FACULTY OF SCIENCE
UNIVERSITY OF COPENHAGEN

Master Thesis

Vilde Maria Lavoll

Survival of fruit and multipurpose tree seedlings planted to restore degraded land in smallholder agroforestry systems in Saesi Tsaeda Emba, Tigray, Ethiopia

Agris Mundus, Sustainable Development in Agriculture
Montpellier SupAgro, University of Copenhagen

Jury president: Dr Emmanuel Torquebiau (CIRAD)

Members of jury: Didier Pillot (Montpellier SupAgro), Lars Holger Schmidt, (University of Copenhagen) and Leigh Ann Winowiecki (ICRAF Nairobi)

Submitted 28. 10. 17

Abstract

Land degradation has been a severe problem in the northern Ethiopian highlands and many studies have demonstrated that agroforestry can serve as a successful tool in restoring degraded lands. Tree planting has hence been included in many land restoration projects, but the survival of seedlings has been low. The objective of this study is therefore to better understand the factors affecting survival of tree seedlings planted to restore degraded land on smallscale farms in Saesi Tsaeda Emba woreda in Tigray, Ethiopia.

The species *Mangifera indica, Coffea arabica, Rhamnus priniodes, Psidium guajava, Casimiroa edulis, Faidherbia albida, Acacia seyal, Persea americana* and *Moringa oleifera* were planted on 59 farms in three watersheds in an on-farm field trial, called planned comparison. Before planting the seedlings, participating farmers agreed upon certain irrigation and mulching treatments. Data on survival, growth, agroecological conditions, stress factors and seedling care were collected 12 months after planting and analysed using a logistic regression model. Focus groups and semi-structured interviews were used to triangulate the findings and to collect data on socioeconomic factors.

Agroecological conditions were found to affect the survival of tree seedlings, but their resilience varied between species. Shade was the only agroecological condition that had a significant positive effect regardless of species. The practices fertilization and shelter had a significant positive effect on seedling survival, while fencing was found to be less important. Weak seedlings were an important mortality reason for *Faidherbia albida.*

Treatments with the most water and most frequent irrigation had the highest survival rate, but it was also shown that the presence of mulch increases the probability of survival when the quantity and frequency of irrigation were reduced. Both the seedling care and survival differed significantly between socioeconomic groups. Farmers with limited labour capacity showed a significantly lower use of seedling care practices, but not a lower seedling survival, than the other farmers. The trees of old farmers were found to have a significantly higher survival than the other trees while the trees of young farmers had a significantly lower survival rate than the other trees. The study showed that the survival of tree seedlings is a result of complex interactions between species, agro ecological conditions and seedling care and studies with larger samples sizes are needed to identify single determinants of success or failure.

Résumé

La dégradation des sols est un problème majeur dans les hauts plateaux du Nord de l'Ethiopie et l'agroforesterie s'est révélée être, à travers de multiples études, un outil efficace pour restaurer ces sols. La plantation d'arbres a donc été mise en œuvre dans de multiples projets de restauration, mais une faible survie des jeunes plants a été constatée. L'objectif de cette étude est de mieux comprendre les facteurs influençant la survie des jeunes plants utilisés pour la restauration de terrains dégradés, dans les petites exploitations localisées en Saesi Tsaeda Emba, Tigray, Ethiopie.

Les espèces *Mangifera indica, Coffea arabica, Rhamnus priniodes, Psidium guajava, Casimiroa edulis, Faidherbia albida, Acacia seyal* et *Moringa oleifera* ont été plantées dans les parcelles de 59 exploitations situées sur trois bassins versants différents. Les exploitants ont appliqué différents traitements d'irrigation et de paillage sur les jeunes plants. Des données concernant le taux de survie, la croissance, les conditions agro-écologiques, les facteurs de stress et les conditions d'entretien ont été collectées 12 mois après la plantation, et analysées à l'aide d'un modèle de régression logistique. Des groupes de discussion et des entretiens semi-directifs ont été menés pour trianguler les résultats et récolter des informations sur les facteurs socio-économiques.

Il a été montré que les conditions agro-écologiques affectent le taux de survie des jeunes plants, mais de manière différente selon les espèces. L'ombrage est le seul paramètre agro-écologique ayant un effet significativement positif, quelque soit les espèces. La fertilisation et l'abri ont un effet significativement positif sur la survie des jeunes plants, tandis que les clôtures ont un effet moindre. La cause principale de mortalité chez *Faidherbia albida* est la mauvaise qualité des plants livrés aux exploitants.

Les traitements avec une quantité d'eau et une fréquence d'irrigation élevées favorisent un taux de survie élevé, mais il a également été montré que la présence de paillage augmente la probabilité de survie lorsque la quantité d'eau et la fréquence d'irrigation sont réduites. L'entretien des jeunes plants et le taux de survie diffèrent significativement avec les groupes socio-économiques. Les exploitants avec une main d'œuvre limitée mettent peu en œuvre les pratiques d'entretien des plants, mais ne présentent pas un taux de survie inférieur à celui des autres exploitants. Les vieux exploitants possèdent des jeunes plants avec un taux de survie significativement plus élevé que celui des jeunes.

Table of Contents

List of figures

List of tables

List of abbreviations

CAP: Community action planning

CEC: Cation exchange capacity

EU: European Union

EC: European Commission

FAO: Food and agriculture organisation of the United Nations

FDG: Focus group discussion

GDP: Gross domestic product

GTZ: German Organisation for Technical cooperation

ICRAF: International Centre for Research in Agroforestry. Brand name: World Agroforestry Centre

ILRI: International Livestock Research Institute

IWSM: Integrated watershed management

ODK: Open Data Kit

RCC: Root collar circumflex

SSI: Semi-structured interview

UNCCD: United Nations Convention to Combat Desertification

Preface

This master thesis is written as a completion of the Master degree Agris Mundus, sustainable development in agriculture at the Faculty of Science, University of Copenhagen and Montpellier SupAgro. The report is written under the supervision of professor Didier Pillot from Montpellier SupAgro, professor Lars Holger Schmidt from University of Copenhagem and Leigh Ann Winowiecki from ICRAF Kenya. The fieldwork was carried out in cooperation with World Vision Ethiopia in Saesi Tsaeda Emba woreda from May to August 2017 and the writing of the thesis took place between August and October 2017.

This thesis would not have been possible without the help and support of a number of people. First of all, thanks to my 3 supervisors. Thanks to Didier Pillot for inspiring talks and support. Thanks to Leigh Winowiecki for always being present with encouraging feedback and guidance. Thanks to professor Lars Holger Schmidt, for volunteering to be my supervisor and for his engagement and committed supervision. Thanks to ICRAF for giving me the unique opportunity to work with them as a research fellow and for their financial support of my fieldwork. I am very grateful for the warm welcome at the ICRAF campus in Nairobi and the ILRI campus in Addis Abeba. Thanks to Samuel Hailu, Niguse Hagazi and Kiros Hadgu and especially to Mekdes Sime for extraordinary help with the visa. Thanks to World Vision Ethiopia for making me feel at home in Freeweyni, and for their hospitality and friendly support. Thie fieldwork would be impossible without the efforts, humour and company of my two interpreters Hagos Gebre and John Abraha. Thanks also to John Nyaga at ICRAF Nairobi for all the support during the construction and correction of the ODK survey. Thanks to Ric Coe for tirelessly answering all my questions about statistics during the data analysis. Thanks to my friend Emily Kinsel for corrections and to my friends and flatmates Jérémie Coédon and Amalia Sacchi for making the fall of thesis writing in Montpellier an enjoyable experience.

Montpellier, October 28th 2017
Vilde Maria Lavoll

1. Introduction

Ethiopia is one of the oldest populated places on earth, and the natural vegetation cover has been affected by human activities since the origin of civilization (Adekumobi 2007). The natural ecology would support forest vegetation in most of the country, but today agricultural land occupies 33% of the country and gives work to 83 % of the population (FAO 2016). During the last century the Tigray region in northern Ethiopia has undergone a land degradation process driven by deforestation in order to clear land for feeding a growing population (Gelaw et al. 2014). The Tigray region is mountainous and cultivation on the steep hills in combination with overgrazing and decreasing tree cover leads to erosion (Mekuria et al. 2007).

In Tigray, firewood for cooking is in high demand and this is amongst the reasons that in 2005 deforestation had almost completely eradicated the region's trees (Nedessa et al 2005). The lack of fuel wood has furthermore lead to a decrease in soil fertility because dung and crop residues are used as fuel instead of being used as fertilizers (Bekele-Tesemma 1997). As a result the content of soil organic matter decreases, which further increases the risk of soil erosion (Nair 1993). Tigray is amongst the most drought prone regions in Ethiopia with low annual rainfall and recurring droughts. Crop failure caused by land degradation and drought has led to food insecurity, resulting in an annual cereal deficit of 180 000 t in the Tigray region (Hagos et al. 2016). Saesi Tsaeda Emba, the location of the fieldwork of this study, is identified as a chronically food insecure woreda (district or third level administrative division in Ethiopia) by the Ethiopian Government and two thirds of the 150 000 residents were dependent on food assistance in 2008-2009 (DPPA 2008, cited from Maxwell et al 2013). One of the main causes of the food security situation is land degradation; therefore land restoration is seen as a key intervention in reversing the downward spiral of land degradation and poverty (World Bank 2007a).

Box 1: Definition of land degradation and land restoration

Land degradation: The persistent decline in the capability of land to provide ecosystem services, especially those concerned with the provision of biological products such as forage, food, fibre and timber.

Land restoration: reversing the land degradation process and enhancing ecosystem services through the adoption of recommended management practices and restorative land uses.

Lal et al. (2012)

1.1 Development policy and political background

Land restoration in Ethiopia was started by the communistic Derg regime in the 1970s, which nationalised all land under the slogan "land to the tiller". The government's nationalisation of the land was made without compensation, and especially in the north there was resistance to the land reform. Food for work projects were used to build terraces and plant trees but they were not very successful because farmers were not involved in the planning stages. In addition, many farmers used these projects as a means to get food instead of as a mean to make useful improvements in soil quality. Farmers would for example uproot their tree seedlings in order to be paid food to plant again by the government (Bekele-Tesemma 1997).

The development sector has been heavily involved in land restoration in Ethiopia around $ 20 million were disbursed yearly during the 1980s and 90s from a range of donors including the FAO, EU and GTZ (German technical cooperation) (Bekele-Tesemma 1997). However, only 25 % of their project goals were reached during this period and the majority of the terraces and forest plantations were destroyed (Alemayehu 1996). The disappointing outcome of these projects was a result of a range of factors but the lack of participation and involvement of the farmers is a common shortcoming (Scoons et al 1996), as well as the projects ignorance of local knowledge and conservation techniques (Kruger et al 1996). Consequently, in 1993 it was estimated that the annual deforestation rate was between 80 000 and 90 000 ha (EFAP 1993).

After the fall of the Derg regime and the establishment of the Federal Democratic Republic of Ethiopia in 1991, the new government expended many resources to promote soil and water conservation. Lessons learned from the failures of past restoration projects have led to the implementation of the integrated watershed management approach (IWSM). The returns on investment in this approach have been high (World Bank 2007a). Land tenure is a crucial factor in a farmer's willingness to invest in soil restoration and, in particular, agroforestry practices. The Rural Land Administration and Use Proclamation, established in 2005, states that any person above 18 years who wants to make a living in agriculture has the right to use land and be given a certificate describing his or her plot (World Bank 2007a). Furthermore Ethiopia has invested heavily in agricultural extension and it now has one of the highest ratios of extension officers to farmers in the world (World Bank 2016). A result of the active investment in extension services, establishment of land tenure, increased access to inputs and availability of improved varieties is an average yield growth for all crops by 7% per year, which has proven to be one of the main drivers behind a growth in GDP from 8 to 60 billion during the last 15 years (World Bank 2016)

1.2 Agroforestry for land restoration

A number of different measures have been implemented to restore the degraded lands in Tigray such as exclosures, stone buds and planting of trees and grasses. Exclosures are plots of land that are taken out of production, with trees allowed to grow and grazing animals kept out (Nedessa et al. 2005). Stone buds are 0,3 -1,2 m high walls built along contours to catch eroding soil, and have been widely adopted in Tigray. Nyssen et al. (2007) found that stone buds decrease soil loss by sheet and rill erosion by 68 % in Tigray. Stone buds and other physical constructers, however, are labour intensive and their effectiveness decreases with time (Nyssen et al. 2004).

Planting of trees has been found to decrease erosion by increasing water infiltration, intercepting rainfall, and reducing the volume and velocity of runoff as well as providing soil stabilization through the roots (Reubens et al. 2007, Nair 1993, Scrothc & Sinclair 1999). Planting of trees in agroforestry systems can furthermore provide many other benefits in addition to reducing erosion, such as nitrogen fixation, animal fodder, firewood, timber, fruits, honey and medicine, depending on the tree species chosen (Nair 1993). Garrity (2004) found that agroforestry has the potential to increase food security, reduce poverty and ensure environmental sustainability. The diverse uses of agroforestry make it an efficient tool for land restoration and the sustainable intensification that is needed to meet the needs of the growing population in Tigray.

Box 2. Definition of agroforestry

Agroforestry is a set of land use practices that involve the deliberate combination of woody perennials including trees, shrubs, palms and bamboos, with agricultural crops and/or animals on the same land management unit in some form of spatial arrangement or temporal sequence such that there are significant ecological and economic interactions among the woody and non- woody components

(Sinclair, 1999)

Agroforestry has been used to restore degraded lands with great success e.g. in Niger where 5 million ha of degraded land have been restored using agroforestry techniques such as planting of *Fadherbida albida* in combination with zai pits and stone buds (Reij et al 2009). The United Nations Convention to Combat Desertification (UNCCDD) estimated that of the two billion ha suitable for forest and landscape restoration worldwide, agroforestry would be among the best solution for restoration of 1.5 billion ha (Lal et al. 2012).

Although recent research highlights the benefits of agroforestry, it should be kept in mind that agroforestry leads to competition for light, water and nutrients with crops and should be carefully planned to make sure trees use of the resources which are not in direct competition with crops (Malezieux et al. 2009).

The experience with agroforestry for land restoration in Tigray is limited, and when it has been applied, the survival of tree seedlings has been low (Reubens et al. 2009). The survival rate of seedlings is a result of a complex interaction between agroecological and socioeconomic factors, and a better understanding of this is needed to facilitate the long-term sustainability of the planted agroforestry systems. Reubens et al. (2009) studied the survival of 3 multipurpose trees planted in gullies in Tigray, but studies on the survival of other multipurpose and fruit tree seedlings in the same region are lacking.

Seedling survival

The survival of planted tree seedlings in afforestation and reforestation projects in Ethiopia has been low (Yohannes 1999). Many factors influence the survival of the seedlings and their importance varies according to species and agroecological conditions (Reubens et al. 2009). Insufficient soil moisture during the early growth stage is one of the most important causes of high seedling mortality; hence watering during this period can improve seedling survival (Yohannes 1999, Khurana & Singh 2001). In a dry climate, keeping water as long as possible in the root zone is of great importance, and Yohannes (1999) found that *Acaia saligna* had a significantly better growth when surface mulch was applied in combination with a sand barrier. A study carried out on seedling survival in gullies in Tigray compared three multipurpose tree species under high and low irrigation treatment and different gully and shelter position (Reubens et al. 2009). In this case the researchers found that irrigation did not have a significant influence on the seedling survival. The most influencing factor was found to be animal browsing and grazing and especially uprooting by rodents. Shelter was also found to have a significant effect on some of the species. Furthermore, weeds can pose a threat to the planted seedlings especially in the first year, due to competition for water, nutrients and light, and weeding can have a positive effect on seedling survival (Andres et al. 2011). Still however, few studies have been conducted on the importance of seedling care for the survival of tree seedlings and hence the framework shown in figure 1 was constructed especially for the analysis in this study.

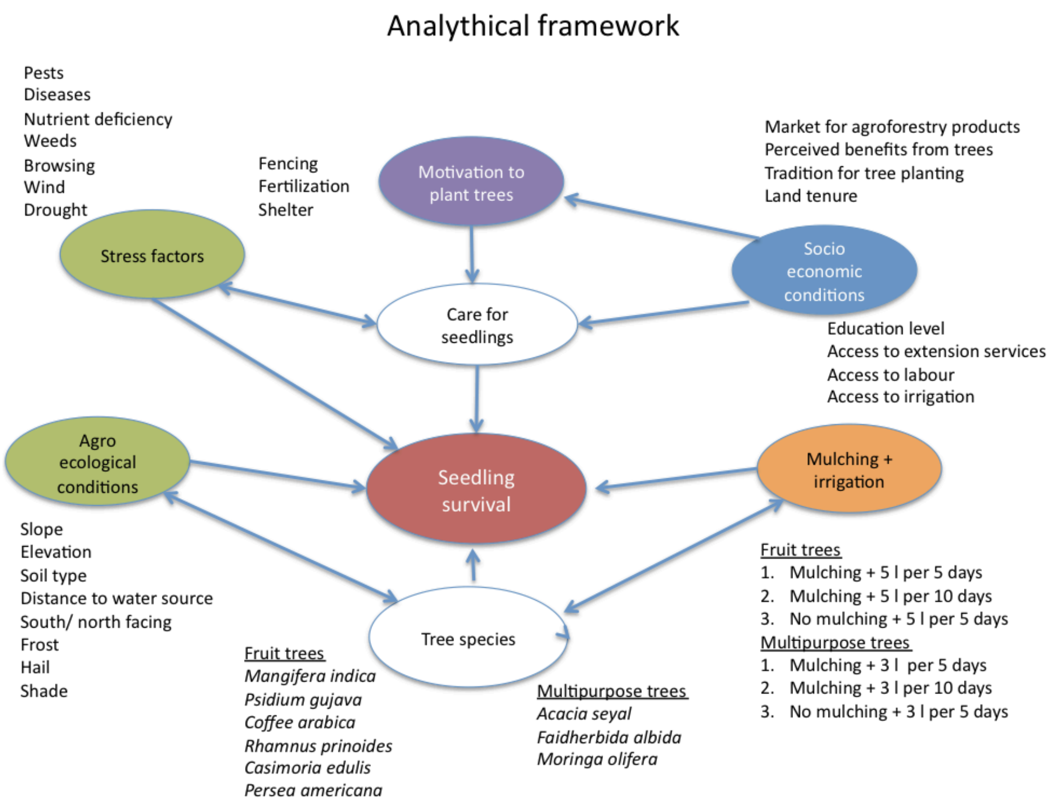

Figure 1: Analytical framework.

According to Garrity (2004), one of the main barriers for adoption of agroforestry by smallholders is the marketing of agroforestry products. Coe et al. (2014) stated ten years later that market access is still one of the main challenges. According to Godoy (1992) both the prices for agroforestry products and alternative crops affects farmer's decision to plant trees and their choice of which tree species to plant. Since the crop will not be ready for harvest in many years, the mechanism is more complex than for many other crops, but a sufficiently high price will encourage a smallholder to plant a tree even if there is a high risk related to the outcome (Godoy 1992). Hagos & Holden (2006) found that perceptions of the benefits of conservation are important factors that influence the willingness to invest in soil physical conservation measures. However, studies are lacking on the relation between perception of benefits of trees and the motivation to plant and care for them (Figure1). Irrigation of the seedlings is an additional activity that might be challenging to incorporate in households with limited labour capacity and during busy farming periods, seedling care might be neglected. Additionally, farmers who lack knowledge about trees and tree planting are likely to have a lower seedling survival rate because firstly they might not know how to properly care for the seedlings and, secondly, because they are not aware of the benefits of the trees and are therefore less motivated to help them survive. Farmers with limited access to irrigation water could have difficulties with following the treatments and hence have a lower seedling survival. If the closest water source is far away, collecting water for irrigation could pose a significant workload increase and during periods with many other farm activities, irrigation might be neglected.

1.4 Problem statement

According to previous studies (Garrity 2004, Reij et al. 2009), it is beneficial for smallholder farmers in degraded dry lands to adopt agroforestry, but there are also some challenges connected to its implementation. One of these challenges is the survival of the seedlings, which is a determining factor for the long-term sustainability of agroforestry-based land restoration.

In the dry climate of Tigray water is indeed a scarce resource, and use of water for irrigation should be kept to a minimum. Sufficient water is, however, crucial to the survival of tree seedlings, especially during the dry season (Yohannes 1999). The amount of water needed to ensure survival varies according to the agroecological conditions and the tree species (Reubens et al. 2009), and few studies have been carried out on different agroforestry species in the Tigray region and Saesi Tseada Emba in particular. Practices such as mulch application are expected to decrease the amount of water needed, but it is not known to what degree such techniques can affect the seedling survival. Overall, knowledge concerning specific local conditions and their effect on the resilience of agroforestry systems is important for smallholders' willingness to adopt agroforestry (Coe et al. 2014).

In addition to the physical factors that affect the seedlings, socioeconomic factors might have a great influence on the seedling survival through differences in the use of seedling care practices. Investment in the seedlings could vary based upon a farmer's motivation to plant trees and his or her perception of their benefits. Furthermore, the amount of time, resources and knowledge farmers can dedicate to seedling care differs and this factor could also explain why some farmers succeed and others do not.

The objective

Analyse the factors affecting survival of fruit and multipurpose tree seedlings planted to restore degraded land in smallholder agroforestry systems in Saesi Tseada Emba, Tigray, Ethiopia

The research questions

1. How do agroecological conditions, seedling care, irrigation and mulching affect the survival of tree seedlings?

H. 1.1 Agroecological conditions have a significant effect on seedling survival and this effect varies between species.

H 1.2 Stress factors have a significant effect on seedling survival and can be mitigated through proper seedling care.

H 1.3 Mulching increases the survival of tree seedlings and reduces the quantity of water needed to make seedlings survive

2. How does seedling care vary between farmers, and what influences farmers' motivation and ability to care for trees?

H 2.1 Perceptions of the benefits of tree planting affects the motivation to plant trees and, furthermore, the willingness to invest the necessary time and resources to ensure their survival.

H 2.2 Perceptions of the benefits of trees, motivations to make them survive and even survival rates are related and differs according to farmers' socioeconomic groups.

H 2.3 Socioeconomic factors can limit the ability to take care of trees, and hence the survival varies with socioeconomic group.

3 Methods

3.1. Study location

The fieldwork of this study was conducted in Saesi Tsaeda Emba, a woreda in the northeast of the Tigray region, which is located in the northern highlands of Ethiopia (figure 2). The study participants lived in three watersheds, May Hantso, Takot and Dimello, all within a distance of approximately 20 km.

Figure 2: Map of Tigray, and the study location. Source: Google earth

The climate in Saesi Tsaeda Emba is cold and semi-arid, with an elevation varying from 2259 m on the lowest farm in May Hantso to 2686 m on the highest farm in Takot. The mean annual 9temperature is 15.8 °C, the mean annual precipitation is 592 mm and hail and frost can occur in the high elevation areas, which can threaten crop production (Maxwell et al 2013). Figure 3 shows that the dry season lasts from September to February followed by two rainy seasons. The first, with a peak in April is called Meher and the second, called Belg takes place in July and August (FAO 2016). Access to water is a significant constraint for both humans and livestock in Saesi Tsaeda Emba (Maxwell et al. 2013), but through the last 10 years wells and canals have been constructed to make irrigation possible.

The soils in the neighbouring woreda, Kilte Awulaelo, were mapped in detail by Rabia et al. (2013) and in this woreda the dominant soil types are leptosols (36%), calcisols (16%) and vertisols (15%). The pH for the leptosol was 8.3 and the mean pH for Kilte Awulaelo was slightly alkaline at 7.8. The leptisols were characterised by a low to medium nitrogen availability, a medium to high phosphorous availability and a high to very high cation exchange capacity (CEC) (Rabia et al. 2013). This soil was, in other words, classified as relatively fertile. No detailed soil information exists for Saesi Tsaeda Emba, but it is assumed that it resembles the soil of Kilte Awulaelo.

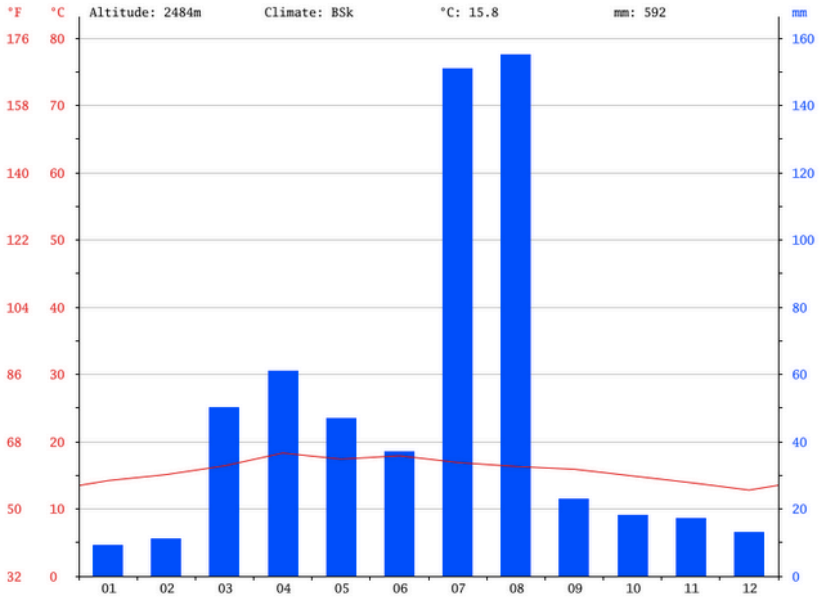

Figure 3: Climate graph Freweyni, Saesi Tsaeda Emba. Source:climate-data.org

.

Demographics and livelihoods

Saesi Tsaeda Emba has a population of about 150 000 people, an area of 251 147 ha and its population's livelihoods depend mainly on agriculture. The language spoken is Tigrinya, the main language in the whole Tigray region and the south of Eritrea. There are few off-farm work opportunities in Saesi Tsaeda Emba, unemployment is high, especially amongst landless youth, and labour migration is, hence, an important livelihood strategy (Maxwell et al. 2013). Access to land is a challenge for young people because land tenure is only passed down after their parents die (Coates et al 2010). Beekeeping is increasing as one of the few livelihood strategies for the landless people (Maxwell et al. 2013). The farmers in this woreda are not able to produce enough food for the local consumption and poor households rely on buying about 60 % of their food. The food crisis in 2008 and the following inflation of food prices had a significant effect upon the people of Saesi Tsaeda Emba (Coates et al 2010). The Productivity Safety Net programme was implemented in the woreda in 2005 to address chronic food insecurity. The program focuses on infrastructure construction and soil and water conservation as part of the governments' disaster risk management approach (Maxwell et al 2013). So-called "household package programs" are also promoted in Tsaeda Emba both by NGOs and the public institutions. Interventions such as bee keeping, improved crop production inputs and livestock fattening are combined with loans from a micro finance institution a cooperative or an extension office (Coates et al. 2010).

The host project

ICRAF (World Agroforestry Centre) was funded in 1978 to promote agroforestry research in developing countries and is today the world's leading institution on agroforestry research. ICRAF has been working in Ethiopia since 2008 and has completed 5 projects on climate change adaption, carbon sequestration and rainwater management. This master thesis was part of the project "Restoration of degraded land for food security and poverty reduction in East Africa and the Sahel: Taking land restoration to scale" funded by International Fund for Agricultural Development (IFAD) and the European Commission (EC) (http://www.worldagroforestry.org/project/restoration-degraded-land-food-security-and-poverty-reduction-east-africa-and-sahel-taking). The project engages with the Dryland Development Programme (DryDev programme) (https://drydev.org/), which is funded by the Dutch Ministry of Foreign Affairs and World Vision Australia. The IFAD/EC project has a timeline from March 2015 to June 2020. The project involves farmers across five countries in sub-Saharan Africa: Kenya, Ethiopia, Tanzania, Niger, and Mali. In Ethiopia DryDev selected six woredas: Saesi Tsaeda Emba, Saharti Samre, Boset, Kilte Awulaelo, Jarso and Gursum. The fieldwork for this thesis was conducted in Saesi Tsaeda Emba where partner organisations included the Relief Society of Tigray (REST), The Orthodox Ethiopian Church with World Vision Ethiopia as the main implementation partner.

3.2 Sampling and project design

A sample of 59 farms was studied for this thesis. These farmers were selected because approximately 60 farmers were participating in the tree planting part of the planned comparison in each watershed, and data were to be collected at all farms 12 months after planting. The initial sampling of the 59 farmers participating in the project was made as a purposeful sampling by World Vision in consultation with the local watershed committee and the farmers volunteered to join. Biophysical factors such as access to water and socioeconomic factors such as plot size, were taken into account during the sampling process.

DryDev conducted a participatory process called community action planning (CAP process), to identify key learning priorities for each of the communities and consultation with the watershed committee (DryDev 2015). In summary, communities identified five fruit trees and four multipurpose tree species for planting on the farms; Apple (*Malus domestica),* guava *(Psidium guajava),* coffee (*Coffea arabica),* casimiroa (*Casimiroa edulis)*, dogwood *(Rhamnus prinoides),* apple ring acacia *(Faidherbia albida),* White thorn (*Acacia seyal)* Sudan teak (*Cordia africana),* and moringa *(Moringa oleifera)*. Because of issues in accessing apple seedlings, the farmers who chose apple did not get their seedlings, and they were instead offered apple mango (*Mangifera indica)* seedlings seven months later. None of the farmers planted Sudan teak (*Cordia africana)* on their farms. Avocado (*Persea americana*) was also planted on a few farms.

The agroecological limitations of the different species can be seen in Table 1. The conditions marked with red in Table 1 cannot be met in Saesi Tsaeda Emba and might be the cause of seedling death or reduced growth and performance throughout the life of the tree.

Table 1 Biophysical limits for the planned comparison species. Red indicates that the limit is exceeded in Saesi Tsaeda Emba. Source: World Agroforestry database 4.0

	Max altitude	Min mean annual temp	Min mean annual rainfall
Mangifera indica	1200 m	19 °C	300 mm
Coffea arabica	3000 m	15 °C	1500 mm
Rhamnus prinoides	2100 m	0°C	
Psidium guajava	2000 m	0°C	1000 mm
Faidherbia albida	2700 m	18 °C	250 mm
Moringa oleifera	1000 m	12.6 °C	500 mm
Acacia seyal	2000 m	18 °C	250 mm
Casimiroa edulis	2400 m	18 °C	
Persea americana	2500 m	-4 °C	300 mm

As can be seen in Table 1, all the chosen species, except *Persea americana*, have some limitations that can render them less suitable for the condition in Saesi Tsaeda Emba with an altitude 2400 m, a mean annual temperature of 15.8 °C and a mean annual rainfall of 592 mm (Figure 3). *Faidherbia albida* was shown to have a positive effect on barley yields when studied on 81 farms in Tigray and is hence one of the species better suited for the climate (Hadgu et al. 2009). *Casimiroa edulis* is also expected to be relatively well adapted, while a more critical problem is the altitude limitation of *Moringa oleifera* and *Mangifera indica.* Rainfall limitations can be compensated by irrigation, so they are less severe.

Before the tree planting World Vision arranged training both for extension workers and farmers. The seedlings for the fruit trees were purchased from nurseries outside of Saesi Tseada Emba while the multipurpose tree seedlings were collected from the woreda office of agriculture and/ or private nurseries. The farmers decided which species they wanted to grow and were given the choice to plant either along natural borders in the farmland or close to the home compound. The treatments shown in Box 3 were decided during the CAP process where the farmers decided amongst them what they needed more knowledge about. The treatment 5l_5d_m e.g. means that the tree seedling received 5 litres of water over intervals of 5 days and that mulch was applied. The mulching material used was grass.

Box 3. Irrigation and mulching treatments for planned comparison

Fruit trees	**Multipurpose trees**
5 l per 5 days + Mulching (5l_5d_m)	3 l per 5 days + Mulching (3l_5d_m)
5 l per 5 days + No mulching (5l_5d_n)	3 l per 5 days + No mulching (3l_5d_n)
5 l per 10 days + Mulching (5l_10d_m)	3 l per 10 days + Mulching (3l_10d_m)

After planting the seedling the farmers' role was to keep the seedlings protected from livestock and other damage and irrigate and mulch according to the treatments. The farmers were also keeping records of the survival and the costs and benefits of the tree planting as e.g. labour.

3.3 Data collection

All the data collection was carried out with the help of an interpreter translating between Tigrinya and English. Two different interpreters were chosen based on interviews with suitable candidates. Both were young men in the end of the 20s and they both held a bachelor degree from an Ethiopian university, where the courses were taught in English. Both of them were familiar with the farming systems in the area and before the data collection started, the objectives and content of the research were explained in detail.

Structured interviews: n = 59

An online structured interview guide was developed with the Open Data Kit (ODK) system. ODK is an open-source set of tools for creation of surveys and data collection including GPS positions for smart phones (https://opendatakit.org/). The survey included questions about the family (household size, education levels etc.), the farm, (e.g. farm size), the agroecological conditions and the agricultural activities and practices. Each interview lasted approximately 2 hours per farmer. The tree seedlings planted with the planned comparison were counted and measured and farmers were asked questions concerning the management of the seedlings. The collected data was then used to make a farmer profiling in order to understand the contextual variables of the farming system and household characteristics. The farmer profiles were later analysed statistically to find eventual correlations between use of seedling care practices and seedlings survival.

Monitoring: n = 1196 tree seedlings

To monitor seedling survival and growth under different treatments, number of seedlings was recorded and the root collar circumflex and height were measured. The root collar circumflex (RCC) was measured around the bottom of the stem at the point of entry into the soil. If the seedling had several stems, it was noted down and the thickest stem was chosen for measurement. Seedling height was measured from the base of the stem until the top of the top shoot. Hanging seedlings were stretched to their full length. If the top shoot was dead, the tallest branch was measured instead. The farmer was then asked about the treatment of the seedling.

A range of different agroecological conditions and stress factors were observed during the monitoring and they were carried out as follows:

Shade: It was observed if the seedling was shaded from above. This could be from a fence or a tree. The seedling was considered as shaded if more then 50 % of the leaf area was shaded at midday.

Shelter: It was observed if the seedling was sheltered from wind. The seedling was considered sheltered if the wind speed was considerably reduced on at least one side. To estimate this the formula of shelter effect described by Chin & Huxley (1996) was used. Thus the seedling was considered sheltered if it was found within an area 10 times the height of a windbreak. A windbreak could include a house or a shelterbelt of trees or the seedlings could be sheltered by a fence if it was made of stones or fabric.

Fence: It was observed if the seedling was effectively fenced. If the seedling was unreachable for livestock, it was considered fenced. If there was a fence, but not one that protects effectively against livestock, the seedling was not considered to be fenced.

Weeds: If there were weeds to such an extent that they limited the seedling growth it was considered a problem. This factor varied depending on seeding size as weeds are more severe when the seedling is small.

Pests: If more than 20 % of the leaf area was eaten by insects, or if the plant was in any other way significantly affected by insects, it was considered a problem.

Disease: If more than 20 % of the leaf area was covered by chlorosis or necrosis (yellow, brown or black parts) or the plant was in any other way significantly affected by disease it was considered a problem.

Nutrient deficiency: If all the seedlings in a planting site had similar symptoms of nutrient deficiency like systematic chlorosis on new or old leaves or purple leaves it was considered that it was due to nutrient deficiency.

Finally, farmers were asked questions concerning trees fertilization, incidents of hail or frost since tree planting, and eventually what measures were taken to protect the seedlings from stress.

Focus Group Discussion: n=6

To understand the perception of the benefits for farmers to plant trees, six focus group discussions were arranged with farmers sampled form the 59 farmers in the planned comparison. Focus group discussion was chosen as a method given that the choice of tree species was a participatory process where the farmers together decided which trees to plant and that focus groups is a good way for studying group behaviours (Desai & Potter 2006).

It was chosen to conduct the focus groups after the ODK collection so that the topics for discussion could be adapted to the situation found in the field. Participants for the focus groups were selected using stratified cluster sampling. Six socioeconomic groups were identified from the preliminary analysis of the ODK data: three groups of motivation driven farmers; the market oriented farmers, the old farmers and the young farmers and three groups of ability limited farmers; farmers limited by access to irrigation, farmers limited by labour capacity and farmers limited by knowledge about trees. The farmers were invited personally at the farms when possible or by leaving a message with the family or neighbours when the farmers were not present.

The young farmers were defined as 35 years old or younger and all the seven farmers corresponding to this were invited to the focus group. The old farmers were defined as 65 years or older and nine farmers fell into this category of which eight were invited to the focus group.

The group of market oriented farmers were defined as the farmers who mentioned market price or demand for two or more species in the planned comparison as reasons for planting them. A group of nine farmers fell into this group, but only seven were invited to the focus group discussion. All the nine were however included in the statistical analysis. The purpose of the focus group was firstly to see whether my assumption about them as market oriented farmers was correct and secondly, to see if there was an eventual relation between the market orientation and the motivation to care for the seedlings.

The farmers with limited access to irrigation were defined as the farmers with a distance of more than 1 km between the planting site and the water source. 15 farmers fell into this category, but only the 5, which were not part of other groups, were invited. All of the 15 were however included in the statistical analysis.

A group of farmers with low labour capacity was defined using two indicators: Households with fewer than 3 members participating in farming activities and farmers that experienced a significant increase in workload after planting the trees. All the 6 farmers corresponding to these criteria were then invited to a focus group discussion. The purpose of the focus group was firstly to see whether my assumption about them as farmers with low labour capacity were correct and secondly, to see if there was an eventual relation between this and the ability to care for the seedlings.

The original indicators for the group of farmers with limited knowledge about trees were farmers with no access to extension and farmers that were not trained before the tree planting. Thanks to the well-functioning extension service in the area, only 3 farmers fell into this category. Another 3 indicators were therefore added: Farmers that were not part of a tradition for tree planting, farmers that had planted fewer than 100 trees on their farm and farmers with less education than primary school. A group of farmers with low knowledge about trees was then defined by adding the farmers with two or more indicators to the 3 who did not attend training or did not have access to extension. This group of 7 farmers were then invited to a focus group discussion. The purpose of the focus group was firstly to see whether my assumption about them as farmers with low knowledge about trees were correct and secondly, to see if there was an eventual relation to the ability to care for the seedlings.

Motivation driven farmers

For the young, old and market oriented farmers 6 exercises were used. The exercises were created for the purpose with inspiration from (Chambers 1997).

1. A ranking of reasons to plant trees in general, where the farmers were asked to give individual reasons for planting trees on the farms and afterwards ranking them together. The purpose of the exercise was to understand the motivation to plant trees in general and how that differs between socioeconomic groups.

2. The farmers were asked to present individual reasons for participation in the DryDev project, draw a mind map together and discuss. The purpose of the exercise was to find out what makes farmers participate in a development project like DryDev and if the model should be changed or kept as it is according to that.

3. A scoring matrix with species on one axis and reasons to plant the trees on the other. The reasons were taken from the ODK answers. The farmers were asked to decide together on a score of between 0 and 6 coffee beans for each combination in the matrix. Afterwards the scores were discussed and follow up questions were asked to understand the farmers' decisions on scores.

4. The farmers were asked to draw a timeline with the events in the project from the invitation until today. Questions were then asked about what happened at the different events. The purpose of this exercise is to understand if whether or not the farmers got the trees they wished for and to which degree this affected the motivation to care for the seedlings.

5. A scoring matrix with species on one axis and mortality reasons on the other. The reasons were taken from the ODK answers, SSIs with development coordinators and informal conversations with the World Vision staff. The farmers were asked to decide together on a score of between 0 and 6 coffee beans for each combination in the matrix. Afterwards the scores were discussed and follow up questions were asked to understand the farmers' decisions on scores. The purpose of this exercise was to find out why the farmers think the trees died, and if the perceived cause of death differs between socioeconomic groups.

6. The farmers were asked to put as many coffee beans as years they expected to wait until they get a benefit from a given tree species. The purpose of the exercise was to see if the farmers have a realistic picture of the time it takes to get a benefit from the trees and if this affects their motivation to care for the different species. It was also interesting to see if the knowledge about this differs with socioeconomic group.

Ability limited farmers

1. A ranking of the main challenges faced with the trees, where the farmers were asked to give their individual challenges and afterwards ranking them together. The purpose of this exercise was to confirm that the invited farmers were corresponding to the socioeconomic groups by observing if the group rate the expected challenges highest.

2. The farmers were asked the top challenges from exercise 1 to make a mind map by placing the challenges in the middle and make a flow chart with the causes and effects of the challenges and eventual interactions. The purpose of the exercise was to understand the underlying causes of the problems the farmers face to be able to come up with holistic improvement suggestions. Furthermore it was important to understand the effects of the challenges to see what can be gained by improving the situation
3. The farmers were asked about their needs to overcome the challenges one by one. The purpose of this exercise was to create participatory suggestions to improvement and to understand farmers' needs and perception of the situation.

4. The farmers were asked about different actors that could be responsible for helping them, write it down, draw symbols for each actor on a mind map and distribute the cards from exercise 3 on the different actors. The purpose of this exercise was to understand farmers' expectations to the project and if it is within the ability of the project to meet them.

5. A scoring matrix with species on one axis and mortality reasons on the other. The reasons were taken from the ODK answers, SSIs with development coordinators and informal conversations with the World Vision staff. The farmers were asked to decide together on a score of between 0 and 6 coffee beans for each combination in the matrix. Afterwards the scores were discussed and follow up questions were asked to understand the farmers' decisions on scores. The purpose of this exercise is to find out why the farmers think the trees died, and if the perceived cause of death differs with socioeconomic group.

Semi Structured Interview: 4

Semi structured interviews (SSI) (Casley, Kumar 1988) were conducted with the development coordinators in each watershed, the irrigation expert in Takot and the managers of the fruit tree nursery in My Megelta. An interview guide was developed with the research questions as a base.

Grand tour: 3

A walk around the area with a key informant was a good way to get an impression of the watershed and was one of the first things on the program when arriving to a new watershed. In May Hantso it was done with an elderly woman who grew up in the closest village, My Megelta, and knew the history well, in Takot it was done with the irrigation expert and the bee keeping expert, and in Dimello it was done with two farmers we met in the closest village, Idaga Hamus, and walked with the 3 km down to Dimello. Questions were asked about the landscape and farming systems we passed by, and there were no pre-prepared interview guide.

3.4 Data analysis

Cleaning of data

After the data collection was finalised, the data was triangulated with the lists of the trees planted on the farms and the data collected 3 months after planting by World Vision. It was then discovered that 115 trees on 12 farms was not showed or mentioned by the farmers during the farm visits. It was also seen that many farmers had given information about trees that were not supposed to be part of the planned comparison. A final field trip was planned to collect the missing data, but due to technical problems with the car, the trip was cancelled. After discussions with World Vision where the quality and correctness of the data was assured, it was decided to trust the data on the species and number of trees planted on each farm. As a result the dataset needed to be corrected and the following set of guidelines was developed and followed to make a final dataset that reflected the truth as well as possible.

§ 1 The trees that should have been planted on the farm according to the World Vision data, and not shown during the farm visit, were assumed to be dead.

One exception to paragraph 1 were made: if more than half of the trees were alive at 3 months and measured by World Vision, the trees were considered as forgotten and not included in the data set. This was the case for 18 trees on two farms.

§ 2 Trees that the farmers claimed was part of the planned comparison but were not in World Vision's lists were kept in the sample as long as the farmers had used the same species and had the same planting time as the planned comparison.

§ 3 If the farmer answered that a tree was planted before 2016 and still part of the planned comparison, it was assumed that he or she remembered wrong if the trees were of a size likely to be planted in 2016, and the trees were kept in the sample.

§ 4 If the trees were of an extraordinary size it was assumed that the farmer showed trees that were actually planted earlier than 2016 and they were hence deleted from the sample as they could impossibly be part of the planned comparison.

§ 5 If the farmer showed or told about a number of trees that was significantly higher than 9 per species, all the excess trees were deleted so only 9 trees per species were left. If the farmers had different treatments for the trees, a representative amount of trees with each treatment were chosen for deletion.

Statistics

The statistical analysis of the data was conducted using a logistic regression model in R studio. A model with survival as the dependent variable and the different factors affecting survival as independent variable, was the base of the analysis. Since a significant difference in survival rate was found between the species, species was included as a constant in the models when the other variables' effect on survival was tested. An ANOVA was made between one model with and one model without each new variable to see if adding it to the model had a significant effect on survival (Apendix 6).

This was done for the variables agroecological conditions (soil fertility, shade, frost and hail) and seedling care (fertilization, fencing, shelter) and the mulch and irrigation treatments. To test for interaction, a third model with two independent variables and an additional interaction variable was created and an ANOVA was made between this model and a model with the two variables without interaction variable.

To test the effect of the socioeconomic groups on survival, each group was tested as an independent variable in the model one by one and here the species was again adjusted for in the model. Lastly, it was tested if there was a relation between socioeconomic group and use of seedling care practices. The seedling care practices were set as dependent variable in a model with socio economic group as independent variable. This is the only model in the analysis without survival as dependent variable, and species was not accounted for in the model due to a too high number of possible combinations.

4. Results

4.1 The agricultural systems in Saesi Tsaeda Emba

The main crops grown in Saesi Tsaeda Emba were wheat, barley, maize, potato and the traditional Ethiopian cereal teff. Potatoes, tomatoes, cabbage and onions have been promoted by World Vision and after the farmers got access to irrigation throughout the last ten years, these crops were now found on many farms (Table 2)

Table 2: Crops and livestock in Saesi Tsaeda Emba

Crops	% of farms with	Livestock	% of farms with
Wheat	93.2	Cow	88.1
Maize	86.4	Donkey	81.4
Barley	76.3	Chicken	74.6
Potato	72.9	Sheep	67.8
Teff	54.2	Goat	5.02
Tomato	47.5	Horse	3.39
Cabbage	47.5		
Onion	37.3		
Pea	25.4		

Pea was the only leguminous crop widely grown at the moment, but growing legumes were promoted as a sustainable intensification practice by the governmental extension. All the farms had livestock, and a typical heard would be three cattle, five sheep, five chickens and a donkey. The cows were milked and the oxen used for ploughing. The sheep were bred for the market and the farmers very rarely eat meat themselves. Eggs and chickens were sold at the market and eggs were also consumed at home.

Table 3: Descriptive statistics of the 59 farmers interviewed with the ODK

	Mean (Std.error)	Min	Max
Age of household head	51.1 (12.7)	20	81
Household size	6.47 (1.88)	2	10
Number of children	3.27 (1.78)	0	7
Number of active	3.81 (2.00)	1	10
Size of farmland (ha)	0.556 (0.305)	0.125	1.5

After adding manure and compost and ploughing several times, the cereals were sown in May and June before the onset of the second rainy season, and harvested in September. No crops were grown in the period between October and December because it is the coldest time of the year and frost can occur. In May Hantso and Takot the fields were left fallow until the cereals were sown again, whereas in Dimello a second crop of potato or vegetables was planted in January and harvested in May before the cereals were sown.

Table 4: Survival rate for the different species

Species	Observations	Estimate	Standard error
Faidherbia albida	458	0.395	0.023
Rahminus prinoides	281	0.803	0.024
Psidium guajava	77	0.776	0.048
Coffea arabica	72	0.952	0.025
Casimiroa edulis	44	0.922	0.045
Acacia seyal	28	0.446	0.083
Moringa oleifera	18	0.026	0.038
Persea americana	5	0.583	0.220
Mangifera indica	205	0.966	0.013

The final dataset consists of data from 59 farms and 1196 observed trees divided on 9 species (Table 4) 794 trees out of the 1196 planted survived, which makes an overall survival rate of 0.666. The species with highest survival rate was *Mangifera indica* and the species with the lowest survival rate was *Moringa oleifera* (Figure 4).

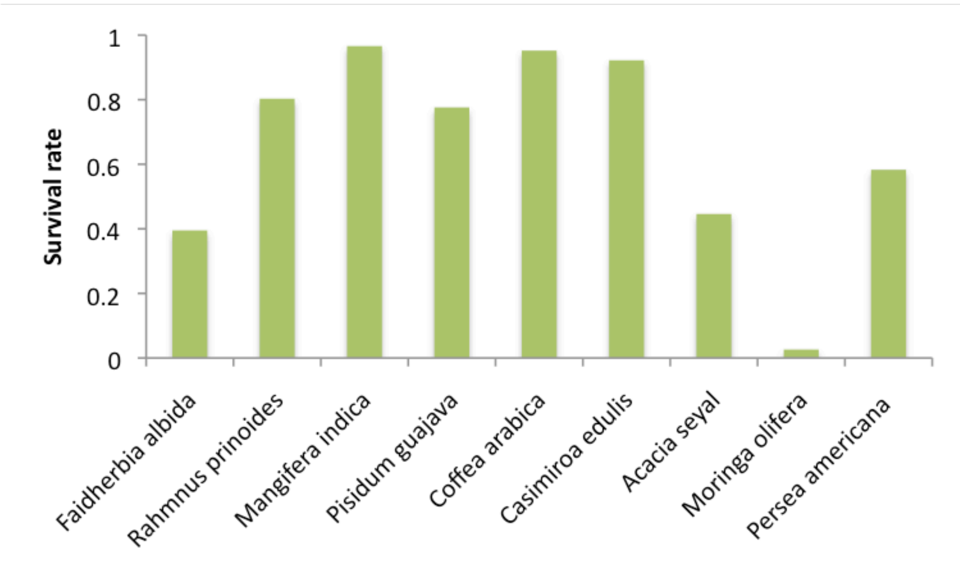

Figure 4: Survival rate for the different species

The survival did not differ significantly between the watersheds, and the number of trees in each watershed was also very balanced, as seen in table 5.

Table 5 Survival rate in the different watersheds when controlled for the influence of species

Watershed	Observations	Estimate	Standard error
May Hantso	405	0.676	0.024
Takot	387	0.687	0.023
Dimello	404	0.628	0.024

4.2 Agroecological conditions

4 agroecological conditions were tested for their effect on seedling survival and shade was the only one found to have a significant effect (Figure 5). All of the agroecological conditions, except from shade, were found to interact significantly with species (Table 6). That shade did not interact with species means that shade had a significant effect on survival regardless of species. The details of which species interacted with which agroecological condition could not be obtained through statistical analysis because of inadequate data.

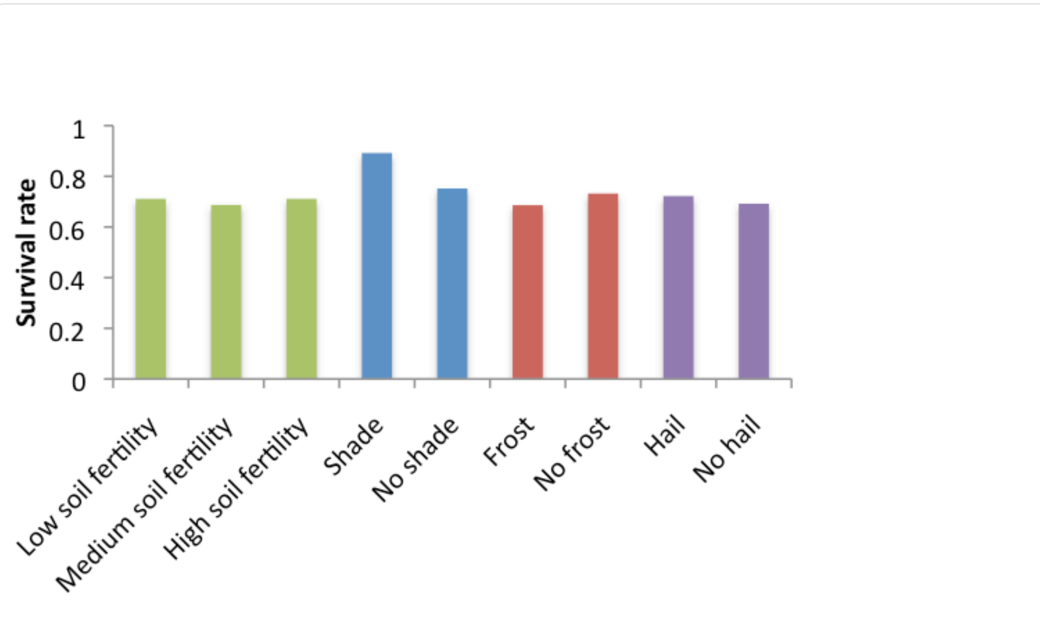

Figure 5: Survival rate under different agroecological conditions, adjusted for influence of species

Table 6 Survival rate under the different agroecological conditions, where the effect of species has been accounted for in the model NS= P > 0.05 ,* P < 0.05, ** P <0.01 and *** P < 0.001

Condition	Observations	Estimate (Std. error)	P value	P value, interaction with species
Soil fertility			0.750	<0.001***
Low	236	0.711 (0.0541)		
Medium	743	0.687 (0.0491)		
High	217	0.711 (0.0565)		
Shade			0.0165*	0.0815
No	937	0.752 (0.0447)		
Yes	116	0.892 (0.0477)		
Frost			0.15	0.00169 **
No	370	0.732 (0.0499)		
yes	826	0.686 (0.0482)		
Hail			0.458	<0.001***
No	1004	0.692 (0.0474)		
Yes	192	0.722 (0.0561)		

4.3 Stress factors and seedling care

In the focus groups the challenges with the tree seedlings were discussed (Appendix 5) and the scoring matrix of the mortality reasons resulted in the summary seen in figure 6.

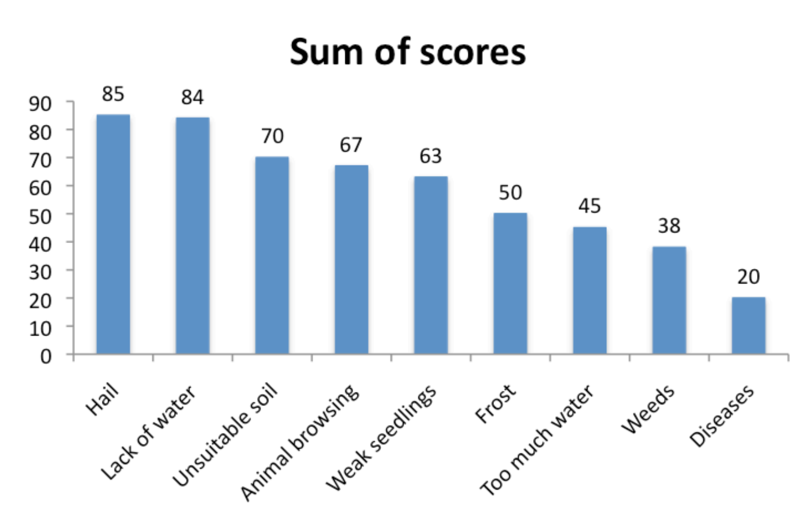

Figure 6: Sum of scores from scoring matrix with the axis species and mortality reasons and scores of 0-6. The exercise was used in 3 focus groups with a total of 13 farmers

Hail was the factor that got the highest sum of scores when adding the scores for all the species in the 3 FDGs who did this exercise. Weak seedlings does not stand out as one of the most important factors when looking at the sum of scores (figure 6), but it was scored as the most important mortality reason for *Faidherbia albida* by all of the socioeconomic groups.

The farmers' efforts to mitigate the stress factors were analysed using the data from the ODK. The most common answers to what the farmers do to increase the survival or production of the trees are summarised in figure 7. Many of the farmers gave several answers to this question, and the terms fertilization, manure and compost might have been used interchangeably.

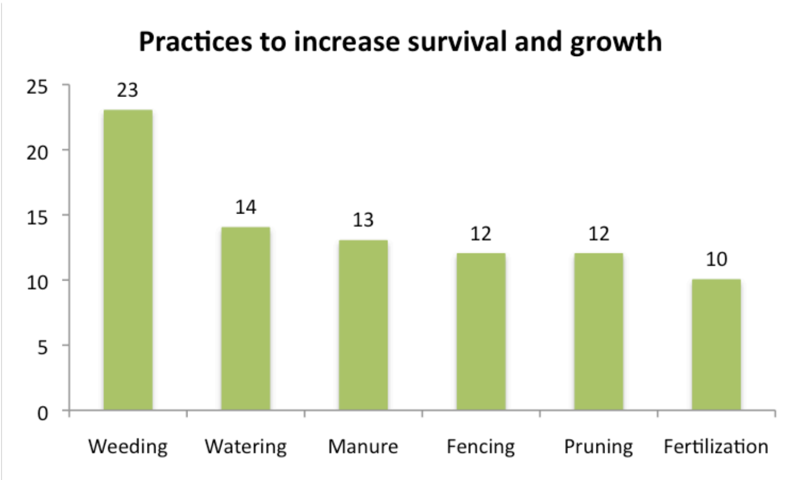

Figure 7: Number of times a practice was given as answer to the question about what is done to increase survival and growth. Data from ODK interviews with 59 farmers.

Different seedling care practices were observed in the field during the farm visits as well as discussed after the measurement of the trees (figure 8).

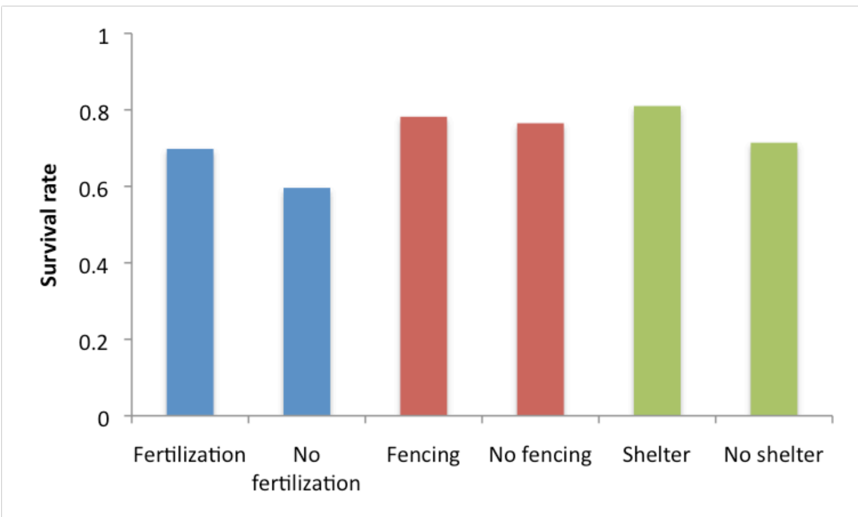

Figure 8: Survival rate under different seedling care practices

Table 7 Survival rate under different seedling care practices, adjusted for the effect of species NS= P > 0.05, * P < 0.05, ** P <0.01 and *** P < 0.001.

Type	Observations	Estimate (Std. error)	P value	P value, interaction with species
Fertilization			<0.00655**	0.0281*
No	301	0.596 (0.0626)		
Yes	881	0.698 (0.0475)		
Fencing			0.504	0.548
No	577	0.764 (0.0177)		
yes	418	0.782 (0.0202)		
Shelter			0.00927**	0.0166*
No	554	0.714 (0.0494)		
Yes	430	0.810 (0.0390)		

Seedlings that were fertilized had a significantly higher survival rate than seedlings that were not fertilized. Fencing was the only seedling care practice that did not have a significant effect, even though it was mentioned in all the focus groups as an important way to reduce animal browsing.

Two of the groups said that even if they fence, the animals sometimes break through the fence, whereas two groups said that browsing is not at all a problem because they fence. To plant the trees in a sheltered position was not mentioned by the farmers as a practice to increase survival and production. Wind was either not mentioned as a challenging factor in any of the ODK interviews or SSIs with key informants. 11 farmers did however mention shelter as a reason for choosing a specific planting site for a total of 60 trees. From the analysis of the observation of planting sites it was demonstrated that shelter had a significant positive effect on the survival rate (table 7).

Finally it was tested whether there was an interaction between species and the seedling care practices and a significant interaction was found for fertilization and shelter (table 7). When tested on species level, the dataset was too small and the combinations too many, to produce significant results on which species was most affected by which type of seedling care.

4.4 Irrigation and mulching treatments

Forty-four different treatments were found at the farms, including the 6 treatments described in the protocol. 56,3 % of the trees received the original treatments, 33.1 % of the trees received alternative treatments adapted by the farmer, 10% of the trees were lacking information about treatments, and 0.5 % were not given a treatment on purpose. In the following analysis the 6 original treatments (Box 3) are referred to as the original treatments, and the farmers adapted treatments as alternative treatments. Because of the high number of alternative treatments only the treatments with more than 15 observations were analysed.

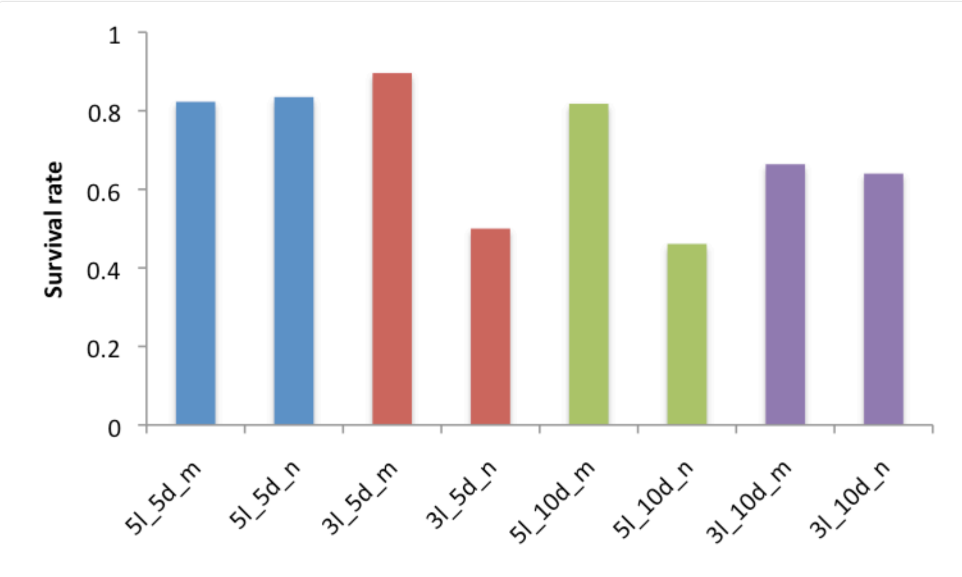

Figure 9: Survival rate under the original treatments including the alternative treatments without mulch and irrigation every 10 days.

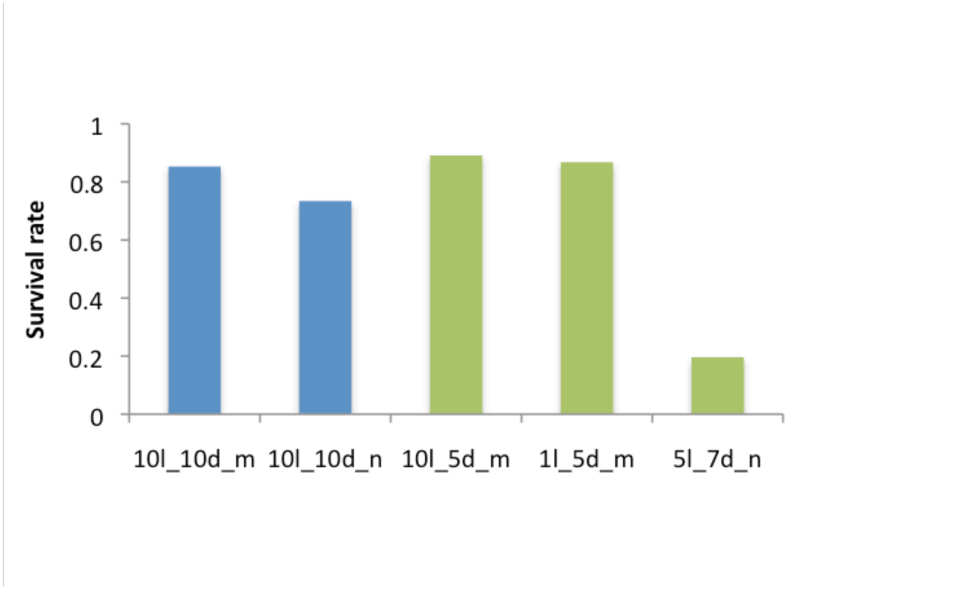

Figure 10: Survival rate under the alternative treatments

Table 8 The survival rate under the original treatments (in bold) and the alternative treatments adjusted for the effect of species. Estimates with the same letter are not significantly different at the p=0.05 level. l= litre, d=day, m=mulch, n= no mulch. See box 3 for detailed description.

Treatment	Observations	Estimate (Std.error)	Significance
5l_5d_m	**222**	**0.823 (0.0256)**	**A**
5l_5d_n	**99**	**0.835 (0.0373)**	**A**
5l_10d_m	**106**	**0.818 (0.0375)**	**A**
5l_10d_n	76	0.461 (0.0571)	B
3l_5d_m	**100**	**0.896 (0.0305)**	**A**
3l_5d_n	**72**	**0.500 (0.0589)**	**B**
3l_10d_m	**75**	**0.664 (0.0545)**	**C**
3l_10d_n	56	0.640 (0.0641)	C
1l_5d_m	18	0.868 (0.0797)	A
10l_5d_m	22	0.891 (0.0664)	A
10l_10d_m	16	0.853 (0.0885)	A
10l_10d_n	31	0.734 (0.0793)	C
5l_7d_n	22	0.196 (0.0846)	D

Table 8 shows that all the original treatments with 5 litres had similar high survival rates and there were no significant difference between them. Between the treatments with 3 litres, a significant difference was found between all the original treatments. The highest survival was found amongst the trees with the most frequent irrigation and mulch; 3l_5d_m. It was also tested for interaction between mulch and irrigation and it was found significant ($p<0.001$). The size of the dataset did however not allow for a detailed analysis of which combination of irrigation and mulch that gave a significant result for interaction.

4.5 Socioeconomic groups

The main method to investigate the effect of the socioeconomic groups on seedling care and survival was the 6 focus groups discussions, but the differences in seedling survival between the groups were also tested statistically (Table 9)

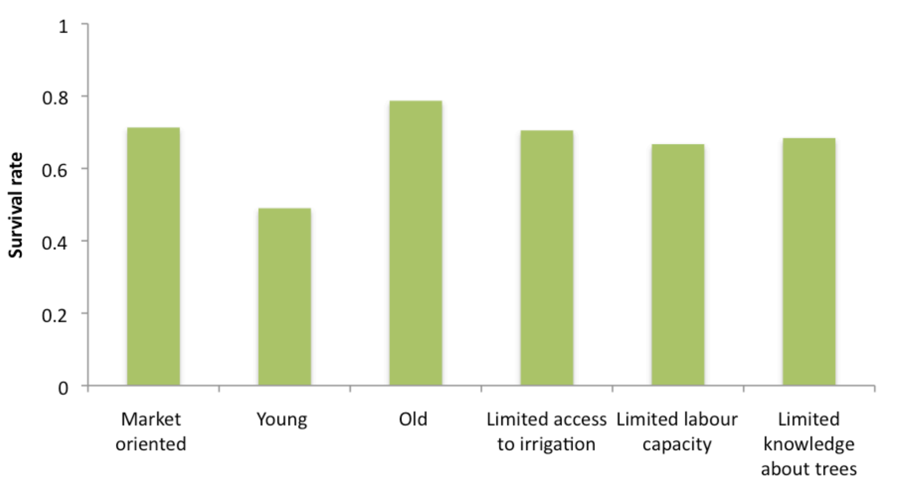

Figure 11: Survival rate in the different socioeconomic groups.

Table 9 The survival rate in the different socioeconomic groups when controlled for the influence of species. Young = 35 years and younger, old= 65 years and older, lim_irr = limited access to irrigation, lim_know= limited knowledge about trees, lim_lab= limited labour capacity, * P < 0.05, ** P <0.01 and *** P < 0.001

Group	No. farmers	No. trees	Estimate (Std error)	p-value
Market oriented	9	177	0.713 (0.0593)	0.658
Young	7	157	0.490 (0.0703)	<0.001 ***
Old	9	192	0.787 (0.0464)	0.00263 **
Lim_irr	15	297	0.705 (0.0539)	0.741
Lim_lab	6	124	0.667 (0.0687)	0.535
Lim_know	7	121	0.684 (0.0678)	0.805

Table 10: The ranking of reasons to plant trees amongst the motivation driven farmers

Ranking	Young farmers	Old farmers	Market oriented farmers
1	Faidherbia for manure	Food	Soil fertility
2	Rahmnus for drinking	Plow materials	Firewood
3	Coffee for drinking	Timber	Fencing the cattle
4	Market	Fertilizer	Useful for the family
5	Faidherbia for fencing	Fencing	Market
6	Food	Firewood/ charcoal	Create an income to buy things
7		Market	

Market oriented farmers

The market oriented farmers was the only group who gave full score on productivity for all the species, and for market for all species except *Faidherbia albida*, during the scoring matrix for reasons to plant the different species (Apendix 4). On the other hand they ranked market amongst their least important reasons to plant trees in the ranking exercise (table 10).

Young and old farmers

The survival of the trees of young farmers was significantly lower than for the trees of the other farmers. The trees of old farmers showed a significantly higher survival than trees of the other farmers (Table 9). Food was rated highest by the old farmers and lowest by the young farmers, as can be seen in table 10. Timber was not even mentioned by the young farmers, while it was occupying two of the top 3 rankings amongst the old farmers. One of the reasons to participate in the project given by the old farmers during the FDG, was to get tree species that are normally not available in the local nursery.

Farmers with limited labour capacity

All the 6 invited farmers came to the focus group discussion and during the discussion it was confirmed that the group had a challenge with finding enough time for all the work on the farm, and this was effecting the seedling care.

" We have economic crisis so we go to another job. If we did not have that, we could stay home and take care of the trees and have more time for weeding"

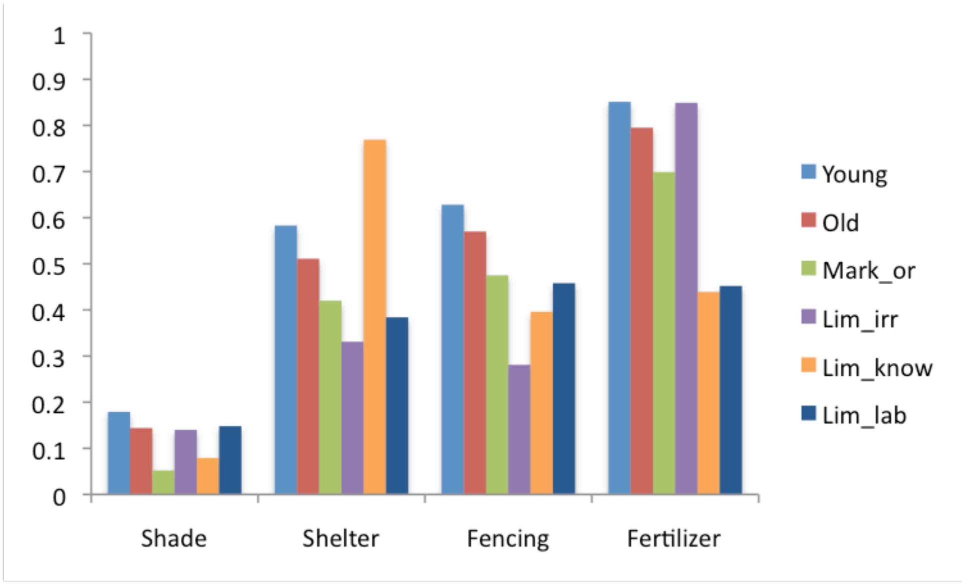

Figure 12: Probability for a tree to be under different seedling care practices in different socioeconomic groups. Mark_or = market oriented, young = 35 years and younger, old = 65 years and older, lim_irr = limited access to irrigation, lim_know= limited knowledge about trees, lim_lab = limited labour capacity

Table 11: Probability for a tree to be under different seedling care practices in different socioeconomic groups.Mark_or = market oriented, young = 35 years and younger, old = 65 years and older, lim_irr = limited access to irrigation, lim_know= limited knowledge about trees, lim_lab = limited labour capacity
The significance levels indicate * p < 0.05, ** p <0.01 and *** p < 0.001

Type	Shade	Shelter	Fencing	Fertilizer
Young	0.179 (0.0337)***	0.582 (0.0438)	0.628 (0.0421)**	0.851 (0.0284) ***
Old	0.144 (0.0266)	0.511 (0.0437)	0.570 (0.0388)	0.795 (0.0291)
Mark_or	0.0521 (0.0175)***	0.420 (0.0388)	0.475 (0.0398)	0.699 (0.0345)
Lim_irr	0.140 (0.0202)	0.331(0.0295)***	0.281 (0.0274)***	0.849 (0.0204)***
Lim_know	0.0792 (0.0246)	0.769 (0.0388)***	0.396 (0.0448)	0.439 (0.0451)
Lim_lab	0.148 (0.0319)	0.384 (0.0453)	0.458 (0.0486)	0.452 (0.0447)

The analysis of the relation between socioeconomic group and seedling care practices (table 11) showed that the farmers with limited labour capacity had among the lowest probabilities for having a tree under the practices shelter, fertilization and fencing (figure 12). On the other hand, the farmers with limited labour capacity had the second highest probability of having a tree planted in the shade.

Farmers with limited knowledge about trees

During the focus group discussion it became clear that this group did not lack knowledge about trees. They were amongst the most active groups in the scoring matrix on different reasons to plant trees and reacted simultaneously and without doubt to most of the questions. The farmers also mentioned details in uses of the trees that none of the other groups mentioned; For example, *Rahmnus priniodes* can be used for shading when it grows big enough and the wood can be used as firewood when it is dry. *Faidherbia albida* is good feed for sheep and goats, but not for cattle because of the thorns.

Table 12: The ranking of challenges with tree seedlings amongst the ability limited farmers

Ranking	Limited labour capacity	Limited irrigation	Limited knowledge
1	Drought	Disease	Insects
2	Weeds	Frost	Lack of water
3	Not enough time to take care of the trees	Weeds	Weeds
4		Lack of water	

Farmers with limited access to irrigation

During the focus group discussion it was confirmed that the participants had challenges with water access and that they expected help from world vision to buy motor pumps and maintain the canal. It was also claimed that world vision had done nothing to help them solve the conflicts rising about the collective management of the irrigation water. During the scoring matrix of challenges with tree seedlings (Appendix 5) lack of water was however only mentioned as a constraint for mango, and not for the other species, in contrast to the other groups who gave scores to nearly all their species. The farmers with limited access to irrigation also rated lack of water lowest of 4 challenges in the ranking of challenges (Table 12), while drought and lack of water was rated as number 1 and 2 for the farmers with limited labour capacity and knowledge respectively. Only two farmers showed up to the discussion, so it is not possible to say if the results are representative for the whole group.

5 Discussion

5.1 Agroecological conditions

Shade was the only agroecological condition found to have a significant effect on survival when the effect of species was controlled for. A positive effect of shade on seedling survival was also found by Andres et al. (2011), when studying the survival of *Cedrela odorata* in a field trial in Nicaragua. That shade has a positive effect on seedling survival is not surprising due to the reduction of temperature extremes and evapotranspiration in the shade (Nair 1993). If the shade is created by another tree, which was often the case, it is also likely that the soil organic matter under the tree is higher and hence the CEC and water holding capacity will be higher under the tree than in the area around.

Shade was, however, not mentioned one single time by he farmers as a reason to choose a certain planting site or as a way to increase survival or production. The development coordinators did not mention planting in the shade as part of the training or that too much sun was a reason for seedling death. It is therefore quite likely that the trees were not planted in the shade on purpose.

The finding that frost did not significantly affect survival is surprising, as a frost event in April 2017 was mentioned both by the farmers, the development coordinators and World Vision. Frost damage was also observed on the tree seedlings and explained as a death cause by the farmers. In the scoring of challenges during the focus group discussions, frost was only given a top score of 6 twice out of 28 possible times, and only one group mentioned it amongst their main challenges with the tree seedlings. One possible explanation to the conflicting findings about frost could be that many farmers did not answer correctly to the question if they experienced frost within the last year. Even if local differences in climate might explain that not all the farmers in a watershed experienced frost, the distribution shown in figure 13 seems to be quite random and even close neighbours gave different answers to whether they experienced frost. This could be because one year is a long time to ask a respondent to remember, or because of translating issues. Frost was not a familiar phenomenon for the translator, and several times he asked for an explanation for what it was. It is therefore quite likely that the results don't represent the reality very well, and that frost was a bigger problem for the farmers than is expressed through the statistical analysis. No significant difference was found in the survival rate between the different levels of soil fertility, in contrast to the findings of Reubens et al. (2009), and this could be connected to the widespread use of both mineral and organic fertilizer found in all watersheds.

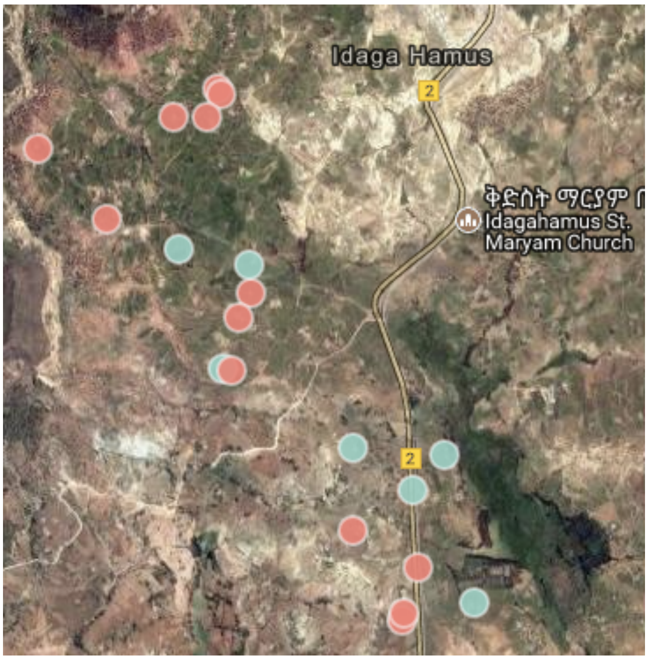

Figure 13: Answers to experienced frost in Takot. Green = yes, red = no

That the seedlings of the farmers who experienced hail during the last year did not have a significantly lower survival than the other seedlings is quite interesting as hail was the mortality reason with highest sum of scores during the focus groups (figure 6). As with frost, neighbouring farmers were answering differently about their experience. Hail is a more local phenomenon than frost, so the random distribution is less surprising than frost. It should also be taken into consideration that only 3 out of 23 farmers participating in the focus groups answered that they experienced hail during the ODK interview. This means that either this 3 farmers were very dominating when giving the scores on hail, or some of the farmers who decided to give hail a high score during the FDG did not answer correctly during the ODK interview. Finally it might have been a translating issue, as the translator did not seem to be familiar with the phenomenon and how it differs from snow. Several times he asked to get it explained again, and it might be that some of the times he forgot the meaning without asking.

The significant interaction between species, soil fertility, frost and hail was expected, as the tolerance of these stresses varies considerably across species (Table 1). The limited size of the dataset prevented a more detailed analysis of the interaction on species level, but this would be interesting to look into in future studies with a larger sample size.

The hypothesis that agroecological conditions affected the survival of tree seedlings can be confirmed for shade and rejected for soil fertility. For hail and frost it is difficult to conclude because it is questionable how well the answers reflect the reality.

5.2 Stress factors and seedling care

That all of the socioeconomic groups scored weak seedlings as the most important mortality reason for *Faidherbia albida* (Appendix 5), was not surprising after having talked to the farmers in the field and in the focus groups. Farmers repeatedly stated that weak seedlings were delivered to them, e.g. they were imported from another woreda and the seedlings were most likely damaged by staying in the vehicles for a prolonged period. One of the two farmers who planted *Moringa oleifera* told us that the seedlings they received were in a very poor condition, and that they died shortly after planting because of that.

When the development coordinators in Dimollo and Takot were asked about the arriving condition of the tree seedlings distributed, he said that especially *Faidherbia albida* arrived dry to the farmers. He explained further that the seedlings needed to be planted after the rain and that they waited so long with planting them because there was no rain. This confirms the finding from the FDG on the arrival condition of the seedlings (Appendix 5). Planting of high quality seedlings is considered to be one of the most important factors for successful tree planting (Grossnickle 2012) and the weak seedlings are therefore very likely to be the explanation of the low survival rates of *Faidherbia albida* and *Moringa oleifera* (figure 4).

Two of the studied seedling care practices had a significant effect on survival regardless of species (table 7). That fertilization of seedlings had a significant effect on survival is not surprising, but yet an interesting finding that should be included in the follow up of the project. Fertilization is not mentioned in the protocol and it was up to the local extension workers or the farmers to decide on the fertilization rates. The development coordinators in the 3 watersheds put emphasis on the importance of fertilization of the seedlings as a way to increase survival, and that was also reflected in the farmers' answers about this issue (figure 8).

This finding should be taken into consideration by the DryDev project, as it will be difficult to compare results across countries and contexts if the fertilization is not in some way standardised. The agricultural policy agriculture led industrialisation (ADLI) in Ethiopia is very focused on access to inputs and extension (Government of Ethiopia 2017), and 58 of the 59 studied farmers used mineral fertilizer on their farm and were trained to do so. This context is hence very different from what could be expected in the other DryDev countries, where fertilizer might be more difficult to access.

Fencing of the trees was an important part of the training the farmer received before planting the trees, and the insignificant effect on survival could be because the fences are not always successful in keeping the animals away from the trees. When the farmers were asked about bites on the leaves of the trees, they often explained it as animal browsing even though the trees were fenced. Animal browsing was found as one of the major causes of seedling death in the studies of Reubens et al. (2009), so it is not surprising that this is a problem despite the farmers' efforts to fence. Another possible reason why fencing is found insignificant could be that the farmers are successful in keeping the animals away from the planting site in general so that a fence is not a determining factor for keeping the animals from browsing the trees.

That shelter was not mentioned by the farmers as a practice to increase survival is quite interesting and might indicate that the trees were not purposefully planted in the shelter, as the trees planted in the shade. A significant effect of shelter on seedling survival was also found by Reubens et al. (2009), who conducted research on seedling survival in gullies in Tigray. This can be explained by a reduction in evapotranspiration and a warmer and moister microclimate in the shelter (Nair 1993).

The hypothesis that proper seedling care can mitigate the effect of stress factors could be confirmed for fertilization and shelter, but not for fencing. The significant interaction with species found for both shelter and fertilizer shows that interesting results could have been obtained if the sample size allowed for an analysis of which species were most affected by which type of seedling care, and further studies with more seedlings are needed to obtain the information that is needed to be able to advice the farmers on the needs of each species.

5.3 Mulch and irrigation treatments

The treatments with irrigation and mulch were found to have a significant effect on the survival regardless of species, which is in line with the theory that irrigation in the first months after planting is crucial for the survival of tree seedlings (Yohannes 1999). The farmers were expected to use the treatment with 3 litres for the multi purpose trees and 5 litres for the fruit trees, but in reality all the treatments were used for all types of trees. A general higher use of the treatments with 5 litres than the treatments with 3 litres and even the invention of treatments with 10 litres, could be because the farmers wanted to make sure that the seedling got enough water to survive.

The hypothesis that the treatments with watering every 5 days and mulch resulted in the highest survival was confirmed. The finding that 3l_10d_m had a significantly higher survival than 3l_5d_n is however surprising and demonstrates that the presence of mulch combined with low irrigation can lead to a higher survival than treatments with more water and no mulch.

The treatments with watering every 10 days without mulch were not supposed to be tested according to the protocol, but the farmers tried them out, which shows an overall interest in tree planting and seedling care. Thanks to the farmers adaption of the treatments it can be seen that the survival differs significantly with the presence of mulch in the treatments with 5 litres per 10 days. This might be because the water starts to become a limiting factor when it is only irrigated every ten days, but that the mulch helps retaining the water available for the plant during a longer period. The question is then why the treatment 3l_ 10d_n has a survival that does not significantly differ from the same treatment with mulch (figure 9). One possible explanation to this is that under this treatment the water becomes so scarce that the effect of the mulch is not enough to keep the plant supplied with water between the irrigation days. The treatment with the highest survival in the experiment was 1l_5d_m. Because there was only 18 trees under this treatment the result is not significant, but it can be an indication that if the plant is mulched and irrigated frequently, the quantity of water can be low without a reduction in survival. The treatment 3l _5d_m shows an equally high survival, which support this indication.

5.4 Perception of benefits and motivation to plant trees

The knowledge about the benefits of trees was in general very high and all the farmers could mention benefits for the species they had planted on their farm. As a result it was not possible to compare groups that did and did not know about the trees' benefits.

It is shown in several studies (Godaoy 1992, Gyau et al. 2014, Pattanayak et al. 2003, Nigussie et al. 2017) that the perception of benefits of trees affects the motivation to plant them, and particularly the market oriented farmers were expected to be more motivated to make their seedlings survive because they could relate the survival of the trees to higher income in the future as found by Nigussie et al. (2017), when studying motives for smallholders to plant wood lots in north western Ethiopia.

The scoring matrix exercise on the reasons to plant trees (Appendix 4) did reveal a difference in perception of benefits between the 3 motivation driven socioeconomic groups (young, old and market oriented farmers), but when looking at the FDG data as a whole, it is difficult to extract clear tendencies. As an example, soil fertility was only given a score 3 for *Faidherbia albida* by the young farmers, but when looking at the results of the ranking exercise (Table 10), the young farmers ranked *Faidherbia albida* for soil fertility as the most important reason to plant trees. A similar situation occurred when the market oriented farmers ranked market lowest during the ranking exercise (Table 10) and afterwards gave all the species, except *Faidherbia albida,* full score on market during the matrix on reasons to plant the different species (Appendix 4). This shows that the farmers answers are not very coherent, which makes it difficult to conclude based on the data. The hypothesis that perception of the benefits of trees differs with socioeconomic group, could therefore neither be rejected nor confirmed and further studies, preferably with a higher diversity of methods for triangulation and more participants, are needed. The study of the motivation to take care of trees was depending on an existing relation between perception of benefits of trees and socioeconomic group. Since no relation was found the study of motivation's effect on seedling care is limited to the literature.

The fact that the farmers were given the tree seedlings for free and were paid to participate in trainings is however a factor that would have made it difficult to study motivation in this context regardless of the findings about perceptions.

Both seedling care and survival differed significantly between socioeconomic groups, but this could not be related neither to perception of benefits of trees nor to motivation to care for seedlings, based on the data of this study. In the following section other possible explanations of the differences in use of seedling care practices and survival rate between the young, old and market oriented farmers, will be discussed.

When looking at the seedling care practices in figure 12 it seems like the low survival of the trees of the young farmers cannot be explained by lacking seedling care. The young farmers have the highest use of all the seedling care practices except shelter, but despite this they are the group with the significantly lowest survival. A possible explanation to this is found in the challenge scoring matrix exercise where animal browsing was the challenge with the highest sum of scores for the young farmers (Appendix 5). The young farmers might have less experience in building good fences against animals than the other farmers and if the animals break through the fences a low seedling survival might be seen even though the seedlings are well cared for. Some of the young farmers did farm their parents land, and some of them even lived in another place because their parents lived at the farm. The daily care of the seedlings such as weeding and protecting against animals could then more difficult and this could be another reason for the low seedling survival amongst the young farmers.

That the old farmers have the significantly highest survival (table 9) might be a result of experience with tree planting and management of seedlings, but it might also be related to a higher motivation to plant trees among old farmers, as suggested by Gyau et al. (2014). A reason why the old farmers might have a higher motivation to make their trees survive, could be that they have experienced the process of land degradation in the region, and seen the consequences. It could also be that the older farmers have more time to take care of the trees because they don't have as many children to take care of as the younger farmers. Some farmers also accused the children for breaking the top shoot of tree seedlings, so this is another way absence of children could lead to a higher seedling survival.

.

5.5 Challenges and seedling care

Limited labour capacity

It was expected to find a relation between limited labour capacity and low seedling survival, due to the farmers' lack of time for seedling care. This was also the case, and the farmers with limited labour capacity had among the lowest probability for using all the labour demanding seedling care practices; shelter, fencing and fertilization (figure 12). This is in accordance with the findings of Deiniger et al. (2003), who found that there is a strong relation between labour availability and investment in trees.

The farmers with limited labour capacity did however have the second highest probability of planting in the shade, which is not a very labour demanding practice. This indicateds that labour is a limiting factor in general for seedling care in this group. When triangulating with the results from the focus group discussion, this finding was confirmed.

The farmers said that they had to work off farm because of the economic crisis, and that this was making it hard to find time to take care of the trees. As all the invited farmers showed up to this focus group, the evidence is quite strong that there is a relation between limited labour capacity and lower seedling care. The seedling survival in this group was however not significantly lower than for the other farmers, which could be due to the influence of other factors not accounted for in the model.

Limited knowledge about trees

The focus group showed that the farmers who were expected to have less knowledge about trees due to low education level and access to extension did not have lower level of knowledge than the other farmers. This might be explained in two ways; either there were no farmers with low knowledge about trees amongst the 59 farmers, or the sample criteria were not precise enough. When talking to the farmers it seemed that the level of knowledge was in general high and only two of the farmers said that they wanted to attend training but did not know how or where to find it.

The outcome of the focus group discussion indicated that lack of knowledge about trees is not a major problem among the farmers and that knowledge is diffused even to the farmers that do not attend training.

Limited access to irrigation

One of the criteria for joining the tree seedling planned comparison was that the farmers should have access to adequate irrigation water to follow the treatments. In the field the situation was however more complex and farmers were describing lack of water as one of their main challenges both for crop production and trees. It was therefore chosen to look more into the topic and a group of farmers with more than 1 km distance between the planting site and the closest water source was sampled. The survival of the seedlings of these farmers was not significantly lower than the other trees, and even when the minimum distance was increased to 1.5 km, the difference remained insignificant. This indicates that World Vision was successful in engaging farmers who were able to apply the irrigation treatments and that distance to water source did not affect the ability to follow the treatments.

As only two farmers with limited access to irrigation showed up to the focus group discussion, no conclusions can be drawn based on that data collected there, but World Vision should consider the challenges with maintenance of the canal and conflicts about the collective management of the irrigation water. It is important that World Vision and the farmers have matching expectations and that the roles are clear from the start.

5.6 Methodology

The implementation of the planned comparison

The overall objective of the planned comparison was to compare treatments in different contexts. In the case of the tree seedlings, the growth and survival was chosen as indicators and comparison of measurements at different times used to assess growth. For the comparability of the measurement data it was crucial to be able to connect the data collected at different times to the same tree.

In Saesi Tsaeda Emba an attempt to facilitate data collection was to number the trees from east to west and ask the farmers to remember the numbers. This method is problematic in several ways. The minority of the trees were planted on an east-west line and if they were planted scattered or south-north, there was no system. This was hence the case for most of the trees and in this situation the data collector had to rely on the farmers memory of what World Vision told them one year ago. When triangulating with the data collected by World Vision at 3 months after planting, it became clear that in most of the cases, the farmers did not remember correctly. The data collected on height and root collar diameter could therefore not be compared with the 3 month data, and is not included in this study. The problem can easily be remedied by labelling each seedling with a simple tag with a number around the stem.

The tree species chosen for Saesi Tsaeda Emba is an interesting part of the planned comparison. As shown in table 1, almost all of them have biophysical limitations that make them theoretically unsuitable for the local climate. The interview with the development coordinator in Takot and Dimello at first revealed scepticism towards the species chosen for the planned comparison, but it turned out that mango ad moringa were the only species that were not earlier planted in the woreda.

Rahmnus prinodius and *Acacia seyal* were traditional trees that were grown at almost all farms also before the planned comparison. Good yielding *Psidium guava* and *Casimiroa* *edulis* trees were also observed in the field as well as *Caffea arabica* trees that served for home consumption. The yields of coffee were not very high due to the suboptimal climate, but the farmers that grew it were happy for what they got as they consume it at home and the market prices are high. Full grown *Faidherbia albida* trees were only observed on one farm in May Hantso, and it will be interesting to see in some years if the seedlings grow up and especially in the slightly colder watersheds Takot and Dimello. *Mangifera indica* and *Moringa oleifera* have never been grown in any of the watersheds before to the knowledge of the researcher, and it will be interesting to see if the mangoes will grow up to yielding fruit trees despite the unsuitable altitude and temperature (Table 1).

The mango trees were planted 3 months before the assessment date and this could explain the high survival of the mango trees. This should also be kept in mind while interpreting the results as for example the insignificant difference between treatments and agroecological conditions found for this species.

That the most important mortality reason for *Faidherbia albida* was weak seedlings distributed, shows the importance of seedling management before planting which could be an even bigger problem than what happens on the farms. It is important that seedlings of best possible quality are delivered to the farmers so that they don't use time and resources on seedlings that already have a low probability of survival.

Data collection

The need to include additional agroecological indicators was demonstrated. For example the information about hail and frost was based on the memory of the farmers and the results would have been more credible if the farmer's answers were triangulated with detailed climate observations. Ideally climate data could have been recorded from the planting date until the end of the project at a selection of farms.

A tree was considered as shaded if 50 % of the leaf area was shaded at midday. This limit was not based on any detailed knowledge about the different species tolerance to sun, and if shading were to be studied more in detail, a different limit would probably be appropriate for each of the species. Furthermore it can be argued that only a few farms were visited exactly at midday, so for the other farms the shading assessment was based on a rough estimate.

Also for the seedling care methods, e.g. shelter and fence, it should be stressed that estimation was used during the assessment due to the variation that is found in an on-farm field trial. The fences used were varying in quality and design, and despite the researchers efforts to set herself in the place of an hungry animal, it is not sure that the criteria of being an effective protection against animal browsing, was correctly recorded. The shelter effect did also vary considerably between types of windbreaks and to which and how many directions it was sheltered, and a measurement of wind speed could have been a way to record this more correctly.

In general it could be said that an on-farm field trial is probably not the best context to precisely study either of the agro ecological conditions or seeding care practices' effect on the survival of seedlings. Significant effects of shade and shelter have already been found in other more controlled experiments (Andres et al. 2011, Reubens et al. 2009, Aerts et al. 2007). On the other hand an on farm field trial has the value that it includes the farmers in the research process so its part of a learning process, and that the growing conditions are reflecting the reality at the farms in a way that is hard to imitate in a controlled trial.

The participation in the focus groups varied between only two farmers to all the invited, and this did affect the outcome of the discussion. For future studies it should be aimed at inviting all the farmers personally and not leaving messages with family members or neighbours. The sampling of the socioeconomic groups could have been improved by using more indicators for each group and finishing more of the data analysis before the sampling of the FDGs. Due to limited time this was not possible and the sampling was done based on a preliminary data analysis.

The weakest points of the data collection process might have been the discovery of 115 tree seedlings that were supposed to be on the farms, but that the farmers did not show or inform about during the farm visits, even though they were asked to remember to tell about dead trees. That the famers did not tell about these trees could be because they were ashamed that their trees were dead, and that they were afraid to be judged for not taking well enough care of them, or that they misunderstood which trees were part of the planned comparison. The data collected at 3 months were not available for triangulation before the last week of the fieldwork because they were originally collected in Tigrinya and were being translated. If the data had been available earlier this situation could have been avoided as a dialogue with the farmers and World Vision probably could have explained what happened with these 115 trees.

Data analysis

The stress factors weeds, pest, disease, animal browsing and frost damage turned out to be difficult to analyze since the symptoms could only be observed on living trees. As a result, the data collected on these stress factors do not contain any information about the dead trees, and the analysis would show a survival rate of 100 % for all these stress factors. If it would have been possible to compare the data with the data collected at 3 months, the effect on growth could have been analysed for these factors, but due to the earlier described issues, this was not possible.

Shade, shelter and fence were recorded in the field and if the trees were dead, the planting site was observed for shade and shelter and it was asked whether the tree was fenced before it died. For the 115 dead trees that the farmers did not inform about however, data is missing on all of the variables observed in the field, and they are therefore omitted from the analysis. It is assumed that the relation between the trees with and without these variables is about the same for these 115 dead trees as in the rest of the sample, and the probability that adding them to the sample would have changed the results significantly, is considered as low. That these trees are left out of the analysis explains the slightly higher survival rates estimated both for trees with and without shade, shelter and fence compared to the other variables. The reason why the variables fertilizer, soil fertility, frost and hail could be included also for the 115 dead trees that the farmers did not inform about, is because these variables were asked about and not observed, and the answer was general for all the seelings.

The different quality of seedlings given to the farmers is one factor that could not be analyzed statistically due to missing data. The issue of seedling quality was discovered some weeks after the data collection started and after that, the question was added to the interviews and also discussed during the focus groups. The fact that almost the whole watershed of May Hantso was not asked about the arrival condition of their trees, made it impossible to make a full analysis of the variable. Given the clear answers found on this problem during the focus groups and SSI, it would be interesting to also include it in the statistical analysis to eventually further strengthen the evidence.

7 Conclusion

This study aimed to understand the factors affecting the survival of tree seedlings across three watersheds within Saesi Tsaeda Emba, Tigray, Ethiopia. A wide range of reasons why seedlings died, were identified. Agroecological conditions affect the survival of tree seedlings and the resilience varied with species. Shade was the only agroecological condition found to have a significant positive effect on survival across all species. Planting in the shade could therefore be recommended in future projects in the drylands of Ethiopia. Proper seedling care can mitigate the effects of stress factors and a significant positive effect on seedling survival was found in the case of fertilizer application and shelter, while fencing was found to be less important. Due to the large numbers of variables, high number of species and limited sample size, it was however not possible to conclude on which factors was most important for which species, but this would be interesting to look into in future studies with a larger sample size.

High mortality amongst species that were delivered in weak condition showed that seedling management before planting can be determining for the survival. The treatments with most water and most frequent irrigation had the highest survival rate, but it was also shown that the presence of mulch increases the probability of survival when the quantity and frequency of irrigation is reduced. This finding showed that farmers can save irrigation water by adding mulch to their trees and mulching could be recommended as a standard procedure during tree planting in drought prone areas.

No relationship was found between perceptions of benefits of trees and the farmers' socioeconomic group. It was however shown that both the use of seedling care practices and survival of tree seedlings differed significantly between socioeconomic groups. Farmers with limited labour capacity showed a lower use of seedling care practices, but not a lower seedling survival than the other farmers. This shows that there is a need for practices that are less labour intense, and e.g. planting in the shade and mulching, that reduces the need of irrigation, could be a suggestion. To plant in the shade of trees could furthermore reduce the damage by frost and hail. The trees of the old farmers had a significantly higher survival, whereas the trees of the young farmers had a significantly lower survival than the other trees, but the data does not provide evidence to conclude on the reasons behind this variation.

This study demonstrated that survival of tree seedlings is a result of complex interactions between species, stress factors and seedling care and that it is difficult to identify single causes of successes or failure. For a more profound understanding of the interactions, further studies with a larger sample size are needed.

Literature

Alemayehu, M. 1996. Traditional ditches in northern Shoa, Ethiopian Highlands. In: Sustaining the soil. Indigenous soil and water conservation in Africa, C. Reij, I. Scoons and C.Toulmin(eds).Earthscan PublicationsLtd.,London,pp 163-169.

Adekumobi, Saheed A. (2007). The History of Ethiopia. Westport: Greenwood Publishing Group

Aerts, R., Negussie, A., Maes, W.H., November, E., Hermy, M. & Muys, B. 2007, "Restoration of dry afromontane forest using pioneer shrubs as nurse-plants for Olea europaea ssp cuspidata", *Restoration Ecology,* vol. 15, no. 1, pp. 129-138.

Andres, P., Salgado, C. & Espelta, J.M. 2011, "Optimizing nursery and plantation methods to grow Cedrela odorata seedlings in tropical dry agroecosystems", *Agroforestry Systems,* vol. 83, no. 2, pp. 225-234.

Bekele-Tesemma,A.1997"A participatory Agroforestry Approach For Soil and Water Conservation in Ethiopia "*Tropical Resource Management Paper series,* no. 17

Caseley, D. J. & Kumar, K 1988. The collection, analysis, and use of monitoring and evaluation data, Johns Hopkins University Press, London, Baltimore. pp. 10-75.

Chambers, R. 1997, *Whose reality counts?, putting the first last,* Intermediate Technology, London, pp 130-157.

Chin, K.O., Huxley, P., 1996, *Tree-crop interaction, - a physiological approach*. ICRAF, CAB

Climate-data.org 2017. *Frewayni* [online] Cited 19.03.17. Available at :<https://en.climate-data.org/location/46877/>.

Crossland. , M. 2016 ”Operationalizing land degradation neutrality for land restoration activities within yhe Gilgal Abay watershed, lake Tana sub-basin, northwestern Ethiopia. Master thesis in Agroforestry, Bangor University.

Coates,J., Maxwell, D., Tadesse, G.,Hailu, S., Nugussie, W.,Z.,Gebrekiros,A.,2010,"Institutional Assessment Report:Tsaeda Amba Woreda, Eastern Tigray". [online] Cited 18.03.17. Available at :<http://fic.tufts.edu/assets/Institutional-Assess-Report.pdf>.

Coe, R. , Sinclair, F., Barrios, E. 2014 ” Scaling up agroforestry requires research ’in’ rather than ’for’ development. *Current Opinion in Environmental Sustainability*. No 6. pp 73-77

Deiniger, K., Jin, S., Adenew, B., Gebre-Selassie, S., Nega, B., 2003 "Tenure Security and Land-related Investment: Evidence from Ethiopia." World Bank Policy Research Working Paper 2991. World Bank, Washington, DC.

Desai, V., Potter, R.B. 2006 Doing Development Research. Chapter: ”Focus Groups” pp.153-161. Sage Publications.

DryDev 2015 "Consolidated Programme Implementation Plan (PIP for the Drylands Development Programme (DRYDEV)". [online]. Cited 18.03.17. Available at : <https://drydev.org/wp-content/uploads/sites/28/2015/11/DryDev-Programme-Implementation-Plan-June-2015.pdf>.

EFAP. 1993. Ethiopian Forestry Action Program. The challenge for development, Vol. II. Final draft consultant report., Ministry of Natural Resources Development and Environmental Protection, Addis Ababa, Ethiopia.
FAO 2016 "Ethiopia aquastat country profile". [online]. Cited 17.03.17. Available at :<http://www.fao.org/nr/water/aquastat/countries_regions/ETH/>.
Garrity, D. 2004, "Agroforestry and the achievement of the millennium development goals", *Agroforestry Systems,* vol. 61-2, no. 1, pp. 5-17.
Gelaw, A.M., Singh, B.R. & Lal, R. 2014, "Soil organic carbon and total nitrogen stocks under different land uses in a semi-arid watershed in Tigray, Northern Ethiopia", *Agriculture Ecosystems & Environment,* vol. 188, pp. 256-263.
Godoy, R. 1992, "Determinants of Smallholder Commercial Tree Cultivation", *World Development,* vol. 20, no. 5, pp. 713-725.
Government of Ethiopia 2017, "Policies and strategies", [online]. Cited 25.10.17. Available at <http://www.moa.gov.et/web/pages/policies-and-strategies>.
Grossnickle, S.C. 2012, "Why seedlings survive: influence of plant attributes", *New Forests,* vol. 43, no. 5-6, pp. 711-738.
Gyau, A., Smoot, K., Kouame, C., Diby, L., Kahia, J. & Ofori, D. 2014, "Farmer attitudes and intentions towards trees in cocoa (Theobroma cacao L.) farms in Cote d'Ivoire", *Agroforestry Systems,* vol. 88, no. 6, pp. 1035-1045.
Hadgu, K.M., Kooistra, L., Rossing, W.A.H. & van Bruggen, A.H.C. 2009, "Assessing the effect of Faidherbia albida based land use systems on barley yield at field and regional scale in the highlands of Tigray, Northern Ethiopia", *Food Security,* vol. 1, no. 3, pp. 337-350.
Hagos, E.Y., Schultz, B. & Depeweg, H. 2016, "Reservoir Operation in View of Effective Utilization of Limited Water in Semi-Arid Areas the Case of Gumsalasa Earthen Dam Irrigation Scheme in Tigray, Ethiopia", *Irrigation and Drainage,* vol. 65, no. 3, pp. 294-307.
Hagos, F. & Holden, S. 2006, "Tenure security, resource poverty, public programs, and household plot-level conservation investments in the highlands of northern Ethiopia", *Agricultural Economics,* vol. 34, no. 2, pp. 183-196.
Khurana, E. & Singh, J. 2001, "Ecology of seed and seedling growth for conservation and restoration of tropical dry forest : a review", *Environmental Conservation,* vol. 28, no. 1, pp. 39-52.
Kruger, H., J., Berhanu F., Gebere, M.,Y, 1996 "Inventory of Indigenous Soil and Water Conservation Measures on Selected Sites in Ethiopian Highlands". *Soil Conservation Research Report 34.* Bern: Centre for Development and Environment (CDE), University of Bern, Switzerland.
Lal, R., Safriel, U. and Boer, B., 2012. Zero Net Land Degradation: a New Sustainable Development Goal for Rio+ 20. A Report Prepared for the Secretariat of the United Nations Convention to Combat Desertification.
Maxwell, D., Vaitla, B., Tesfay,G., Abadi, N., 2013. "Resilience, Food Security Dynamics, and Poverty Traps in Northern Ethiopia" [online] Cited 26.03.17. Available at:<https://reliefweb.int/sites/reliefweb.int/files/resources/Ethiopia%20Resilience-Food-Security-Dynamics.pd>.
Malezieux, E., Crozat, Y., Dupraz, C., Laurans, M., Makowski, D., Ozier-Lafontaine, H., Rapidel, B., de Tourdonnet, S. & Valantin-Morison, M. 2009, "Mixing plant species in cropping systems: concepts, tools and models. A review", *Agronomy for Sustainable Development,* vol. 29, no. 1, pp. 43-62.

Mekuria, W., Veldkamp, E., Halle, M., Nyssen, J., Muys, B. & Gebrehiwota, K. 2007, "Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia", *Journal of Arid Environments,* vol. 69, no. 2, pp. 270-284.
Nair, P., K.,R.,1993,*An introduction to agroforestry.*Kluwer Academic Publishers, Dordrecht, The Netherlands. pp 325-338.
Nedessa, B., Ali, J., Nyborg, I., 2005 "Exploring Ecological and Socio-Economic Issues for the Improvemnet of Area Enclosure Management- A case study from Ethioia", [online] Cited 20.03.17. Available at :<http://www.eldis.org/vfile/upload/1/document/0708/DOC18719.pdf>.
Nigussie, Z., Tsunekawa, A., Haregeweyn, N., Adgo, E., Nohmi, M., Tsubo, M., Aklog, D., Meshesha, D.T. & Abele, S. 2017, "Factors Affecting Small-Scale Farmers' Land Allocation and Tree Density Decisions in an Acacia decurrens-Based taungya System in Fagita Lekoma District, North-Western Ethiopia", *Small-Scale Forestry,* vol. 16, no. 2, pp. 219-233.
Nyssen, J., Veyret-Picot, M., Poesen, J., Moeyersons, J., Haile, M., Deckers, J. & Govers, G. 2004, "The effectiveness of loose rock check dams for gully control in Tigray, northern Ethiopia", *Soil Use and Management,* vol. 20, no. 1, pp. 55-64.
Nyssen, J., Poesen, J., Gebremichael, D., Vancampenhout, K., D'aes, M., Yihdego, G., Govers, G., Leirs, H., Moeyersons, J., Naudts, J., Haregeweyn, N., Haile, M. & Deckers, J. 2007, "Interdisciplinary on-site evaluation of stone bunds to control soil erosion on cropland in Northern Ethiopia", *Soil & Tillage Research,* vol. 94, no. 1, pp. 151-163.
Pattanayak, S., Mercer, D., Sills, E. & Yang, J. 2003, "Taking stock of agroforestry adoption studies", *Agroforestry Systems,* vol. 57, no. 3, pp. 137-150.
Rabia, A., H., Afifi, R.,R., Gelaw, A.,M., Bianchi, S., Figueredo, H., Huong,T., L., Lopez, A., A., Mandala, S., D., Matta, E., Ronchi, M., Solomon, M., G., Yusuf, M., M., Alessandro, V.2013"Soil mapping and classification:a case study in the Tigray Region, Ethiopia.Journal of Agriculture and Environment for International Development.Vol 107. pp.73-99.
Rej C, Tappan, G., Smale, M. 2009 *Agroenvironmental Transformation. Another kind of "Green revolution"* IFPRI Discussion paper.
Reubens, B., Poesen, J., Nyssen, J., Leduc, Y., Abraha, A.Z., Tewoldeberhan, S., Bauer, H., Gebrehiwot, K., Deckers, J. & Muys, B. 2009, "Establishment and management of woody seedlings in gullies in a semi-arid environment (Tigray, Ethiopia)", *Plant and Soil,* vol. 324, no. 1-2, pp. 131-156.
Scoons, I. et al. 1996. *Sustaining the soil: indigenous soil and water conservation in Africa.* Chris Reij, I. Scoons and C. Toulmin (eds). Earthscan Publications Ltd., London. pp. 1-27
Schroth, G., Sinclair, F., L. 2003, *Trees, Crops and Soil Fertility*, *concepts and research methods.*CABI publishing, Oxon, UK. pp 326.
Sinclair, F.L. and Walker, D.H. (1999). A utilitarian approach to the incorporation of local knowledge in agroforestry research and extension. In: Agroforestry in sustainable agricultural systems (eds. Buck, L.E., Lassoie, J.P. and Fernandes, E.C.M.). New York: Lewis Publishers, pp. 245-275.
Yohannes, F. 1999, "Improvement of water application efficiency by moisture conservation methods for establishment of planted tree seedlings", *Communications in Soil Science and Plant Analysis,* vol. 30, no. 7-8, pp. 1119-1125.
World agroforestree database 2017. [Online] Cited 15.03.17. Available at :<http://www.worldagroforestry.org/output/agroforestree-database>.
World Bank 2007a. Determinants of the adoption of sustainable land management practices and their impacts in the Ethiopian highlands. [online]. Cited 20.03.17. Available at:

<http://documents.worldbank.org/curated/en/753391468021600129/Determinants-of-the-adoption-of-sustainable-land-management-practices-and-their-impacts-in-the-Ethiopian-highlands>.
World Bank 2007b Second Loess Pleateau whatershed rehabilitation project.[online] Cited 27.03.17. Available at: <http://documents.worldbank.org/curated/en/812911468218977436/pdf/41122.pdf>.
World Bank 2016 Ethiopia's great run, The growth acceleration and how to pace it [online] Cited 17.04.17 Available at: <http://documents.worldbank.org/curated/en/693561467988949839/pdf/99399-REVISED-PUBLIC-thiopia-Economic-Update-2-11-16-web.pdf>.

Appendix

Appendix 1: Interview guide ODK

Name, date & time
Your name (first name, last name)
Community facilitator / enumerator's name
Date
yyyy-mm-dd
Introduce yourself. Explain we are carrying the survey for ICRAF and its partners to help understand important aspects of farm management and how they influence the success of the planned comparison trials.
Make sure that a suitable respondent lives in the household and is available for the interview. The respondent should be the senior male or female from the household who participates in agricultural activities of the farm. If none is available postpone the interview.
Do you agree I interview you?
Yes
No
Country
Ethiopia Kenya
County
Kitui Machakos Makueni
Location
Sub-county
Ward/ Division
Location
Sub-location
Village
Woreda
Watershed
Zone
Which PC /DryDev activity are you engaged in?
Select all that apply. Note: A farmer may be involved in one or more PC activity so ensure to capture all.
Tree planting
Zai pits
Pest Control
Farmer Managed Natural Regeneration Bee Keeping
Compost Making Don't know
GPS location at homestead
latitude (x.y °) longitude (x.y °) altitude (m) précision (m)

Interviewee information
Interviewee's name?
Age of interviewee?
in years
Gender of interviewee?
Male Female
Are you the household head or what is your relationship to him/her?
Household head
First wife and only wife
Spouse of household head Son/daughter of household head Grandchild of household head
Parent of household head Nephew/niece of household head Other relative
Other
Describe other relationship to household head?
Marital status of interviwee?
Single Married Divorced Widowed
Who is incharge of the PC activities on the farm?
Record the name of the person incharge of establishment and monitoring of tree planting, Zaipits or other activities under the DryDev project in the family/household
Are you participating in any other projects besides DryDev?
List all projects that the farmer is involved in besides activities promoted by DryDev.
Farmer income & employment
What is your primary source of income?
Agriculture - from own farm
Agriculture - from farm labourer
Cash gifts from relatives/ friends outside the household Formal employment
Casual employment
Formal business
Informal business
What are the main products you produce from your farm for cash income?
Ask the farmer what source of income the household relies on most
Cereals Vegetables Fruits Timber Firewood Meat
Milk Eggs
What is the farmer's secondary source of income?
Agriculture - from own farm
Agriculture - from farm labourer
Cash gifts from relatives/ friends outside the household Formal employment
Casual employment
Formal business
Informal business
None
Do you hire any labour for farmwork?
Yes No
Household information
Level of household head education?
Household head may or may not be the respondent
No formal schooling
Primary
Secondary
Tertiary (including college/university/vocational courses) Other (specify)

Describe other level of household education?
How many people are there in the household?
Type of house
Permanent (Ironsheets/tile roof + bricks/stones/block/timber wall Semi-Permanent (Ironsheet/tiles + mud wall)
Grass thatched
Grass house
Household dependants
How many children are there?
Below age of 18 years
» Childrens' information
What is the highest level of eduction among the children?
No formal schooling
Primary
Secondary
Tertiary (including college/university/vocational courses)
How many of the household members mentioned are active on the farm?
Farm characteristics
What is the size of your farm?
Make sure hectares is unit that is recorded. If the respondent provides another unit, work with him or her to convert into hectares (1 hectare =2.471 acres)
Do you own it?
Ask the farmer the methods he obtained the farm or specific arrangements that exists currently. All farms under the household.
Private through purchase
Private through customary inheritance Communal
Government
Settlement Scheme
Rented
Leasing out to others
No, But I have a land use right certificate Don't know
How many hectares do you use to cultivate crops? In the last 12 months
Make sure hectares is the unit that is recorded. If the respondent provides another unit, work with him or her to convert into hectares, 1 hectare= 2.471 acres .
Soil types
Farmer's description of soil quality
Description of the whole farm
Low (very little can grow without significant fertilizer, either chemical or organic)
Medium (yields are maximized with chemical or organic fertilizer use, but fair yields can be obtained without)
High (good yields can be obtained without adding either chemical or organic fertilizers)
How can you tell if soil is fertile or not?
Record soil quality indicators used by farmer e.g. soil colour, plant species present, soil organisms, etc.
Are there different types of soil in your farm?
yes no
How many different types of soil do you observe in your farm?
» Soil types in the farm
Location of established PC's
Under which soil type is the tree planting PC established?

Where farmers identified presence of different soil types in their farms, allow them to point out the soil type in the area they have planted trees using the description given above e.g soil type 1, soil type 2,...e.t.c

Under which soil type is the Zai pits PC established?

Where farmers identified presence of different soil types in their farms, allow them to point out the soil type at the area under Zai pits using the description given above e.g. soil type 1, soil type 2,...etc

Soil erosion

Do you experience problems of soil erosion on your farm?

yes no

What types of soil erosion have you observed on your farm?

Select all that apply in the overall farm. Read out the options to the farmer and select ones they have observed

Gully Sheet Rill None

Have you observed any soil erosion where the PCs are established? If yes, what type (s) of erosion?

Select all that apply where the farmer has established the PCs. Read out the options to the farmer and select ones they have observed

Gully Sheet Rill None

Do you take any measures to control soil erosion on your farm?

Yes or No

yes no

What do you use to reduce soil erosion?

Select all that apply

Live fence

Plant residues

Terraces

Fanya juu

Stone bunds

Others

Describe other method used to reduce soil erosion

Soil characteristics

State of soil surface on the farm

Crusted Not crusted

What percentage of your farm has many rocks /stone, gravel cover?

Read out the options to the farmer and together select the appropriate option

Less than 5 %

5-40 %

More than 40 %

Topography

Position on topographic sequence

This is position of your whole farm in relation to topography of the area

Upland

Ridge/crest

Midslope

Footslope

Bottomland

Tree numbers and species count

Are you part of a tradition for tree planting?

Yes No

Number of tree species present in your farm?
Number of tree species currently on the farm
» Tree species
How many of these trees on your farm did you plant?
Count and write down the number of tree in the farm the farmers have planted themselves. Exclude those from natural regeneration.
Trees for food security and livelihoods
What products do you currently obtain from the trees grown on your farm?
Timber Firewood Fruits Honey Fodder Others
Are these products for home consumption or for sale?
Home consumption Cash income
Both
Are the products obtained from the trees on your farm sufficient for your household need?
Yes No
Describe the inadequate product or service?
Tree survival and products
Do you apply any method for protecting trees inorder to increase survival or production?
These maybe protection against cattle, watering, sun or addition of manure/fertilizer.
Are there changes in market either in price, supply or demand which affects the trees/ tree products?
If yes, please describe
Is there tree(s) that has disappeared in your farm which was there before?
Yes No
Mention the tree(s) and describe the reason for disappearance?
Land cover & land-use history
Select the land cover (s) that correctly describe your farm?
Herbaceous crops Woody crops
Multiple or layered crops Grassland
Tree covered area
Shrubs
Regularly flooded area
Sparsely natural vegetated areas
What has been the land use practices in the previous years?
Describe land use history of the farm including past management, frequency of burning, soil & water conservation measures practiced
Crop production
How many crop types were planted on the farm in last 12 months?
By listing the crops first then the number can be reached. This may need to be done on paper before entering in ODK.
» Crops planted in last 12 months
What are the major factors effecting crop production in your farm?
Low soil fertility
Unreliable rainfall
Drought
Low soil moisture
Wrong crop selection
Pests

Diseases
High cost of farm inputs Lack of available labor None
Others
How do you enhance crop productivity on your farm?
Select all that applies. Do not read out options. Select option based on respondent's answer but probe to ensure that the right option is selected.
Fertilizer
Manure
Tillage practices
Use of improved crop varieties
Use of local varieties well suited to the area Others
Crop rotation
Is crop rotation practiced?
The practice of growing a series of different types of crops in the same area in a sequential season, meaning, that the succeding crop belong to a different family than the previous one.
Yes No
What is the actual crop rotation on your farm?
Fallow
Is fallow (leaving part of land uncultivated) practiced in one or more seasons?
Yes No
Approximate percentage (%) of field left fallow at any given time
When was the farm last fallowed?
years
During the last fallow, for how long was the farm left as fallow?
years
Crop residues treatment
Is the land burnt?
Yes No Yes No
When was it last burnt?
years
How many times a year is burning practiced?
How are crop residues treated?
Select all that apply. Do not read out options. Select option based on respondent's answer but probe to ensure that the right option is selected.
Burnt
Left in the field
Other
Describe other crop residue treatment
Farm-yard manure
Was farmyard manure applied to the farm during the last season?
Yes No
Was it purchased or produced on your farm?
Purchased Produced
Which crop did you cultivate with help of farmyard manure?
Select the currency used by the farmer
Kenya Shillings Ethiopian Birr
What was the cost of manure?
Was labour hired for collecting and spreading farm yard manure on your farm?
yes no

How much was the cost for the hired labour to collect and spread farm yard manure last season?
Cost per day multiplied by number of days labour was hired
Compost
Was compost applied to the farm during last season?
Yes No
Did you produce/prepare the compost yourself?
Yes No
Describe how you prepare/make compost?
Which crop did you cultivate with help of compost?
What was the cost of compost if externally sourced?
Was labour hired for making and spreading compost on your farm?
yes no
How much was the cost for the hired to make and spread compost labour last season?
Cost per day multiplied by number of days labour was hired
Mulching
Was mulch applied to the farm during the last season?
Materials such as decaying leaves or bark, spread around or over a plant to enrich or insulate the soil
Yes No Yes No
Did you obtain the mulch from your farm (internally) or sourced externally?
Internally
Externally
What is the source of mulch used?
e.g from grass, crop residues, tree prunings
Which crop did you cultivate with help of mulch?
What was the cost of mulch?
Was labour hired for collecting and spreading mulch on your farm?
yes no
How much was the cost for the hired labour to collect and spread mulch last season?
Cost per day multiplied by number of days labour was hired
Inorganic fertilizer application
Was inorganic fertiliser/chemical used in the farm last season?
Yes No
How many different types of fertilizer/chemical did you apply last seaon?
» Fertiliser
Pesticides application
Was pesticides used in the farm during the last season?
Yes No
How many types of pesticide were used?
» Pesticide
Herbicide application
Was herbicides used in the farm during the last season?
Yes No
How many types of herbicide were used?
» Herbicide Livestock keeping
Do you keep livestock?
e.g. cattle, goats, sheep, chickens etc.
yes no
In total, how many livestock types are present in your farm?

» Livestock

Distance of landmarks from farm

Distance from farm to nearest main road

in km

Distance from farm to nearest main market

Distance to nearest main market (km). Road with regular public transport

Name of the market

Main produce sold at the market

Allow the farmer to give the names of the main farm produce sold at the market and note them down

Distance from farm to nearest water source

Distance to water source (km)

Farmers understanding of climate change

Have you heard of climate change?

yes no

What aspects of climate change have you heard of?

Select all that apply. Do not read out options. Select option based on respondent's answer but probe to ensure that the right option is selected.

Rising temperatures Drought
Floods
Erratic rainfall
Low rainfall Strong winds Cold spells Others

Have you experienced or noticed any changes in climate in your locality or farm?

yes no

What changes have you experienced

Select all that apply. Do not read out options. Select option based on respondent's answer but probe to ensure that the right option is selected.

Erratic rainfall
Low rainfall
Flooding due to heavy rainfall
Prolonged drought
Increasing temperatures
Others

To what extent have the changes identified above impacted on agricultural activities on your farm?

Select all that apply. Do not read out options. Select option based on respondent's answer but probe to ensure that the right option is selected.

Reduced crop yield
Change in planting time
Crop failure
Increased pests and diseases infestation Flooding of crop fields
Reduced soil moisture
Others

Which of the practices listed below do you use in your farm in response to climate change

Select all that apply. Read out the options to the farmer and select ones they use.

Agroforestry
Drought tolerant crops
Rain water harvesting
Irrigation

Soil and water conservation
Application of fertilizers and organic inputs
Using diiferent cropping systems
Others
Preferred language
Which is your preferred language?
How well do you understand your preferred language?
Excellent
Good
Somewhat
How well do you read your preferred language?
Excellent
Good
Somewhat
How well do you write your preferred language?
Excellent
Good
Somewhat
Source of agricultural advice
Do you ever receive agricultural advice?
Yes No
Where do you receive the advice from?
TV
Radio
Lead farmers or other farmers Self help groups
Government extension
School children/youth
Written materials
Phone
Internet
Development agencies
Others
Rank the top source of advice that you currently get?
TV
Radio
Lead farmers or other farmers Self help groups
Government extension
School children/youth
Written materials
Phone
Internet
Development agencies
Others
Rank the second top source of advice that you currently get?
TV
Radio
Lead farmers or other farmers Self help groups
Government extension
School children/youth
Written materials

Phone
Internet
Development agencies
Others
Rank the third top source of advice that you currently get?
TV
Radio
Lead farmers or other farmers Self help groups
Government extension
School children/youth
Written materials
Phone
Internet
Development agencies
Others
Given the choice, what would be your top preferred mode of receiving agricultural information/advice?
TV
Radio
Lead farmers or other farmers Self help groups
Government extension
School children/youth
Written materials
Phone
Internet
Development agencies
Others
Given the choice, what would be your second top preferred mode of receiving agricultural information/advice?
TV
Radio
Lead farmers or other farmers Self help groups
Government extension
School children/youth
Written materials
Phone
Internet
Development agencies
Others
Given the choice, what would be your third top preferred mode of receiving agricultural information/advice?
TV
Radio
Lead farmers or other farmers Self help groups
Government extension
School children/youth
Written materials
Pnone
Internet
Development agencies

Others

Do you have anything to add on information and communication for agriculture?
Are you a member of any farmer orgainsation group?
Yes No
Mention the name and benefits obtained from the group?
What type of training would you ideally like to receive to improve your farming activities?
GPS location at tree planting location
Location of planted trees if they are all within 50 metres
latitude (x.y °) longitude (x.y °) altitude (m) précision (m)
Tree species
How many tree species did you plant?
» Tree species in PC

How many trees individual did you plant?
Tree number
How many minutes did you spend watering one tree?
Is labour for watering the tree hired?
Hired labour Household labour
What is the cost of labour per watering?
in Birr
How many minutes did you spend mulching one tree?
Did you hire labour for mulching the tree?
Yes No
What is the cost of labour per mulched tree?
in Birr
Is the planting site part of a collective grazing system?
Yes No
Did you have trees on your farm before the DryDev project?
Yes No
What was keeping your from planting trees before the DryDev?
No access to seedlings
Did not know how to grow trees
Did not know about the benefits
No tradition for growing trees
No market for tree products
Prefer other crops
Other
If other, please specify?
What was keeping you from planting more trees before the DryDev?
No access to seedlings
Not enough land for more trees
low prices
Not labor for more trees
Other
If other, please specify?
Have you experienced any disadvantages connected to the tree planting?
Yes No
What kind of disadvantages have you experienced?

Competition with other crops
Water use
Less other crops means less food
Less other crops means less income
More work
Less grazing land
Other
If other, please specify?
Did you experience hail after the trees were planted?
Yes No
Did you experience frost after the trees were planted?
Yes No
Are the trees protected by a fence?
Yes No
Do you have a problem with weeds at the planting site?
Yes No
Do you control the weeds in some way?
Yes No
How do you control the weeds?
Weeding
Herbicides
Mulch
Burning
Other
If other, please specify?
Do you have problems with pests on the trees?
Yes No
What kind of pests have you experienced?
Do you control the pests in some way?
Yes No

How do you control the pests?
Pesticides Bio pesticides Cover
Traps
Other
If other please specify?
Do you have problems with diseases on the trees?
Yes No
What kind of diseases have you experienced?
Do you control the diseases in some way?
Yes No
How do you control the diseases?
Fungicides
Bio fungicides
Other
If other please specify?
Do you use any fertilizer on the trees except mulch?
Yes No
What kind of fertilizer do you use?
Farm yard manure

Compost
Inorganic
fertilizer
Other
If other please specify?
How much per tree?
in grammes
How do you protect the seedlings during burning?
Did any of your seedlings got stolen?
Yes No
How many seedlings got stolen?
Did you experience a significant increase in work after the trees were planted?
Yes No
Was it especially difficult to find time during a specific part of the year?
Yes No
Which season was it especially difficult?
Did you attend training before planting the trees?
Yes No
Was it adapted to your level of literacy?
Yes
No
Thank the respondent for their participation and end the interview

Appendix 2: Interview guide SSI with development coordinators

Introduce your self, ask if the informant agrees to be interviewed. Ask if he knows the DryDev planned comparison, Name, age of the informant, position.

1. Is there a tradition for tree crops in the area and did farmers already have trees on their farms before the DryDev Project? If so what kind of trees? If not what do you think keeps people from planting trees?

2. Why do you think farmers in this village chose to participate in the tree-planting project?

3. How do you think the species chosen are adapted to the climate? Have coffee, mango, guava and Faidherbia, moringa been grown here before? Why did the farmers choose these species?

4. How was has the weather been since august 2016 compared to other years?

5. What kind of problems do farmers have with the tree seedlings that could lower the survival and growth? What do the farmers do to protect the trees from these problems?

6. The farmers decided on different treatments to test with mulch and irrigation, how was this process on deciding on the different treatments? Do you have the impression that they have followed the treatments as agreed? If not why not?

7. Where does the irrigation water come from? Does all farmer have equal access to irrigation water, if not why not, and who have better access than others?

8. Does the farmers in this village have land use certificates? How does the system work? How long are the contracts? Has there been any situation where a farmer has lost their contract?

9. Do you know if the fruits and coffee will be for sale or for home consumption? Existing Market? How to sell the products? Has the DryDev programme done anything to prepare the marketing of the products?

10. Which time of the year is most busy for the farmers?

11. Does any of the farmers in this village hire labour for farm work? If so do you know if anyone hired extra labour to take care of the trees?

12. How is the system of extension in this village? Were the farmers trained before the tree planting? What was the content of this training?

13. What do you think are the main causes of seedling death in this village?

Appendix 3: Indicators for socioeconomic groups

Group	Indicator
Market oriented farmers	• Farmers that mentioned market as a reason to plant 2 or more of the species in the planned comparison
Old farmers	• Farmers 65 years and older
Young farmers	• Farmers 35 years old or younger
Limited access to irrigation	• Distance between water source and planting site over 500 m
Limited labour capacity	• Households with less than 3 members active on the farm and no hired labour • Farmers which experienced a significant increase in workload after the trees were planted
Limited knowledge about trees	• Farmers with no access to extension or who did not attend training before planting • Farmers with less education than primary school • Farmers that was not part of a tradition • Farmers that planted fewer than 100 trees on the farm

Appendix 4: Scoring matrix tables on reasons to plant trees from the FDGs

Column explanations:

1. Animal feed
2. Suitable for the environmental conditions
3. We know how to grow and use it
4. Market
5. Productivity
6. Soil fertility
7. The project told us to plant it
8. Useful wood
9. Human consumption
10. Shade or fence

Young farmers

	animal f	suitable for	know how to	market	productivi	soil fert	project t	useful woo	human co	shade or fe	sum of scores
mango		1	4	6	6		2		6		25
apple_ring_acacia	6	4	4	2	4	3	2	3		4	32
rahminus		2	4	6	3		2		6		23
coffee		3	2	6	3		2		6		22
guava		2	4	6	5	2	3		6		28
sum of scores	6	12	18	26	21	5	11	3	24	4	130

Old farmers

	animal feed	suitable fo	know how to	market	productivity	soil fert	project told	useful woo	human co	shade or f	score
mango		3	5	6	5	5	5		5		34
apple_ring_acacia	5	5	4			6	5	5		3	33
rahminus			4	6	5	4	5		5		29
coffee		3	4	6	5	4	4	3	3		32
guava		3	4	5	5	3	5				25
	5	14	21	23	20	22	24	8	13	3	
											153

Market oriented farmers

	animal fee	suitable fo	know how	market	productivit	soil fert	project tol	useful woo	human cor	shade or fe	score
mango		3	3	6	6	5	4		6		33
apple_ring	6	6	6		6	6	6	6		6	48
rahminus		6	6	6	6	4	6		6		40
coffee		4	4	6	6	3	6		6		35
guava		6	6	6	6		6		5		35
	6	25	25	24	30	18	28	6	23	6	
											191

Low labour capacity

	Animal brow	weak seedling	frost	hail	insects	weeds	diseases	lack of water	to much wa	unsuitable	total
mango	2		3	1		2		6		2	16
apple_ring_ac	2	6	3	1		2		4			18
Rahminus	2			1		1		6			10
kazmeer	2		1	1		2		6			12
guava	2		6	1		1		6			16
	10	6	13	5	0	8	0	28	0	2	72

Limited irrigation

	Animal bro	weak seedling	frost	hail	insects	weeds	diseases	lack of wate	to much wa	unsuitable so	total
mango	2	6	2	6	5	6	6	5	3	3	44
apple_ring_acacia	2	6	3	4		4			4	5	28
Rahminus	2	3		5		4			6	4	24
											0
	6	15	5	15	5	14	6	5	13	12	96

Low knowledge

	Animal br	weak seedlin	frost	hail	insects	weeds	disease	lack of	to muc	unsuitable soil		total
mango	3	4	5	3	3			5	3	6		32
apple_ring	3	4		3	3				4	3		20
Rahminus	3		3	3	3			5		5		22
coffee	3		3	4	3			6	3	5		27
guava	3			3	3			4	3	4		20
	15	8	11	16	15	0	0	20	13	23		121

Appendix 5: Scoring matrix tables on challenges with the trees from FDGs

Column explanations:

1. Animal browsing
2. Weak seedlings
3. Frost
4. Hail
5. Insects
6. Weeds
7. Diseases
8. Lack of water
9. Too much water
10. Unsuitable soil

Limited labour capacity

	Animal bro	weak seedling	frost	hail	insects	weeds	diseases	lack of water	to much wa	unsuitable	total
mango	2		3	1		2		6		2	16
apple_ring_ac	2	6	3	1		2		4			18
Rahminus	2			1		1		6			10
kazmeer	2		1	1		2		6			12
guava	2		6	1		1		6			16
	10	6	13	5	0	8	0	28	0	2	72

Limited irrigation

	Animal bro	weak seedling	frost	hail	insects	weeds	diseases	lack of wate	to much wa	unsuitable so	total
mango	2	6	2	6	5	6	6	5	3	3	44
apple_ring_acacia	2	6	3	4		4			4	5	28
Rahminus	2	3		5		4			6	4	24
											0
	6	15	5	15	5	14	6	5	13	12	96

Limited knowledge

	Animal br	weak seedlin	frost	hail	insects	weeds	disease	lack of	to muc	unsuitable soil		total
mango	3	4	5	3	3			5	3	6		32
apple_ring	3	4		3	3				4	3		20
Rahminus	3		3	3	3			5		5		22
coffee	3		3	4	3			6	3	5		27
guava	3			3	3			4	3	4		20
	15	8	11	16	15	0	0	20	13	23		121

Appendix 6 : R code

Illustration of the use of the Logistic regression model using hail as an example

```
#hail

m0<-glm(survival~species,family="binomial",data=data10)
m1<-glm(survival~species+hail,family="binomial",data=data10)
m2<-glm(survival~species+hail+species:hail,family="binomial",data=data10)

#testing for significance of hails effect on survival
anova(m0,m1, test="LRT")
#testing for significance of interaction between hail and species
anova(m1,m2, test="LRT")

# Estimates for the survival with hail adjusted for species
bm1<-brglm(survival~species+hail, family ="binomial",data=data10)
lsm1<-lsmeans(bm1,"hail",type="response")
summary(lsm1, infer=c(TRUE,TRUE))
cld(lsm1)

#interaction on species level
bm2<-brglm(survival~species+hail+species:hail, family ="binomial",data=data10)
lsm2<-lsmeans(bm2, "hail",  by="species", type="response")
summary(lsm2,infer=c(TRUE,TRUE))
cld(lsm2)
```