primary education level. The rest of farmers had different type of education like higher education which is the lowest percentage with a value of 0.6%. In East Tigray 1.7 % of the participants attended higher education. This level of education was absent in the remaining three zones of the project. East Harerge is also one of the zones characterized by "no-formal" education with about 54.8% of the participants having this level of education (Figure 6).

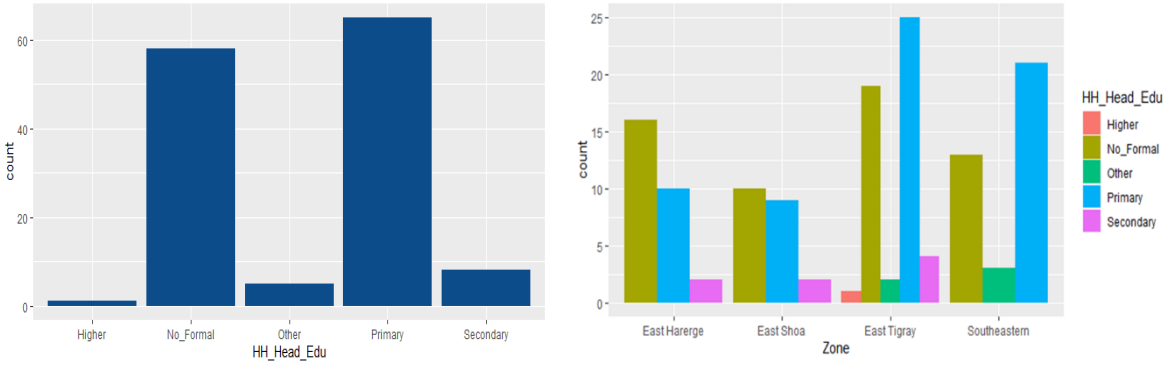

Figure 6. Education level of household heads in the different project areas.

Household population is the population enumerated in a given private household during a census. Through our survey the median of household population in all project sites were about 6 members. This value was the same in the four zones but the range of variation was not the same across zones. In East Shoa, East Tigray and Southeastern the range of household population was equal to 8 but in East Harerge the range was higher with a value of 9 persons in one household (Figure 7).

Figure 7. Household population violin plot in the different project areas.

Farms descriptions

Most of the farms (about 41.9%) in our project sites were owned through a "land use right". This type of ownership is reflected in 100% of East Shoa farms. Farms under governmental ownership constitute 33% of the total land involved in the project activities. The area of Southestern was characterized by the highest rate of "government ownership" across all project areas (Table 1).

Table 1. Land ownership by zone

Ownership	Governmental	Inheritance	Land use	Purchase	Uknonw
East Harerge	3.2%	77.4%		19.4%	
East Shoa			100 %		
East Tigray	20.0 %	8.3%	71.7%		
Southeastern	84.6 %	13.5%			1.9 %
Total	33.1%	20.9%	41.9%	3.5%	0.6 %

The average farm size in East Tigray is equal to 7.5 ha. In East Shoa this average size was higher with a value of 31.06 ha and in Southeastern and East Harerge, the average farm size was about 59.55 ha and 100.35 ha, respectively. For the distribution of farm size, East Harerge, East Shoa and East Tigray were characterized by sizes which are concentrated around 5 ha (median value). Farms sizes in Southeastern were however distributed around median value of 2 ha (Figure 8).

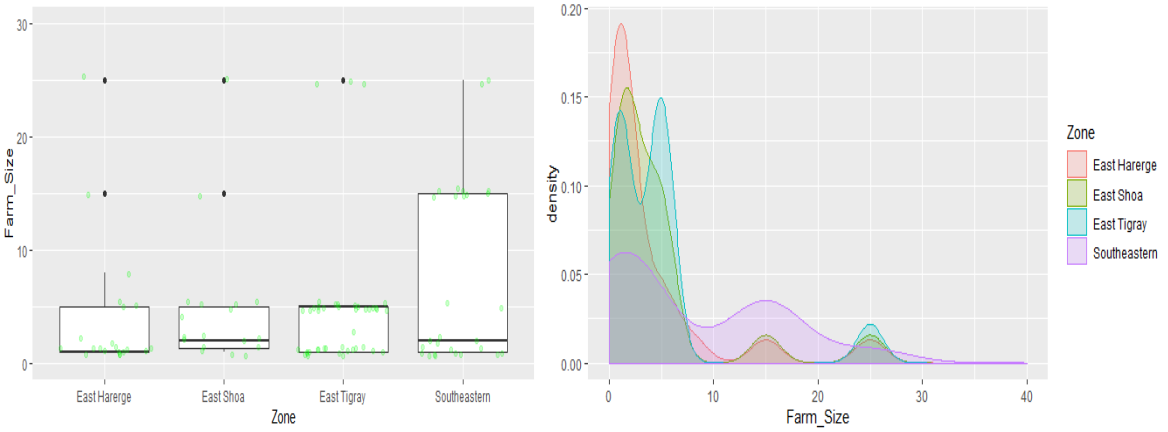

Figure 8. Distribution of farm sizes in the different study areas of the project

The share of cultivated land is a ratio (percentage) of cultivated area to the total surface of the farm. The average cultivated area was equal to 100 % in East Harerge, 97 % in East Shoa 89 % in East Tigray

and 97 % in Southeastern. This variable was distributed around a median value of 100 %. This median value was recorded for all considered areas (Figure 9).

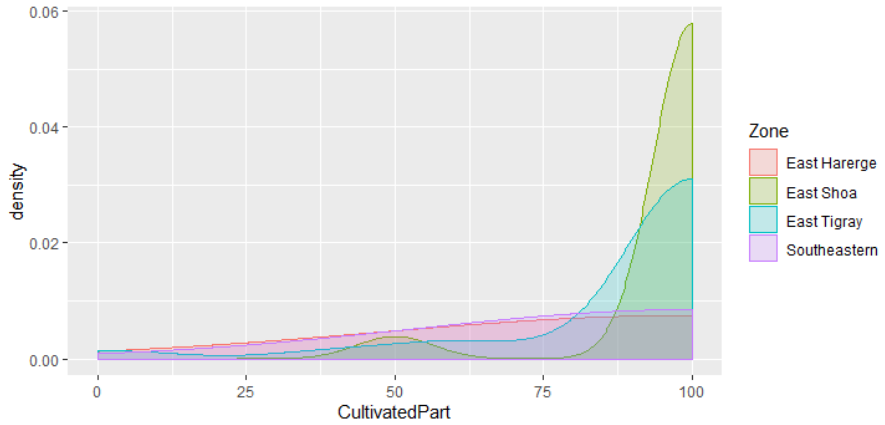

Figure 9. Share of cultivated land (percentage) density for the different project areas.

Only 0.58 % of soils has been judged of high-quality in the considered farm sample. Most of the farmers perceptions about their soils was medium (76.74 %) to low (22.6%) (Figure 11 and table 2).

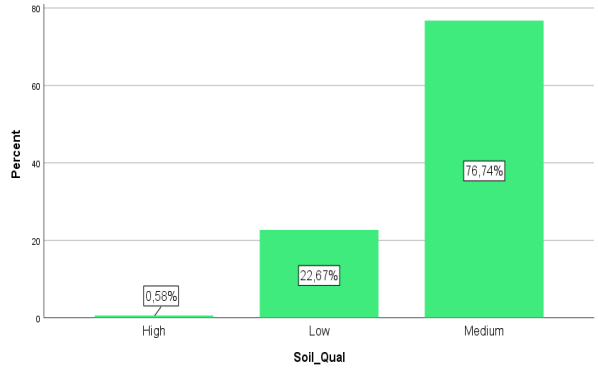

Figure 10. Farmer's perception about soil quality in the study areas

The collected data also reflects about the distance of farms to the most strategic locations such as a nearest road, Market, or even a source of water that can be used for both irrigation and domestic use. These three distances have been collected through the survey data: distance to the nearest road, distance to market, and distance to the closest water source (Table 3).

Table 2. Mean distances of farmers to key facilities in the different considered counties

County	Distance to road (Km)	Distance to market (Km)	Distance to water source (Km)
East Harerge	7.41	14.4	22.7
East Shoa	2.51	11.37	6.44
East Tigray	9.2	17.65	9.75
Southeastern	3.7	17.09	3.75

Figure 12 shows the distance to road in three counties considered by the project in Ethiopia. An ANOVA test was performed to compare across counties in terms of farms distance to market. The test was significant at 5% and showed that there is a significant difference across these countries regarding this distance. We then proceeded with a Tukey test for pairwise comparison across the four project areas (Table 3). The Tukey test showed that East Tigray is the area where farms are the furthest to main

roads compared to East Shoa and Southeastern (Table 3 and 4). all possible comparisons of counties based on distances of farmers to main roads can be found in Table 4.

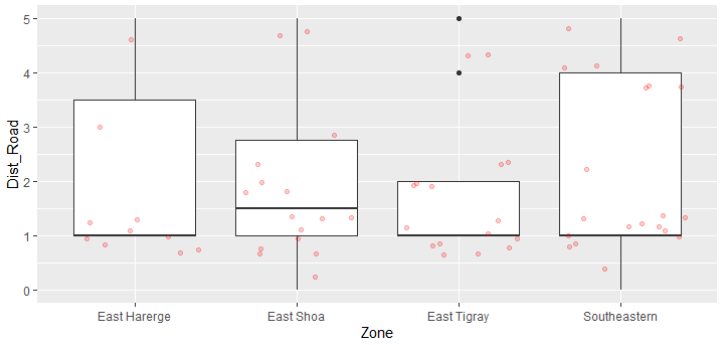

Figure 11.Distance (in km) between farms and the nearest road for the different project areas in Ethiopia.

Table 3. Results of the Tukey test for pairwise comparison of average distances to main roads

County	County	Diff	Sig.
East Harerge	East Shoa	4.9	0.203
	East Tigray	-1.8	0.826
	Southeastern	3.6	0.333
East Shoa	East Harerge	-4.9	0.203
	East Tigray	-6.7	0.012
	Southeastern	-1.2	0.948
East Tigray	East Harerge	1.8	0.826
	East Shoa	6.7	0.012
	Southeastern	5.5	0.015
Southeastern	East Harerge	-3.6	0.333
	East Shoa	1.2	0.948
	East Tigray	-5.5	0.015

Table 4 Multiple comparative table of distance to main road across different counties

Test	**Conclusion**
East Tigray Vs East Shoa	East Tigray > East Shoa
East Tigray Vs Southeastern	East Tigray > Southeastern
Other combinations	No Sig

The same type of analysis was conducted for the “farms distance to market”. Figure 13 shows the distribution of this variable across the four considered counties. We performed an ANOVA test to compare the existence of significant differences across counties in relation to this variable. The ANOVA was not significant (at 5%), which means that there is no difference across farms of different counties in terms of their distance to markets.

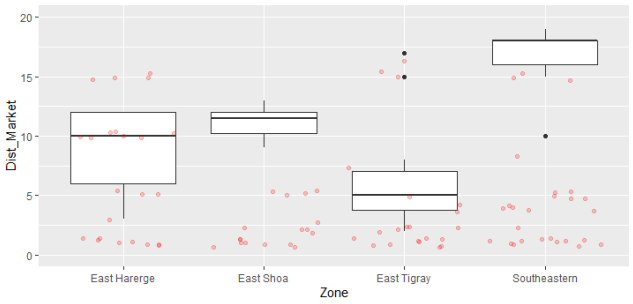

Figure 12. Distribution of distances between farms and the nearest market for the considered project areas

The same type of analysis was further conducted for the "distance to the nearest water source". Figure 14 shows the distribution of this distance for farms in the four. An ANOVA test for the difference of means didn't show any significance at 5% level, which means that all farms in the sample have similar/equal access to water sources.

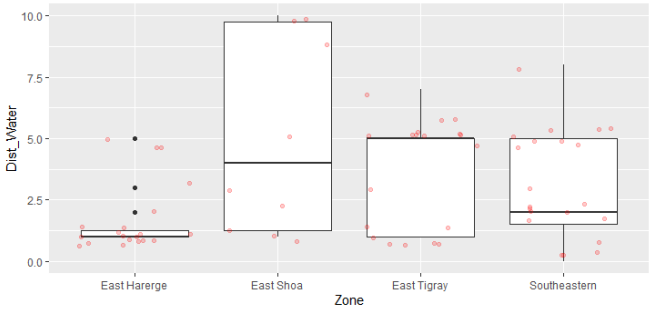

Figure 13. Distance (in km) between farm and the nearest water source per county

Statistical characterization of the tree experiments in Ethiopia

Tree species panted in the project areas in Ethiopia

About 20 different species have been planted in the project areas in Ethiopia (Figure 16). Some species exclusivity existed in specific zones, such as the example in East Harerge where all the Jacaranda mimosifolia of the project have been planted. The same was for Carica papaya and Melia volkensii which were exclusively planted in East Shoa (Figure16 and Table 5).

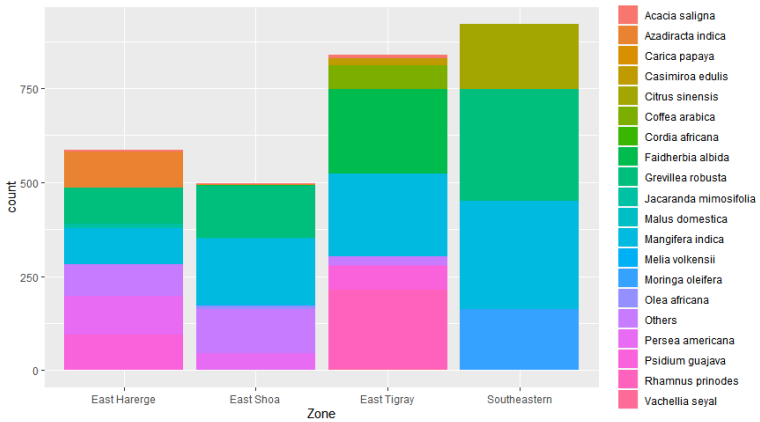

Figure 14. Distribution of tree experiments according to the planted species

Table 5. Distribution of Tree species in counties

Species	East Harerge	East Shoa	East Tigray	Southeastern
Acaciasa saligna	35.7%	7.1%	57.1%	
Azadiracta indica	97.0%	3.0%		
Carica papaya		100.0%		
Casimiroa edulis			100.0%	
Citrus sinensis				100.0%
Coffea arabica			100.0%	
Cordia africana			100.0%	
Faidherbia albida		0.4%	99.6%	
Grevillea robusta	17.6%	25.7%		56.7%
Malus domestica	33.3%	66.7%		
Mangifera_indica	12.1%	22.3%	27.9%	37.7%
Melia volkensii		100.0%		
Moringa_oleifera				100.0%
Olea africana		100.0%		
Persea americana	68.7%	30.7%	0.7%	
Psidium guajava	59.4%		40.6%	
Rhaminus prinodes			100.0%	
Others	37.5%	52.2%	10.3%	
Jacaranda mimosifolia	100.0%			

Trees survival indicators are usually related to a set of factors which are either related to farmers practices such as watering, mulching, manuring, etc. or to other agroecological contextual factors such as soil quality and texture, weather, altitude, the origin nurse of the tree, tree species, etc. The below sections of the report will try to provide a comprehensive assessment and analysis of the trees survival rate in relation to some of these management and contextual factors.

The first variable we assessed was the distribution of the survival rate across locations/counties. This is illustrated in figure 17, showing that the probability of tree's planting survival per project area was 84 % in East Harerge , 93.4% in East Shoa, 99.5% in East Tigray and 80.7 % in Southeastern (Table 6).

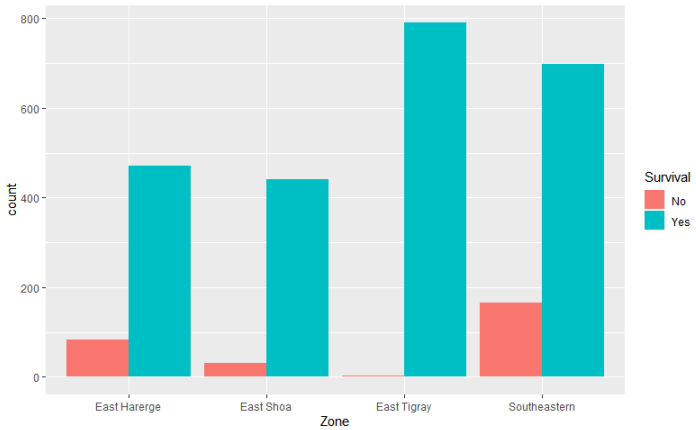

Figure 15. Tree's survival rate across the different project areas.

A significant Chi-square test showed that survival is significantly different across these project zones. This correlation was estimated to be moderate as the V-Cramer value was about 0.256.

Table 6 percentage of tree's survival across the different project areas/counties

Zone	Survival	
	No	Yes
East Harerge	16.0%	84.0%
East Shoa	6.6%	93.4%
East Tigray	0.5%	99.5%
Southeastern	19.3%	80.7%
Total	10.9%	89.1%

An additional analysis of survival rates in each of the considered 8 watersheds is presented in Figure 18. A Chi-square test showed that survival is significantly different across watersheds and this relationship was judged to be strong as the V-Cramer value was about 0.33. The best survival rate was recorded for trees planted in May Hantso watershed (100 %) while about 27.9% of tree plantations in Atami failed (Table 8).

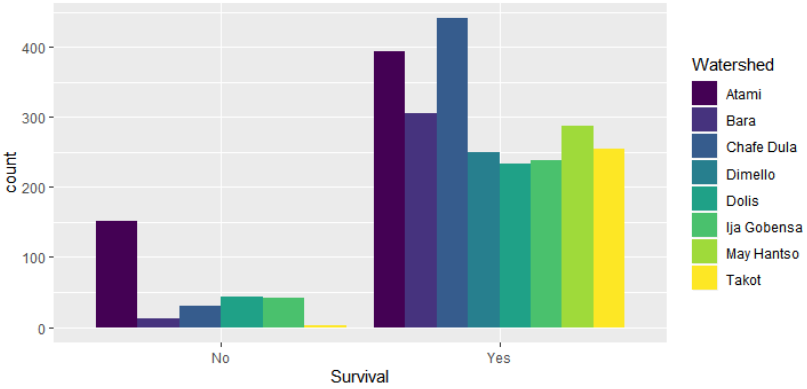

Figure 16. Distribution of Survival per nurseries

Table 7 Survival probability by nurseries

Watershed	Survival	
	No	Yes
Atami	27.90%	72.10%
Bara	4.20%	95.80%
Chafe Dula	6.60%	93.40%
Dimello	0.40%	99.60%
Dolis	17.20%	82.80%
Ija Gobensa	14.80%	85.20%
May Hantso		100.00%
Takot	1.10%	98.90%
Total	10.90%	89.10%

Another Chi-square test for comparison of survival rates across planted tree species was significant thus suggesting that survival of the tree experiments in Ethiopia is correlated to the tree specie. This relationship was moderate as the V-Cramer value was about 0.239. Figure 19 presents the survival rates for the different tree species planted. Table

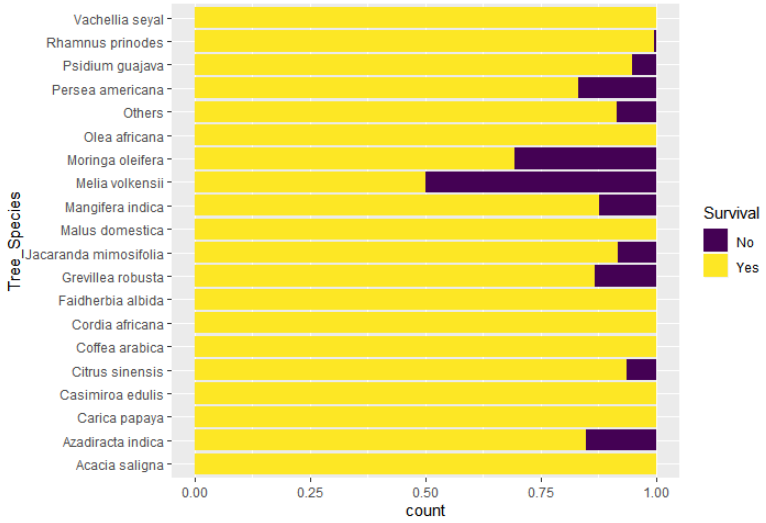

Figure 17.Survival by species

Table 8. Tree's survival for the different species in the different considered watersheds.

	Chafe Dula	Ija Gobensa	May Hantso	Dolis	Dimello	Takot	Atami	Bara
Acaciasa saligna	100.0	100.0	100.0					
Azadiracta indica	66.7	88.6		82.4				
Carica papaya	100.0							
Casimiroa edulis			100.0		100.0	100.0		
Citrus sinensis							100.0	93.7
Coffea arabica			100.0					
Cordia africana					100.0			
Faidherbia albida	100.0	100.0	100.0			100.0		
Grevillea robusta	93.6	63.0		79.2			74.6	98.1
Malus domestica	100.0			100.0				
Mangifera_indica							72.5	
Melia volkensii	50.0							
Moringa_oleifera							69.2	
Olea africana	100.0							
Persea americana	97.8	75.9		77.6	100.0			
Psidium guajava		89.4		93.6	100.0	100.0		
Rhaminus prinodes			100.0		100.0	99.1		
Others	91.3	100.0	100.0	78.6	100.0			
Jacaranda mimosifolia		100.0		88.9				

Relation between tree survival by farmers practices (technical packages).

The effect of some of farmer practices on trees survival rates is provided in table 9. A chi-square test was showing that fertilizer and mulch only have weak effect on survival of the trees. More information about other management practices can be read in Table 9. Variables considered in table 9 were grouped using a CATegorical Principal Components Analysis (Figure 20). Results of this PCA were simplified and presented on two axes to extract the most discriminant variables which influence the survival. The most relevant variables are the ones placed far from the origin point, such as Weed Control, Watering, the niche where the plantation was done, etc.

Table 9. Survival probability by a set of variables

Farmer applications		Survival Probability (%)	Test	Relationship
Mulch	Yes	92.4	Parametric	Weak (0.1)
	No	85.9		
Watering	Yes	93.6	Parametric	Moderate (0.26)
	No	73.8		
Disease Problem	Yes	100	Non Parametric	Very weak (0.04)
	No	88.9		
Pest problem	Yes	84.8	Parametric	Very weak (0.089)
	No	90.9		
Weed problem	Yes	89.3	Parametric	Very weak (0.005)
	No	89		
Cover	Low	89.6	Parametric	Very weak (0.068)
	Medium	89.5		
	High	78.3		
Fencing	Yes	88.4	Parametric	No sig
	No	91		
Pruning	Yes	97.2	Parametric	Weak (0.157)
	No	86.2		
Fertilizer	Yes	97.6	Parametric	Weak (0.147)
	No	86.6		
Niche	Ex_Boundary	94	Parametric	Moderate (0.221)
	In_Boundary	87.9		
	Scattered	90.6		
	Woodlot	78.2		
	Home_Compound	95.3		
	Along_Terraces	100		
	Other	63.2		
Water Regime	Five Five	94.5	Parametric	Moderate (0.228)
	Five Ten	94.1		
	Three Five	91.7		
	Three Ten	93.2		

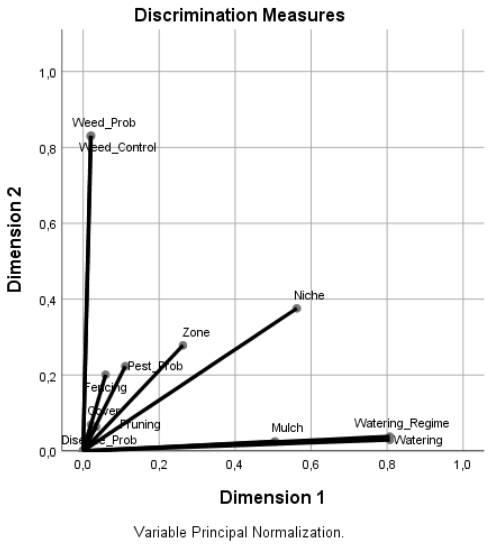

Figure 18. Independent variables classification to identify the most influencing management practices

The dataset shows that the different practices shown in Table 9 were combined in 19 different ways, thus resulting in 19 different technical packages that were used for all the experiments implemented in Ethiopia. Table 10 presents these 19 options/packages and their respective content. Furthermore, table 11 shows the survival rate recorded for every management option implemented. Few options resulted in a 100% survival rate including options 4, 6, 9, 10, 12, etc. (See table 11). But it is also worth noting that most of the other options resulted in very high survival rates, with exception of options 1 and 3. An Exact test of Fisher concluded that the survival rate is significantly correlated with the management option chosen (sig. 0.00 < 0.05). This relationship is estimated to be strong as the V-Cramer was equal to 0.483.

Table 10. Combinations of different management practices (options) implemented in the tree experiments of Ethiopia.

Options	Water	Water Regime	Mulch	Weed Control
Option 1	No	***	No	Yes
Option 2	No	***	Yes	No
Option 3	No	***	Yes	Yes
Option 4	Yes	5 liters / 5 days	No	No
Option 5	Yes	5 liters / 5 days	No	Yes
Option 6	Yes	5 liters / 5 days	Yes	No
Option 7	Yes	5 liters / 5 days	Yes	Yes
Option 8		5 liters / 10 days	No	No
Option 9	Yes	5 liters / 10 days	No	Yes
Option 10	Yes	5 liters / 10 days	Yes	No
Option 11	Yes	5 liters / 10 days	Yes	Yes
Option 12	Yes	3 liters / 5 days	No	No
Option 13	Yes	3 liters / 5 days	No	Yes
Option 14	Yes	3 liters / 5 days	Yes	No
Option 15	Yes	3 liters / 5 days	Yes	Yes
Option 16	Yes	3 liters / 10 days	No	No
Option 17	Yes	3 liters / 10 days	No	Yes
Option 18	Yes	3 liters / 10 days	Yes	No
Option 19	Yes	3 liters / 10 days	Yes	Yes

*** *: Other irrigation practice*

Table 11. Tree's survival rate for the different management options

Options	Survival
Option 1	64.50%
Option 3	44.00%
Option 4	100.00%
Option 5	97.70%
Option 6	100.00%
Option 7	97.90%
Option 9	100.00%
Option 10	100.00%
Option 11	97.10%
Option 12	100.00%
Option 13	97.50%
Option 14	100.00%
Option 15	95.40%
Option 17	100.00%
Option 18	100.00%
Option 19	96.10%

Figure 20 combines the survival rate, specie, and the management option. It shows that significant differences of the survival rates across “species X option” is only valid (significant) for Mangifera indica, Moringa oleifera, Grevillea robusta and Citrus sinensis. It is also important to note that the same correlation was recorded for Mangifera indica in Kenya, which the survival was also correlated to the management option.

Figure 19. Survival rates for the different “specie X option”

We also analyzed the survival rates across “options X niches” (see Figure 21). This shows that survival rates of trees are significant across all “options X niches” for only options 1, option 3, option 11, option 13 and option 15. This indicates that the niche in which we implement these management options matters for the survival of the trees.

Figure 20. Survival rates distribution across “options X niches” cases.

Performances of the survived trees.

two additional variables have been measured for the survived trees, the height and the diameter. The height of the tree (all trees considered together) varied from 0 to 295 cm, the calculated mean was equal to 44.79 cm. The circumference[1] of the trees varied from 0 to 96.0 cm, with a calculated mean equal to 3.9 cm (see table 12 for more details).

Table 12. Statistical description of height and circumference of the survived trees

	N	Range	Minimum	Maximum	Mean
Height	2111	295	0	295	44.79
Circumference	2551	96.00	00	96.00	3.9

An ANOVA test showed that height and circumference of trees was significantly different (at 5%) across the counties (figure 22 and 23) are significant. A Tukey test, for pair wise comparison of means across the four zones shows that there are quite significant differences across the considered counties in terms of trees growth performances (Table 13). Based on these Tukey tests, final classification of the counties, in terms of eight and circumference are as presented in tables 14 and 15.

Table 13. Tukey test for height and circumference of survived trees.

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.
Height	East Harerge	East Shoa	24,590*	1.627	0.000
		East Tigray	22,682*	1.415	0.000
		Southeastern	5,745*	1.719	0.001
	East Shoa	East Harerge	-24,590*	1.627	0.000
		East Tigray	-1.909	1.474	0.195
		Southeastern	-18,845*	1.767	0.000
	East Tigray	East Harerge	-22,682*	1.415	0.000
		East Shoa	1.909	1.474	0.195
		Southeastern	-16,937*	1.575	0.000
	Southeastern	East Harerge	-5,745*	1.719	0.001
		East Shoa	18,845*	1.767	0.000
		East Tigray	16,937*	1.575	0.000
Circumference	East Harerge	East Shoa	2,67602*	0.19273	0.000
		East Tigray	2,11490*	0.16912	0.000
		Southeastern	,61535*	0.17247	0.000
	East Shoa	East Harerge	-2,67602*	0.19273	0.000
		East Tigray	-,56112*	0.17328	0.001
		Southeastern	-2,06067*	0.17655	0.000
	East Tigray	East Harerge	-2,11490*	0.16912	0.000
		East Shoa	,56112*	0.17328	0.001
		Southeastern	-1,49954*	0.15042	0.000
	Southeastern	East Harerge	-,61535*	0.17247	0.000
		East Shoa	2,06067*	0.17655	0.000
		East Tigray	1,49954*	0.15042	0.000

The average measured height of trees in East Harerge was about 59.7 cm which is higher than Southeastern (with a value of 53.8 cm), and East Tigray and East Shoa (with respectively 37.03 cm and 35.3 cm) (Figure 23). Tree's height in East Harerge were concentrated around a median value of 53 cm.

[1] Measure around the trunk of the tree at four and a half feet (4.5') above the ground on the tree's uphill side (if not on even ground). If the tree forks below or bulges at 4.5', measure the circumference where the tree reaches normal size or tapers below the 4.5' foot point. See http://www2.oaklandnet.com/oakca1/groups/pwa/documents/webcontent/oak025506.pdf

For Southeastern, the median value was about 42.5 cm, while in East Shoa and East Tigray this value was about 35 cm and 34 cm respectively.

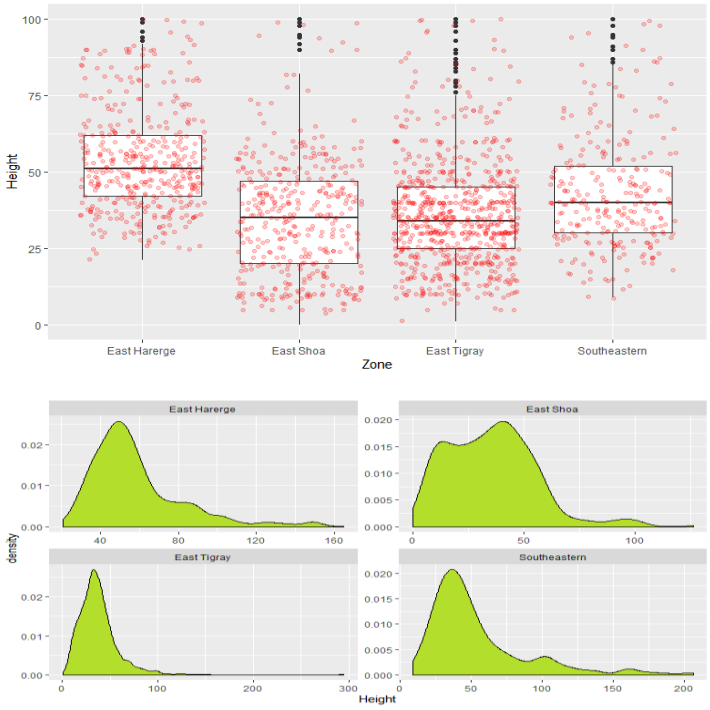

Figure 21. Distribution of Height of trees per county in Ethiopia

Table 14.Multiple compare tables

Test	**Conclusion**
East Harege Vs Other zones	East Harege > Other zones
East Shoa Vs East Tigray	No sig
Southeastern Vs East Shoa	Southeastern > East Shoa
Southeastern Vs East Tigray	Southeastern > East Shoa
Result	East Harege > Southeastern > (East Shoa , East Tigray)

.

The measured tree's circumference in East Harerge was about 5.2 cm which is higher than Southeastern (with a value of 4.8 cm), East Tigray and East Shoa (with respective values of 2.6 cm and 3.22 cm) (Figure 24). For circumference distribution, this indicator was concentrated around a median value of 4 cm in East Harerge, 4.2 cm in Southeastern, and 3 cm in both East Shoa and East Tigray.

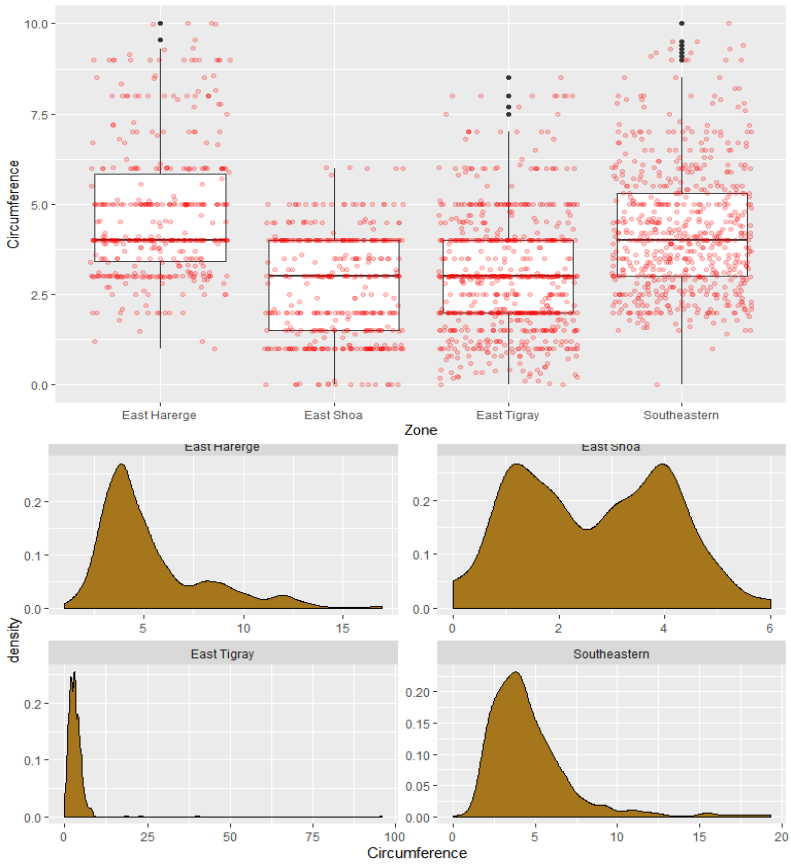

Figure 22. Circumference and circumference density per zone

Table 15.Multiple compare tables

Test	Conclusion
East Harege Vs Other zones	East Harege >>
East Shoa Vs East Tigray	East Shoa < East Tigray
Southeastern Vs East Shoa	Southeastern > East Shoa
Southeastern Vs East Tigray	Southeastern > East Tigray
Ranking of counties:	East Harege > Southeastern > East Shoa > East Tigray

An ANOVA test showed that differences of height and circumference between the different tree's species (figure 24) are significant at 5%. We proceeded with a Bonferroni test, for pair wise comparison of height and circumference means across these species. Results of this test shows the classification of the height by specie from the smallest one to the highest (Table 16).

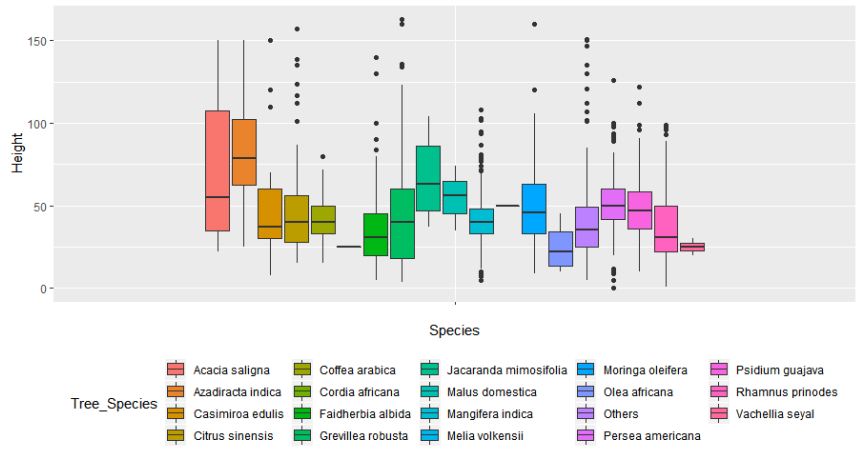

Figure 23. Distribution of tree's height for the different species

Table 16. Bonferroni test for ranking of trees height across species

Height						
Scheffe[a,b]						
Watershed	N	Subset for alpha = 0.05				
		1	2	3	4	5
Dimello	251	32.12				
Chafe Dula	440	35.01	35.01			
Takot	264	35.69	35.69			
May Hantso	295		42.12	42.12		
Atami	215			45.15	45.15	
Dolis	245				52.80	
Ija Gobensa	255					66.14
Bara	146					66.68
Sig.		0.915	0.163	0.964	0.096	1.000

To further distinguish the differences between trees experiments in terms of height, we further explored the resulting height of the considered combinations of "species X watershed". With the method of estimated marginal means, we can compare the same tree specie in different watersheds (Figure 25). Results are presented in figure 25, thus showing that "*Azadiracta indica*" planted in "Ija Gobensa" reached the highest height across all other trees and locations.

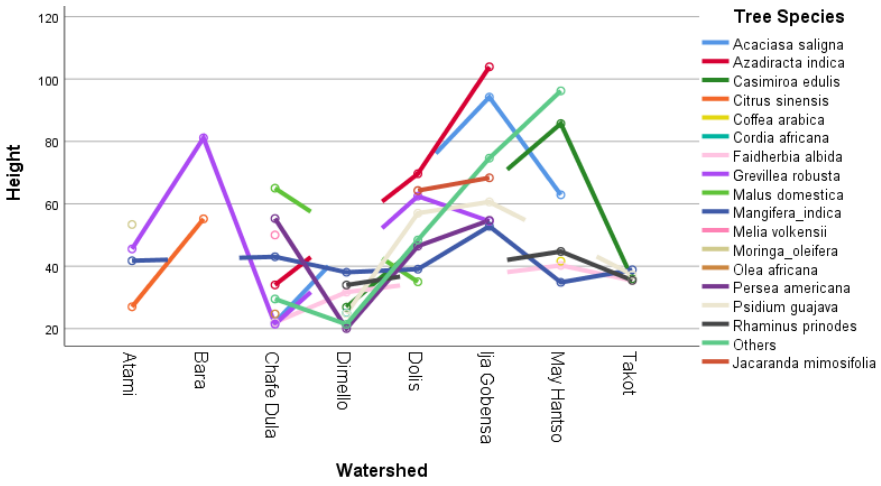

Figure 24. Height by species and watersheds

As mentioned in table 10, a set of 19 technical (management) options have been tested in the project areas in Ethiopia. An ANOVA test showed that differences of height (figure 26) between the options is significant at 5%. We then proceeded with a Tukey test, for pair wise comparison of means of height across the options. This latter test shows the significant comparisons which are presented in table 18.

Table 17. Tukey test for average height comparison across the considered options

Options		Mean Difference	Std. Error	Sig.
Option 1	Option 6	-26,262*	12.635	0.038
	Option 11	-14,089*	5.054	0.005
	Option 12	-34,679*	15.357	0.024
	Option 13	-30,504*	5.488	0.000
	Option 14	-35,129*	13.788	0.011
	Option 15	-20,669*	5.054	0.000
	Option 19	-29,429*	4.856	0.000
Option 5	Option 13	-25,793*	5.880	0.000
	Option 14	-30,418*	13.949	0.030
	Option 15	-15,958*	5.478	0.004
Option 6	Option 1	26,262*	12.635	0.038
	Option 9	32,333*	15.937	0.043
	Option 17	28,386*	14.160	0.046
Option 7	Option 13	-25,744*	5.820	0.000
	Option 14	-30,369*	13.924	0.030
	Option 15	-15,909*	5.413	0.003
	Option 19	-24,669*	5.229	0.000
Option 9	Option 6	-32,333*	15.937	0.043
	Option 12	-40,750*	18.171	0.025
	Option 13	-36,575*	11.156	0.001
	Option 14	-41,200*	16.866	0.015
	Option 15	-26,740*	10.949	0.015
	Option 19	-35,500*	10.859	0.001
Option 11	Option 1	14,089*	5.054	0.005
	Option 13	-16,415*	6.414	0.011
	Option 17	16,213*	8.149	0.047
	Option 19	-15,340*	5.883	0.009
Option 12	Option 1	34,679*	15.357	0.024
	Option 9	40,750*	18.171	0.025
	Option 17	36,803*	16.634	0.027
Option 13	Option 1	30,504*	5.488	0.000
	Option 5	25,793*	5.880	0.000
	Option 7	25,744*	5.820	0.000
	Option 9	36,575*	11.156	0.001
	Option 11	16,415*	6.414	0.011
	Option 17	32,628*	8.425	0.000
Option 14	Option 1	35,129*	13.788	0.011
	Option 5	30,418*	13.949	0.030
	Option 7	30,369*	13.924	0.030
	Option 9	41,200*	16.866	0.015
	Option 17	37,253*	15.198	0.015
Option 15	Option 1	20,669*	5.054	0.000
	Option 5	15,958*	5.478	0.004
	Option 7	15,909*	5.413	0.003
	Option 9	26,740*	10.949	0.015
	Option 17	22,793*	8.149	0.005

Option 17	Option 11	-16,213*	8.149	0.047
	Option 12	-36,803*	16.634	0.027
	Option 13	-32,628*	8.425	0.000
	Option 14	-37,253*	15.198	0.015
	Option 15	-22,793*	8.149	0.005
	Option 19	-31,553*	8.028	0.000
Option 19	Option 1	29,429*	4.856	0.000
	Option 5	24,718*	5.296	0.000
	Option 7	24,669*	5.229	0.000
	Option 9	35,500*	10.859	0.001
	Option 11	15,340*	5.883	0.009

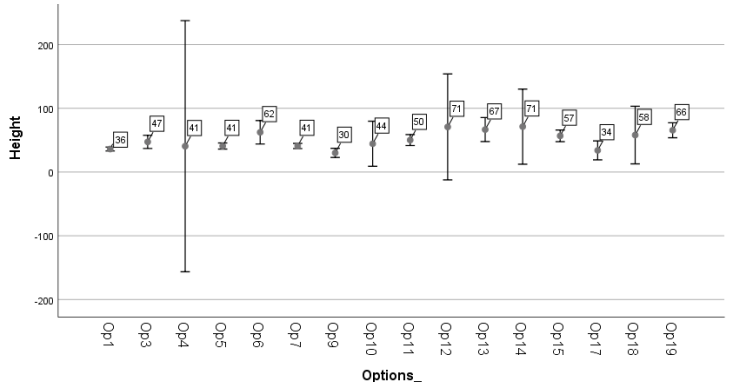

Figure 25. Distribution of tree's height by options

Figure 27 provides a comparison of the tree's height across the combinations of "option X specie". With the method of estimated marginal means, we can compare the same tree species in different options (Figure 27). This analysis shows that Most important height was obtained for Azadiracta indica planted using technical packages (options) 12, 13, and 14.

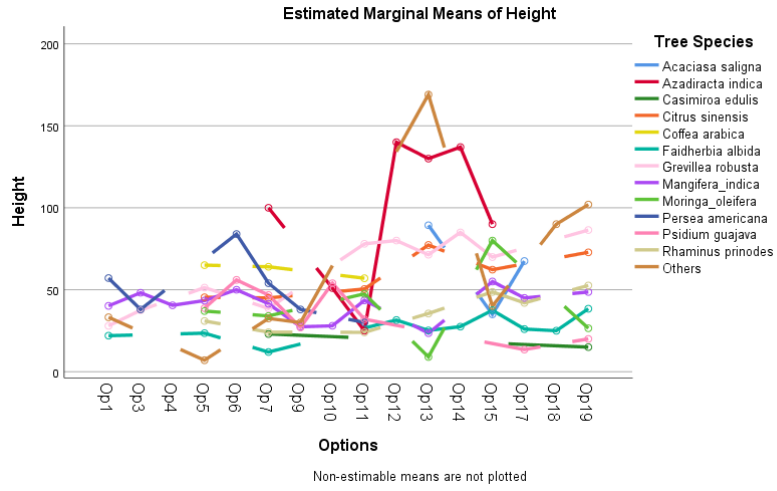

Figure 26. Height by species and options

Conclusions.

This report analyzed socioeconomic and tree's experiment data in Ethiopia for the year 2019. It provides an overview of the main factors which are enabling tree's survival rates in the studied areas and shed light on the most important management options and agroecological contexts which favor

the success of tree's plantations. Trees are effective for soil protection and for mainstreaming a large set of ecosystem services. They also have implications in terms of food security. Results of this project report provide recommendations about the most enabling factors which can help reaching high survival rates of new tree's plantations. These factors can be taken into consideration by the development stakeholders for effective implementation of large land restoration actions in sub-Saharan African countries.