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.

Kenya – Data of 2018

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Foreword

This report summarizes main findings from data analysis about land restoration using tree plantations in Kenya. 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 Kenya. 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 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 (2018) data about the survival rate of 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 2018 in Kenya.

Statistical analysis of farmers and farms profiles in Kenya

Overall Geographical distribution of the sample

Most of the farmers considered in the data set are in Kitui county (including 638 farmers which represents 47.5% of the total sample). About 402 farmers from the region of Machakos have been also considered in the sample, which represents 30% of the total sample. Only 302 farmers have been considered in Makueni county (22.5% of the total sample).

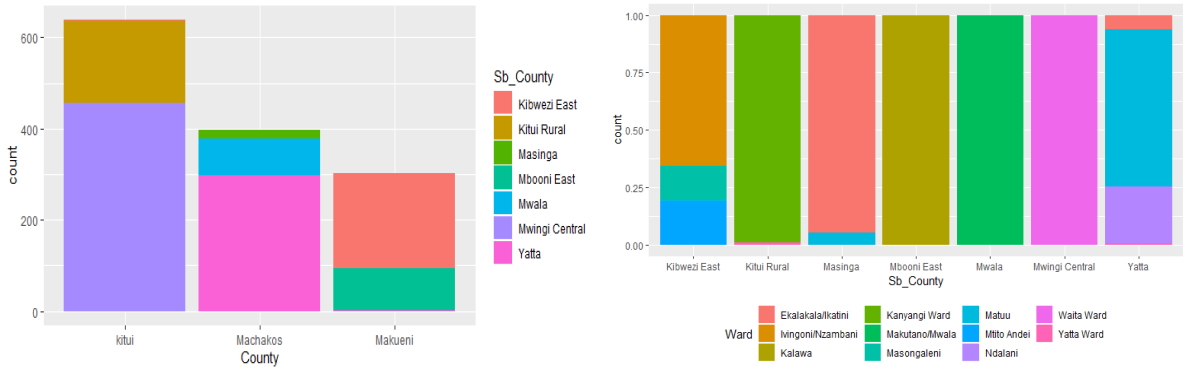

Figure 1. Location of farms in counties and sub-counties of Kenya.

Figure 1 also shows the distribution of farmers by "Ward", which is the smallest political unit in the Kenya system of local government (counts in the Wards figure is expressed in percentages).

Farmers profiles

Most of the farmers involved in the project in Kenya are female (about 76%), with the highest rate of female participation in Makueni county with 78.5% (Figure 2). Figure 2 also provides a gender distribution of the participant farmers to the project in the different sites.

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

In the different project sites the age of the participants is represented by a box plot (Figure 3). The medium age of farmers is about 45 years in Kalawa , 42 years in Lower Yatta and Mtitio Andei, 50 years in Mwala, 43 years in Waita and 48 years in Yatta. The biggest range of age variation (72 years) is observed in Kalawa with a difference between a maximum age of 90 years and a minimum age 18 years.

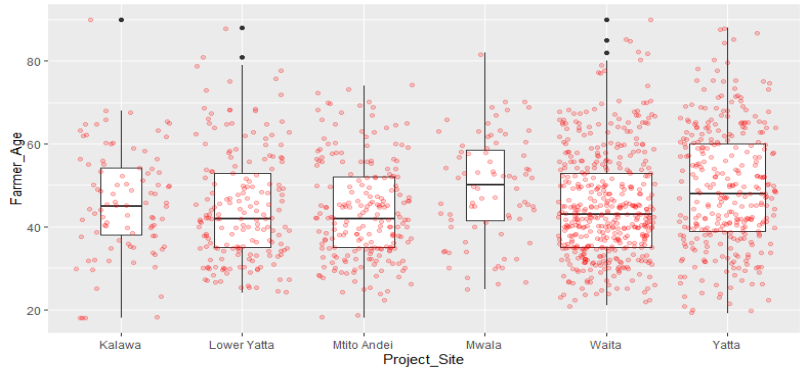

Figure 3. Farmer age distribution by project site in Kenya

Female famers are younger than male farmers in all project sites, except for Kalawa. Median age of female farmers is about 45 years while median age of male farmers is equal to 44 years (Figure 4). The lowest median of female farmers age is recorded in Mtito Andei with a value of 40 years while the highest median age of female farmers has been registered in Mwala. For the male farmers the highest median (57 years) has been registered in Yatta.

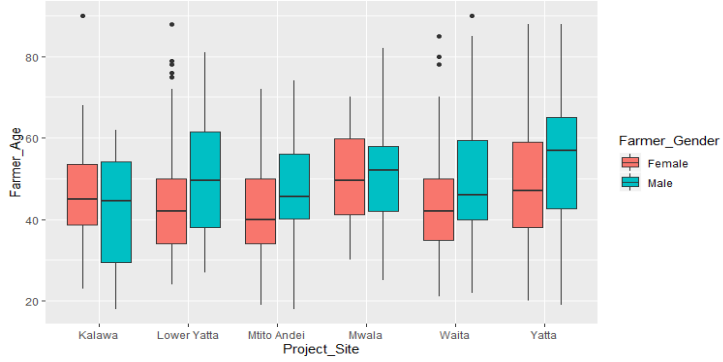

Figure 4. Age of participant farmers in Kenya by project site and gender.

About 73.2% of the household heads involved in the project are male and only 26.8% are female. These proportions are distributed in the project sites differently (Figure5). In Lower Yatta, only 16.7% of the household heads are female while proportions of female household heads which is about to 28 % in Waita and Yatta.

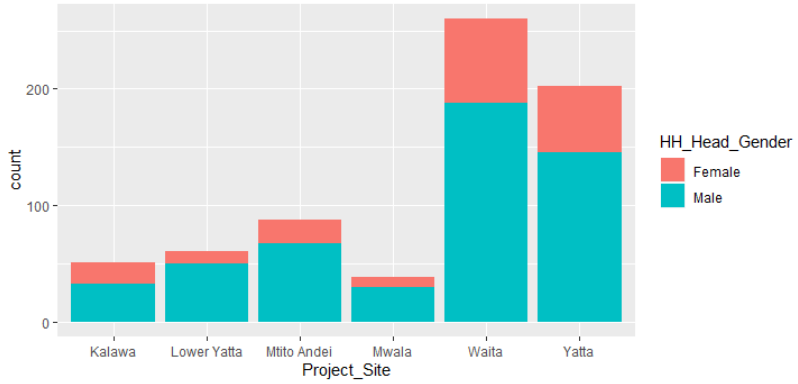

Figure 5. Household Head Gender per project site

About 63.8% of household heads have a primary school education level while about 21.5% attended secondary school. The rest of farmers had other types of education such as higher or "no formal" education. In Makueni, 1.3 % of participants are below primary. 6.7% of the participants in Machakos attended Higher education, which is the biggest proportion across other counties (Figure 6). About 72.3% of the participants attended a primary level of education in Kitui county which is the highest percentage for this type of education in comparison to Machakos and Kitui.

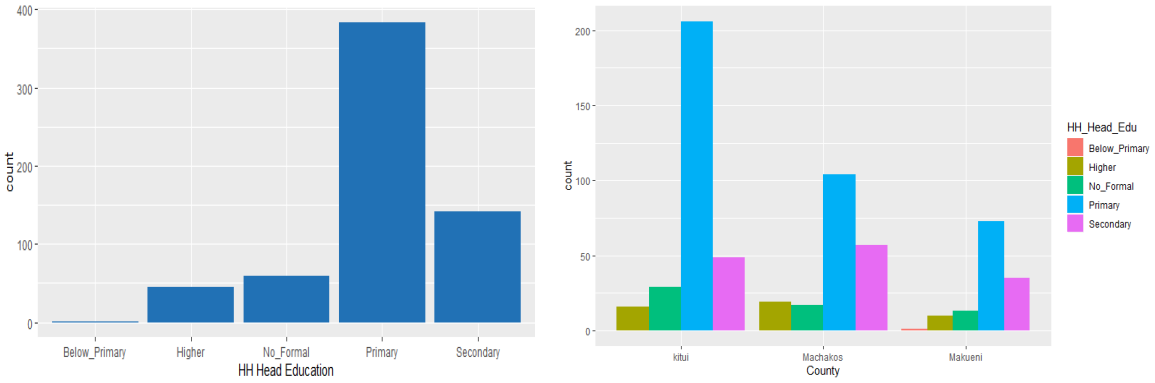

Figure 6.Education level and Education level by county

Household population is defined as the population enumerated in private households during a census. Survey results in Kenya show that the median of the household population was 5 in Machakos and Makueni and 6 in Kitui. The highest value was 36 household members, registered in Makueni (Figure 7).

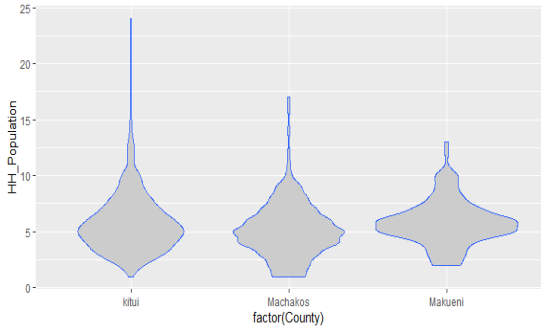

Figure 7. Violin plot of household population by county

Farms description

Most of farms (for about 65.8% of cases) was owned through inheritance. Governmental lands are only found in Machakos while leased lands are mostly found in Makueni. Rented lands are exclusively found in Kitui with a percentage of 0.3% of the total lands in this region. it is also important to note that a large part (16.9%) of lands where the project experiments have been implemented are characterized by an unknow ownership (Table 1) which demonstrates a structural problem related to tenure security and incentives for land restoration investments.

Table 1. Land ownership by county (in % of total sample farms)

Ownership	kitui	Machakos	Makueni	Total
Communal	0.5	0.3	0.7	0.4
Governmental	0	0.8		0.2
Inheritance	67.4	67.0	60.9	65.8
Leasing out	0		0.3	0.1
Purchase	17.2	13.5	17.2	16.1
Rented	0.3			0.1
Settlement		0.8		0.2
Unknow	14.6	17.8	20.9	16.9

Average farm size of the considered farms in our sample is about 3.33 ha. Average farm sizes in Kitui, Machakos, and Makueni were respectively equal to 3.3 ha, 2.31 ha, 4.62 ha . The largest farms involved in the project were in Machakos with an average value of 202.3 ha. For the distribution of farm size, in Kitui the sizes are concentrated around 3.00 ha which is the median value. This value is higher than Makueni (median of 2.5 ha) and Machakos (median value of 1.5 ha) (Figure 8).

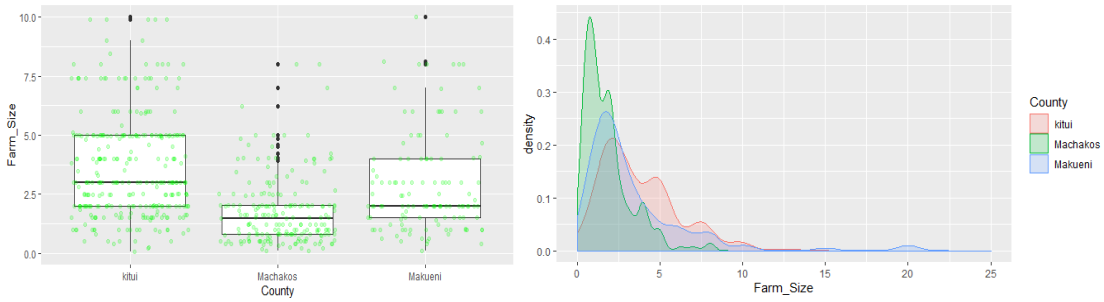

Figure 8. Farm size distribution by county

Cultivated part (of the farm) is a ratio (percentage) of cultivated area to total area of a farm. The mean of cultivated area per farm in our sample is equal to 75.3 % (considering all project sites). This value is equal to 78.5 % in kitui, 77.6 % in Machakos and 65.5% in Makueni. This variable is very important to consider as the non-cultivated land is usally an area that can suitable for additional fruits or forest trees plantations. In terms of distribution, the cultivated part is concentrated around 80% in Kitui which is also the median value observed in Machakos. this median value is lower in Makueni with a value of 66.6 % (Figure 9).

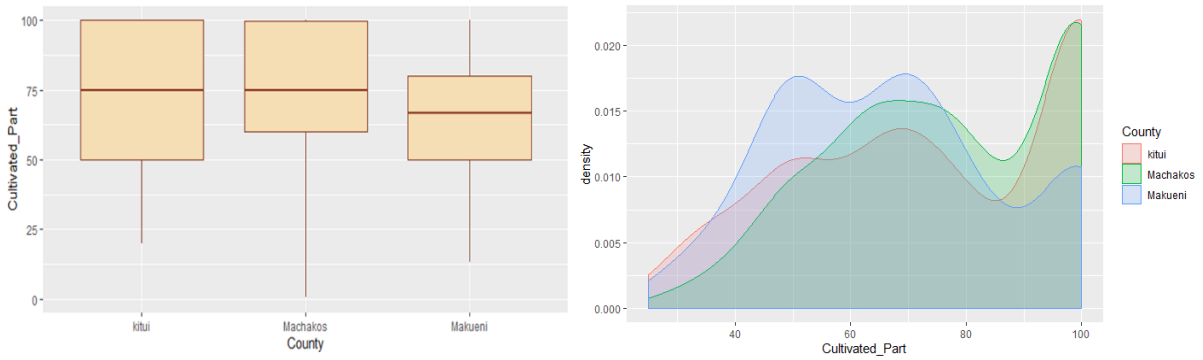

Figure 9. Cultivated part (percentage) by county

Another important socio-demographic question is about land ownership for different categories of age. Figure 10 provides an overview response to this question where we observe that for all counties older household heads are usually the ones owning larger farms in comparison to younger household heads. In Machakos, the cultivated part decreases with older household heads and bigger farms. In Kitui, however, the share of cultivated land is influenced by the size of the farm. If the farm size increases the share of cultivated land generally decreases (Figure 10).

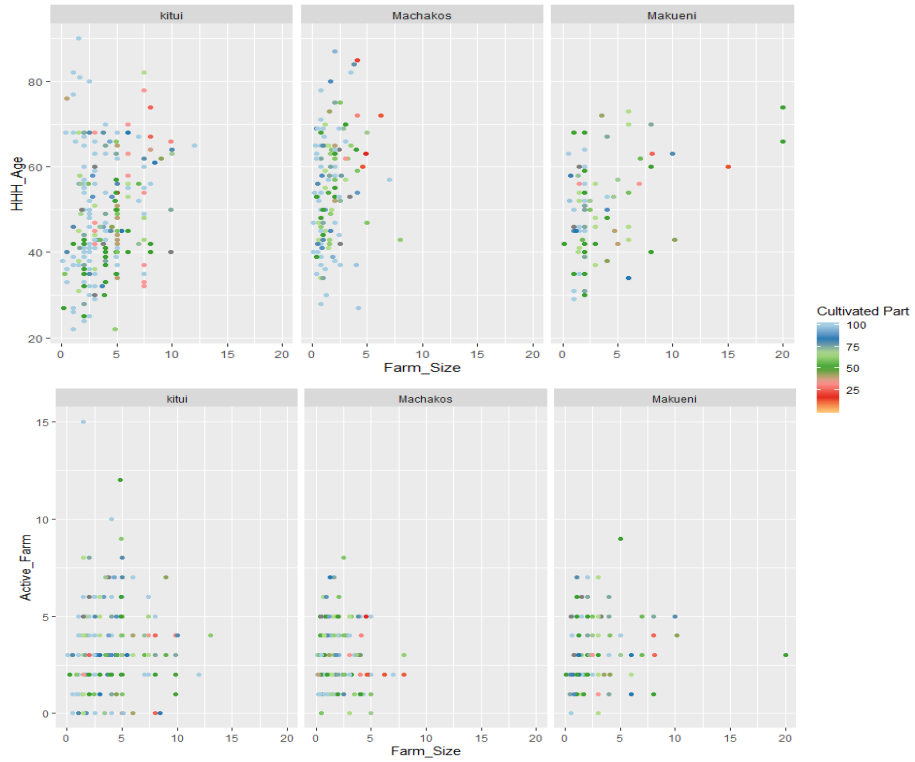

Figure 10.Cultivated part explained by farm size, household head age and active farm

the share of cultivated land decreases in a large farm with low household members number in Machakos and Makueni. However, a different pattern was observed in Kitui where we founded that some highly populated households in large farms do have a low share of cultivated land in their farms (Figure 11).

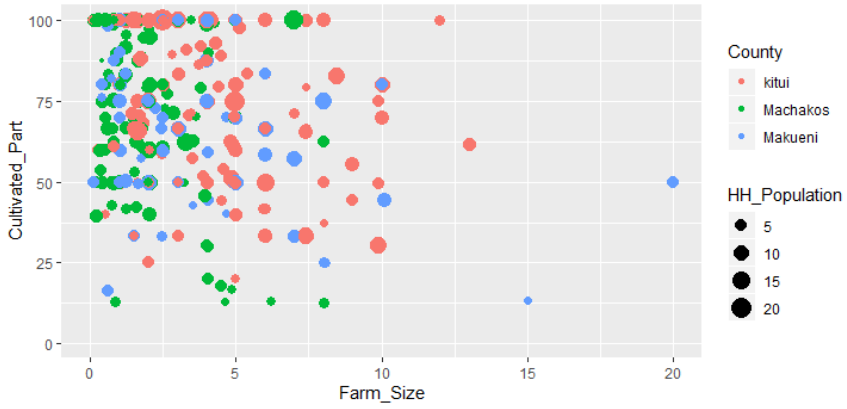

Figure 11. share of cultivated land, household population, and farm sizes in the different counties.

Erosion is affecting about 63.7% of the lands considered in our sample, all counties included. The most affected county is Makueni there 80.1% of the lands were touched by erosion. The percentage is lower in Kitui (61%) and for Makueni it was the least affected county in comparison to the others with 55.5 % (Figure 12).

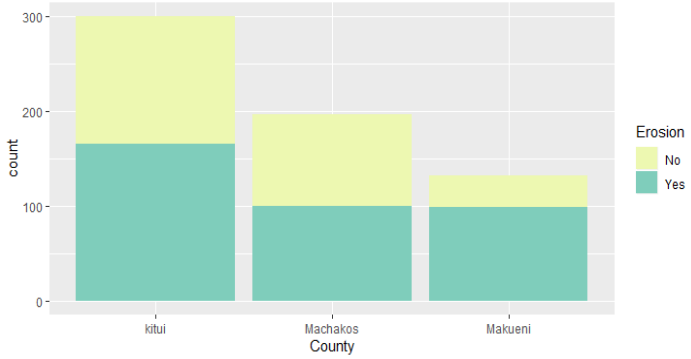

Figure 12. Land affected by erosion in the different counties

The soil quality differs from a county to another. In all counties, 16 % of soils were judged by farmers as being of high-quality while the majority was perceived as of medium quality (62%). Among all counties, kitui was particularly distinguished by a better soil quality (20.2 % of soils perceived by farmers in this region as being of high-quality) (Table2). Farms with high soil quality are usually of small size while farms with low soil quality are usually large ones (Table 3).

Table 2. Distribution of (farmers' perceptions of) soil quality by county

Soil quality	High	Low	Medium
Kitui	20.2%	21.3%	58.5%
Machakos	15.3%	26.8%	58.0%
Makueni	8.3%	18.2%	73.5%
Total	16.0%	22.2%	61.7%

Table 3. Size by soil quality

Soil quality	Mean	Median	Minimum	Maximum
High	2.67	2.00	0.09	10.12
Low	4.49	2.34	0.05	202.30
Medium	3.08	2.02	0.10	54.00

Three types of distances have been surveyed in the questionnaire: distance to the nearest road, distance to market, and distance to the closest water source (Table4). The distribution of these average distances in each of the considered counties is presented in Table 4 (see also Figures 13, 14, and 15). An Anova test has been performed to validate any significant differences across counties in terms of farms distances roads. The ANOVA test showed that differences between groups are significant at 5%, we then proceeded with a Tukey test, for pair wise comparison of means across the three counties (Tables 5 and 6). Results (Table 5) shows that we can only compare Kitui to the two other counties, in terms of distance to roads. The same series of tests was repeated for the "distance to market" and "distance to water sources".

Table 4.Mean distances of farms per counties to key strategic resources and locations

County	Distance to road (Km)	Distance to Market (Km)	Distance to water sources (Km)
Kitui	5.57	8.80	2.15
Makueni	1.63	6.10	1.75
Machakos	2.16	4.71	1.04
Total	3.66	6.97	1.73

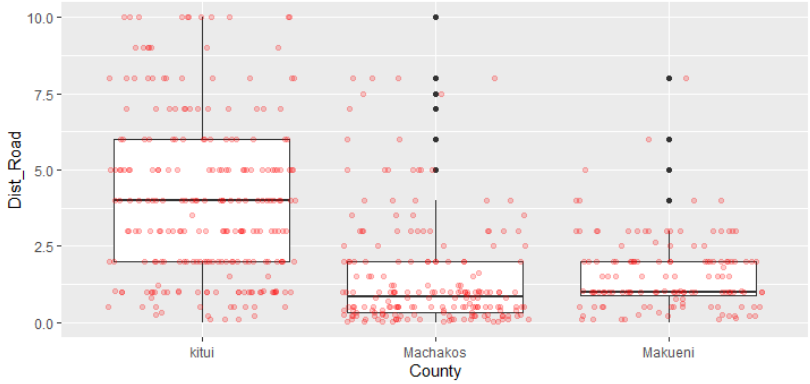

Figure 13.Distance (in km) between farm and the nearest road per county

Table 5. Tukey test results

County	County	Diff	Significance
Kitui	Makueni	3.94*	.000
	Machakos	3.41*	.000
Makueni	Kitui	-3.94*	.000
	Machakos	-0.53	0.167
Machakos	Kitui	-3.41*	.000
	Makueni	0.53	0.167

Table 6 shows that Kitui is the farthest county to roads compared to Machakos and Makueni. We are not, however, able to compare Machakos and Makueni (Insignificant) since their pairwise comparison through the Tukey test was shown to be insignificant (table 5).

Table 6. Multiple comparative table across counties for the distance to road variable.

Test	**Conclusion**
Kitui Vs Machakos	Kitui > Machakos
Makueni Vs Kitui	Makueni < Kitui
Other combinations	No Sig

Figure 14 shows the distribution of farms distance to market in the three considered counties. To compare the distances we have to pass to an Anova test .

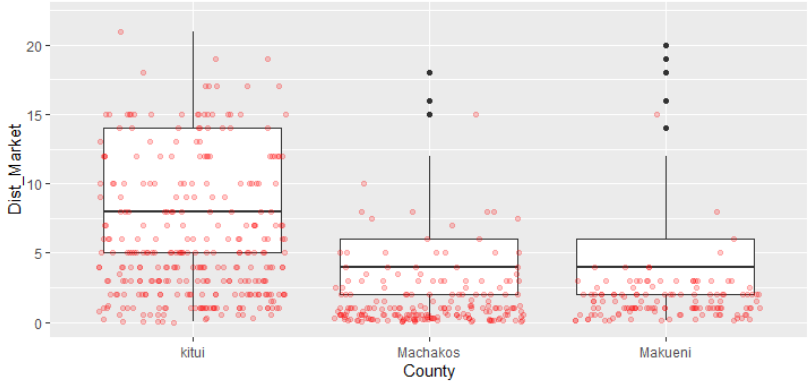

Figure 14. Distribution of distance (in km) between farms and the nearest market per county

An ANOVA test showed that differences between the groups are significant at 5%, we then proceeded with a Tukey test, for pair wise comparison of means across the three counties. Results (Table 7) show that all counties are mutually and significantly different in terms of farms distance to markets. These results also suggest that Kitui is the farthest county to market compared to Machakos and Makueni. We can actually rank counties in terms of average distance of their respected farms (from the farthest to the nearest) as follow: Kitui , Makueni, and Machakos (See also table 7).

Table 7.Tukey test for pairwise differences of farmers distance to market across counties

County	County	Diff	Significance
Kitui	Makueni	2.70*	0.000
	Machakos	4.08*	0.000
Makueni	Kitui	-2.70*	0.000
	Machakos	1.38*	0.001
Machakos	Kitui	-4.08*	0.000
	Makueni	-1.38*	0.001

Table 8. Multiple comparative table across counties for the distance to market variable.

Test	Conclusion
Kitui Vs Machakos	Kitui > Machakos
Makueni Vs Kitui	Makueni < Kitui
Makueni Vs Machakos	Makueni > Machakos

The same type of analysis was also done for the distance of farms to the nearest source of water (see figure 15) The ANOVA test for mean differences across counties was significant at 5%, and then the

Tukey test for pairwise comparison of means which sowed that all counties are significantly different from each other n terms of distance of their farms to water sources. This is also demonstrating that farmers in the three counties do not have equal access to water resources for their irrigation and domestic use.

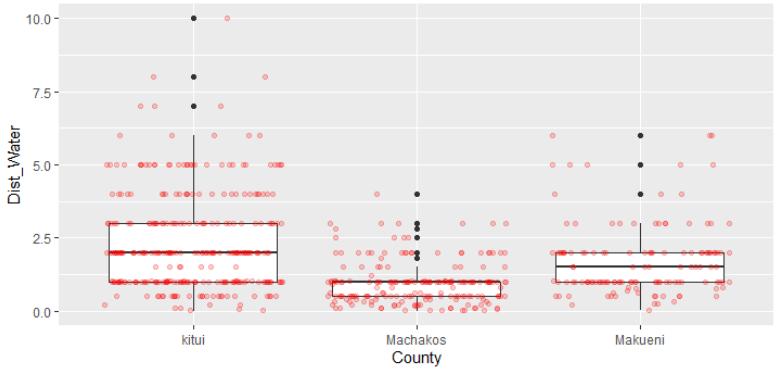

Figure 15. Distribution of distance (in km) between farms and the nearest water source per county

Table 9.Tukey test results

County	County	Difference	Significance.
Kitui	Makueni	0.40719*	0.000
	Machakos	1.11527*	0.000
Makueni	Kitui	-0.40719*	0.000
	Machakos	0.70808*	0.000
Machakos	Kitui	-1.11527*	0.000
	Makueni	-0.70808*	0.000

In average, Kitui farmers are the farthest to water sources compared to Machakos and Makueni. These counties can be classified based on this average distance (farthest to the nearest) as follows: Kitui, Makueni, Machakos (table 10).

Table 10. Multiple compare tables

Test	Conclusion
Kitui Vs Machakos	Kitui > Machakos
Makueni Vs Kitui	Makueni < Kitui
Makueni Vs Machakos	Makueni > Machakos

Statistical characterization of the tree experiments in Kenya

Tree species panted in the project areas in Kenya

The total number of tree plantations (experiments) is distributed across regions as follows: 5492 in Kitui, 6814 in Machakos and 5190 in Makueni with different species plantations in each of the counties (Figure 16 and figure 17). Kitui is the county that planted more Carica papaya, Mangifera indica, Melia volkensii and Moringa oleifera than the other counties. Machakos is the county that planted more Azadirachta indica, Calliandra calothyrsus and Senna siamea than the other counties (Table11).

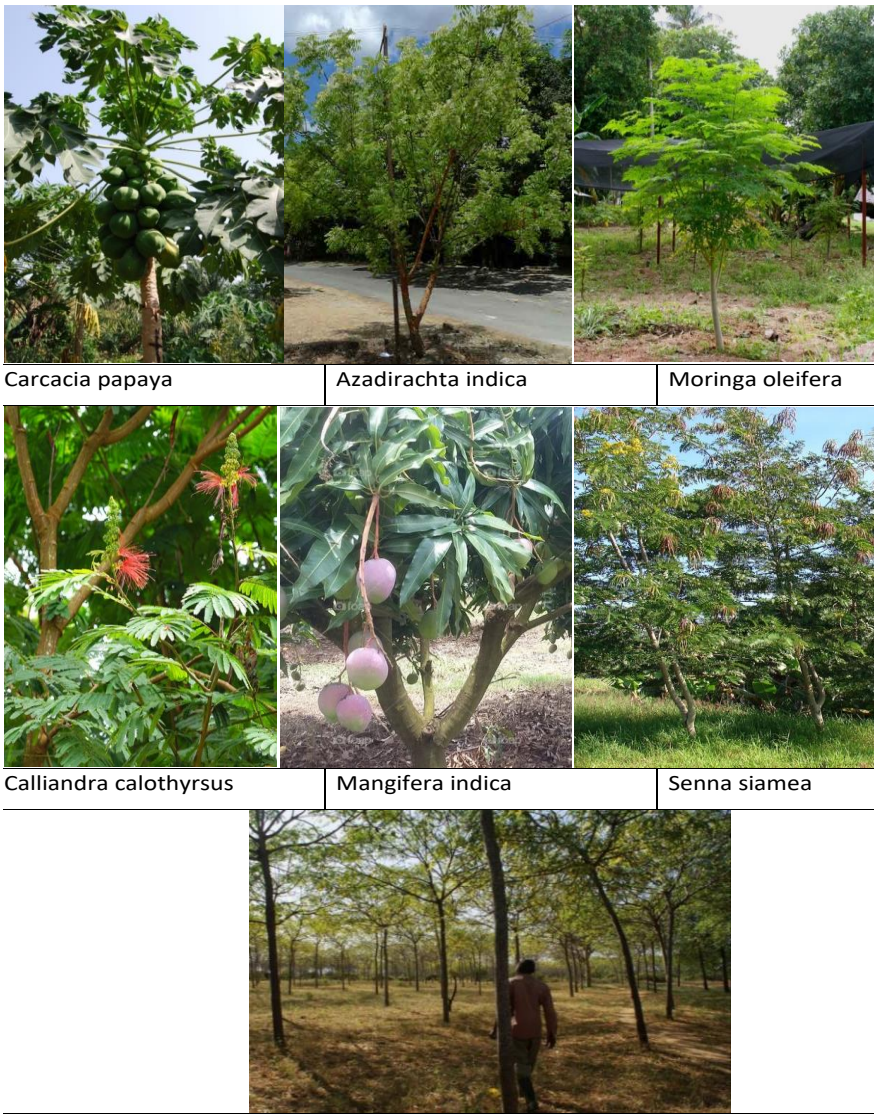

Figure 16. The different tree species experimented in Kenya.

The distribution of these species across the counties is presented in Table 11.

Table 11. Distribution of Tree species in counties (in % of tree planted)

Species	Kitui	Machakos	Makueni
Azadirachta indica	0.30	60.8	38.8
Calliandra calothyrsus		100.0	
Carica papaya	94.6	2.1	3.3
Mangifera indica	40.0	35.7	24.3
Melia volkensii	38.7	26.2	35.1
Moringa oleifera	68.5	0.1	31.4
Senna siamea	2.9	65.1	32.0

One of the most important variables discussed in this report is the survival rate of the considered species in the experiments conducted in the Kenyan counties. 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 obtained “survival rates”, as collected by

the survey of 2018, will be assessed and analyzed in relation to most of these contextual variables and factors. Available statistics shows that trees survival differs between counties (see figure 17). The frequency of tree's planting survival per county is: 53.4 % in kitui, 32.2 % in Machakos and 43.3 % in Makueni (Table 12).

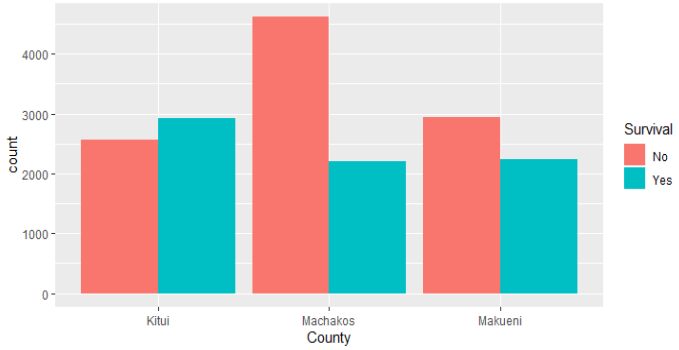

Figure 17. Trees survival rates by county

A Chi-square test for the difference of survival rates across counties was significant showing that Survival of trees is different from one county to another a V-Cramer test showed however a weak relationship between tree's survival and counties (V Cramer = 0.179).

Table 12. Tree's survival by county

County	Survival	
	No	Yes
Kitui	46.6%	53.4%
Machakos	67.8%	32.2%
Makueni	56.7%	43.3%
Total	57.8%	42.2%

Table 13. Distribution of tree's survival rates according to their nurseries of origin

Nurseries	Survival	
	No	Yes
African wood growers	50.00%	50.00%
Bidii Nursery	42.70%	57.30%
Jishinde ushinde	68.10%	31.90%
Kathonzweni SHG	71.30%	28.70%
Katulwa farm	37.80%	62.20%
Kitise tree	28.40%	71.60%
Kwa Ngoka	63.90%	36.10%
Machakos RRC	29.70%	70.30%
Mikengeta	100%	0%
Mikuuni	71.90%	28.10%
Miti	60.50%	39.50%
Muku	32.70%	67.30%
Mutembuku	71.40%	28.60%
Nzambani agricultural CBO	70.50%	29.50%
Own	50.00%	50.00%
Sokimau	64.00%	36.00%
Waita rock	41.90%	58.10%
Total	57.80%	42.20%

One of the most important variables which may affect tree's survival rates in the origin of the nursery from where these trees have been taken to the field. Figure 20 shows a summary distribution of trees survival rates according to the 17 nurseries from which the trees have been supplied to the project experiments. A Chi-square (Significant) test sowed that Survival is significantly related to "Nursery of origin" and the strength of this relation was judged to be moderate as the V-Cramer value was equal to 0.273. The best survival probability is registered with the trees obtained from "Kitise tree nursery" and "Machakos RRC" (higher than 70 %). All plantations of trees obtained from Mikengeta nursery failed (Table 17).

Another important variable is the tree specie itself. Some species might be more sensitive than others when planting them outside controlled environments. A Chi-square (Significant) test performed to validate this relation showed that survival is significantly related to the "tree species" but this relation was shown to be weak as the V-Cramer value was only around 0.124. The best survival probability was registered for Calliandra calothyrsus (70.6%) and the worst one was recorded for Azadirachta indica, and was equal to 32.5% (Figure 19).

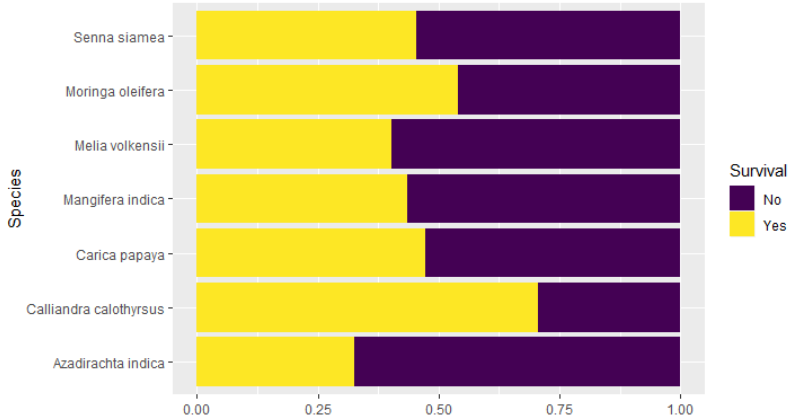

Figure 18.Survival rates for each of the considered trees species.

If we combined both "species" and the "nurseries" variables, we can then extract table 14. This table shows for example that the best survival of "Azadirachta indica" (for which we had the lowest survival rate in Kenya) was obtained when the plant origin was "Bidii" Nursery.

Table 14. Survival per specie and nursery

	Azadirachta indica	Calliandra calothyrsus	Carica papaya	Mangifera indica	Melia volkensii	Moringa oleifera	Senna siamea
African wood growers				50.00	50.13	0.00	20.00
Bidii Nursery	100.00			43.08	50.00	63.66	
Jishinde ushinde	56.25			17.00	28.13		32.29
Kathonzweni SHG	40.68				20.10		0.00
Katulwa farm				50.00	0.00		62.41
Kitise tree					58.65		
Kwa Ngoka	38.90			30.00	33.90	32.80	33.30
Machakos RRC		70.58		0.00			
Mikengeta				0.00			
Mikuuni	27.04		75.00	32.84	18.07	0.00	32.94
Miti			44.40	40.28	0.00		30.36
Muku	0.00		100.00	67.13	100.00		66.60
Mutembuku				25.00			33.30
Nzambani agricultural CBO	33.30		25.00	29.59	0.00	50.00	
Own							
Sokimau	22.43		0.00	37.06	28.57		42.24
Waita rock	100.00		47.33	61.28		69.69	

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

The effect of some of farmer practices on trees survival rates is provided in table 15. A chi-square test was showing that fertilizer and mulch do not significantly affect the survival of the trees. More information about other management practices can be read in Table 15.

Table 15.Survival probability by a set of variables

Farmer applications		Survival rate (%)	Chi-Square (Sig)	Relationship
Mulch	Yes	41.0	0.09	No sig
	No	42.5		
Manure	Yes	46.6	0.00	Weak (0.097)
	No	36.9		
Fertilizer	Yes	30.3	0.51	No sig
	No	42.2		
Watering	Yes	46.2	0.00	Moderate (0.21)
	No	14.6		
Shade	Yes	49.3	0.00	Weak (0.04)
	No	41.6		
Planting Hole	Big	43.5	0.00	Weak (0.05)
	Other	33.9		
	Small	42.3		
Fencing	Yes	46.9	0.00	Weak (0.05)
	No	40.1		

All these variables were grouped using a CATegorical Principal Components Analysis (Figure 20). Simplified on two axes to extract the most discriminant variables which influence the survival. The most relevant variables are the ones placed far from origin point (Planting Hole, survival, and Manure).

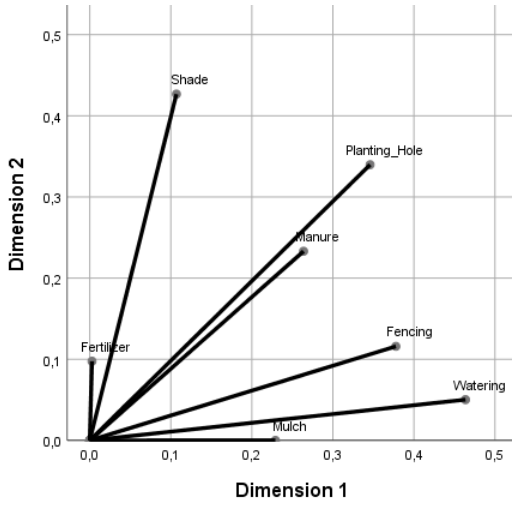

Figure 19. Independent variables classification for farmers practices influencing trees survival rates.

The dataset shows that the different practices shown in Table 15 were combined in six different ways, thus resulting in six different technical packages that were used for all the experiments implemented in Kenya. Table 16 presents these six options/packages and their respective content in addition to number of observations where each of these packages was implemented. Furthermore, table 17 shows

the distribution of these options across the considered counties (5492 in Kitui, 6814 in Machakos and 5190 in Makueni).

Table 16. Description of the tested options/packages and their respective content.

Options	Planting Hole	Manure Quantity (kg)	Mulching	Observations
Option 1	Small*	2	No	662
Option 2	Small*	2	Yes	324
Option 3	Small*	0	Yes	550
Option 4	Big**	4	No	189
Option 5	Big**	4	Yes	130
Option 6	Big**	0	Yes	574
Option 0 (Farmer's practice)	Other***	Other	No/Yes	15088
Total				17517

Small=1.5 ft. diameter x 1.5 ft. depth; Big**=2.5 ft. diameter x 1.5 ft. depth; Other***=Common hole sizes*

Table 17. Distribution of the different trees plantation options across counties

Options County	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Farmers practice	Total
Kitui	189	53	222	38	11	216	4763	5492
Machakos	387	247	308	151	119	346	5256	6814
Makueni	86	24	20	0	0	12	5048	5190
Total	662	324	550	189	130	574	15067	17496

A Chi square test concluded that "Options" and "Survival rates" are linked (with sig. 0.01 < 0.05). Some options (such as Options 1, 4, 5 and 6) increase the survival probability Compared to farmer practice. However, other options, such as Options 2 and 3, decrease the survival probability compared to farmers practice (Table 18).

Table 18. Distribution of survival by options with comparison to farmers practice.

Options	Survival		Total
	No	Yes	
Farmer Practice Option 0	57.80%	42.20%	100.00%
Option 1	57.70%	42.30%	100.00%
Option 2	63.90%	36.10%	100.00%
Option 3	62.50%	37.50%	100.00%
Option 4	56.10%	43.90%	100.00%
Option 5	53.10%	46.90%	100.00%
Option 6	53.00%	47.00%	100.00%
Total	57.80%	42.20%	100.00%

Figure 21 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, Melia volkensii and Senna Siamea.

Figure 20. Survival rates for the different "specie X option"

We also analyzed the survival rates across "options X niches" (see Figure 23). This shows that survival rates of trees are significant across all "options X niches" except option 6. This indicates that the niche in which we implement the management options matters for the survival of the trees.

Figure 21. Survival rates distribution across "options X niches" cases.

Performances of the survived trees.

For the survived trees two other variables have been measured, the height and the diameter of the tree. The height of the tree (all trees considered together) varied from 2 to 1,008 cm, the calculated mean was equal to 76.9 cm. The diameter at the root collar varied from 0 to 160 cm, the calculated mean was equal to 5.48 cm (Table 19).

Table 19.Statistical description of height and diameter of the survived trees

Variables	N	Plage	Min	Max	Mean
Height	6517	1006	2	1008	76.92
Diameter	4695	160	0	160	5.48

An ANOVA test showed that differences of height and diameter between the counties (figure 23 and 24) are significant at 5%, we then proceeded with a Tukey test, for pair wise comparison of means across the three counties. Results (Table 20) shows the level of statistical significance of differences in height and diameter of trees across counties.

Table 20.Tukey test for height and diameter of survived trees.

Dependent variable	County	County	Diff	Sig.
Height	Kitui	Machakos	42.774*	0.000
		Makueni	1.886	0.189
	Machakos	Kitui	-42.774*	0.000
		Makueni	-40.888*	0.000
	Makueni	Kitui	-1.886	0.189
		Machakos	40.888*	0.000
Diameter	Kitui	Machakos	3.369*	0.000
		Makueni	1.560*	0.000
	Machakos	Kitui	-3.369*	0.000
		Makueni	-1.809*	0.000
	Makueni	Kitui	-1.560*	0.000
		Machakos	1.809*	0.000

The average measured height of trees in Kitui was about 91.41 cm which is higher than the average height values of 89.5 cm and 48.63 com, respectively recorded in Makueni and Machakos (Figure 24). Results of the ANOVA and Tukey tests allow to rank the counties based on the average height and diameter of the trees. This ranking is presented in Table 21.

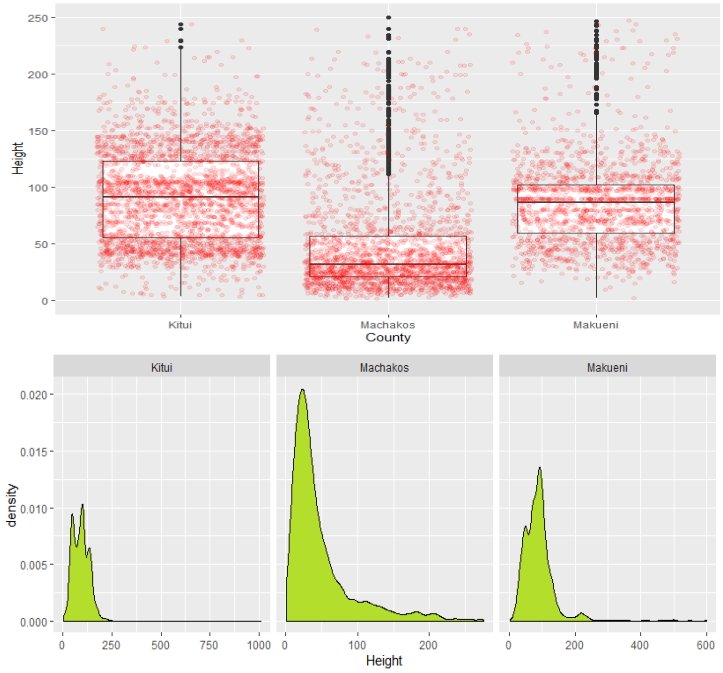

Figure 22. Distribution of Height of trees per county.

Table 21.Multiple comparison table of trees height

Test	Conclusion
Kitui Vs Machakos	Kitui > Machakos
Makueni Vs Machakos	Makueni > Machakos
Other Combination	No sig

The measured diameter of trees in Kitui is about 6.4 cm which is higher than the values of 5.28 cm and 3.47 cm respectively obtained in Makueni and Machakos (Figure 24). Only the significant combinations obtained in Table 20 can however be compared. results of the Tukey test for pairwise comparison of counties and for ranking these counties based on the average value of tree's diameter obtained are presented in table 22.

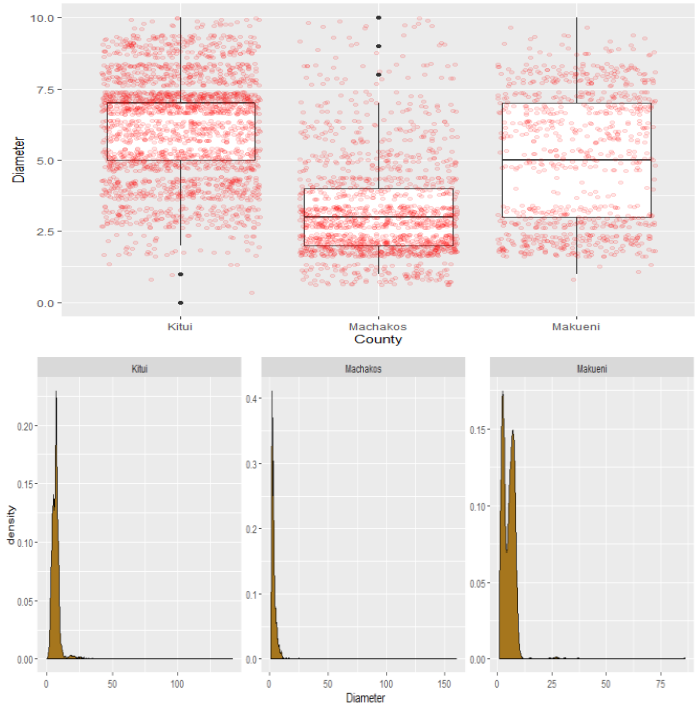

Figure 23. Diameter distribution and density in the three counties

Table 22.Multiple compare tables

Test	Conclusion
Kitui Vs Machakos	Kitui > Machakos
Makueni Vs Kitui	Makueni < Kitui
Makueni Vs Machakos	Makueni > Machakos

Another ANOVA test showed that differences of height and diameter between species (figure 26) are significant at 5%, we then proceeded with a Bonferroni test, for pair wise comparison of means across different species. Results (Table 23) show the classification of the trees species based on their respective average height (from the smallest one to the highest).

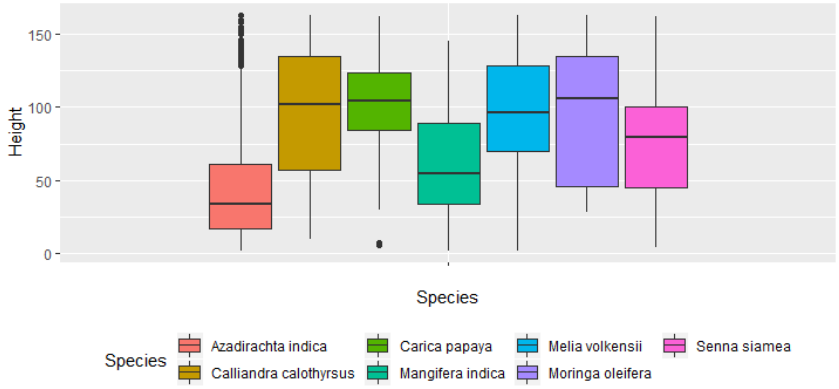

Figure 24. Distribution of tree's height for the different species

Table 23. Bonferroni test for differences of trees diameter across species

Species	N	For alpha = 0.05					
		1	2	3	4	5	6
Azadirachta indica	718	46.83					
Mangifera indica	2824		60.21				
Senna siamea	834			77.82			
Melia volkensii	1303				102.49		
Moringa oleifera	525					114.37	
Carica papaya	159					119.02	
Calliandra calothyrsus	154						131.53

To further distinguish the differences between trees experiments in terms of height and diameter, we have to further explore the resulting diameters of the considered combinations of "species X nurseries". With the method of estimated marginal means, we can compare the same tree specie in different nurseries (Figure 27).

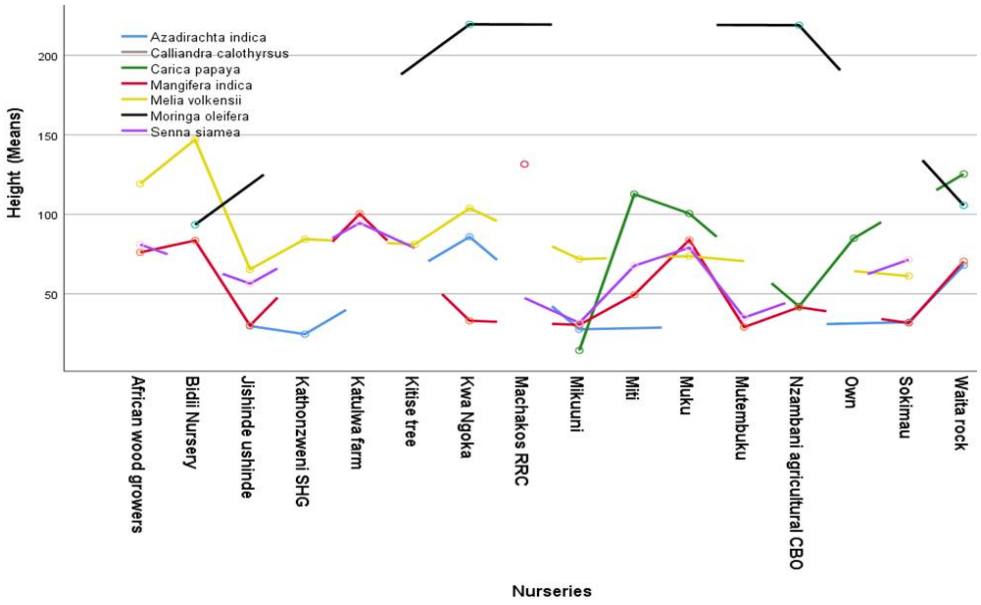

Figure 25. Average height trees distributed by "species X nurseries"

For the survived trees we also tested the correlations between the main farmers practices such as manure, use of fertilizers, etc. with the height and diameter of trees. Pearson Correlation test was used to draw these correlations. Figure 28 Shows that watering and height are negatively correlated. It also shows that an increase of the time of watering (number of hours watering) will increase also the time of mulching (number of minutes spent for mulching).

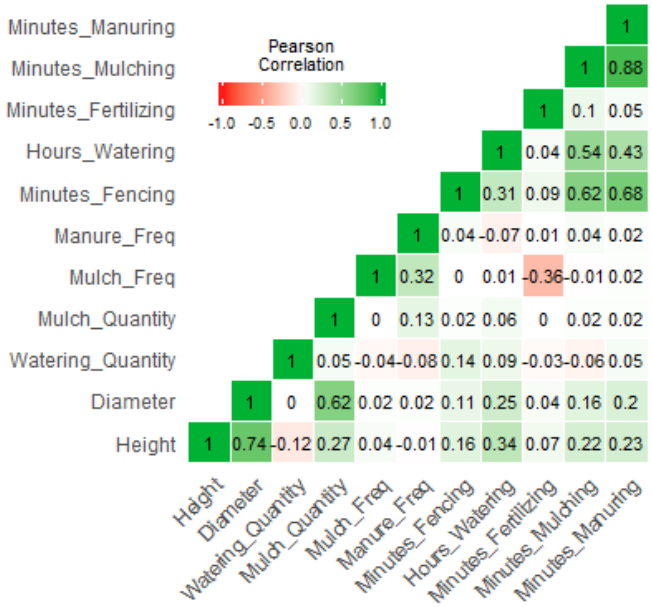

Figure 26.Correlation heatmap between independent variables in relation to tree's height and diameter

Taking the six identified technical options/packages identified in the dataset and illustrated in table 16, an ANOVA test showed that differences of height and diameter between these options (figure 28) are significant at 5%. We then proceeded with a Tukey test, for pair wise comparison of means across different options. Only significant comparisons are grouped in table 24. Results show Option 3 is not significantly different from other options, and thus we cannot compare it with Farmer Practice. The only conclusion that we can give through this test is that farmers' practice gave a better height compared to Op1, Op2, Op3, Op4.

Table 24. Tukey test height mean comparison by options

Option	Option	Diff	Sig
Farmer Practice	Option 1	12.68*	0.001
	Option 2	17.28*	0.006
	Option 5	30.92*	0.00
	Option 6	10.78*	0.022
Option 1	Option 3	-17.34*	0.007
Option 2	Option 3	-21.94*	0.006
Option 3	Option 5	35.58*	0.00
	Option 6	15.44*	0.038

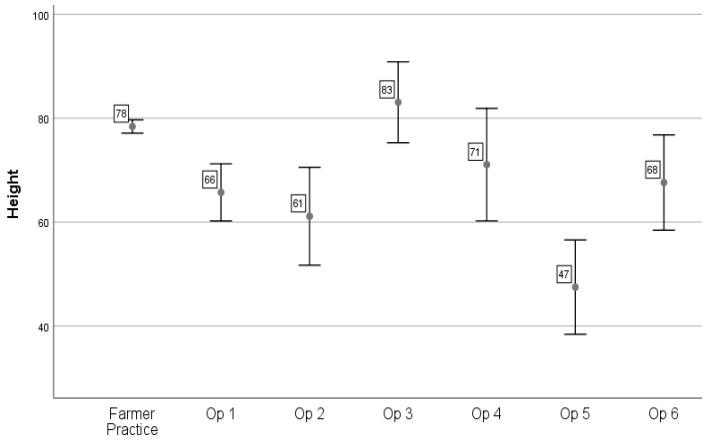

Figure 27. Distribution of tree's height by options

Figure 28 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 28). This analysis shows that Most important height was obtained for Moringa as planted using technical package/option 2.

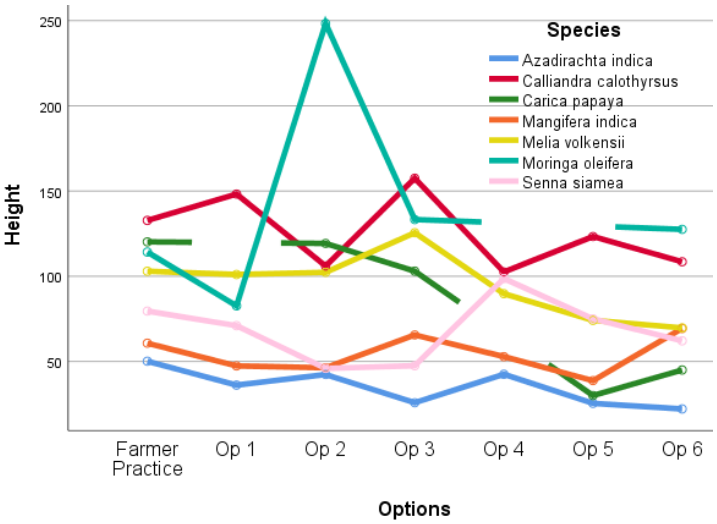

Figure 28. Height by species and options

Conclusions.

This report analyzed socioeconomic and tree's experiment data in Kenya for the year 2018. 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.