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Composting of an invasive weed species *Parthenium hysterophorus* L.

– An agroecological perspective in the case of Alamata woreda in Tigray, Ethiopia

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Title

Composting of an invasive weed species *Parthenium hysterophorus* L. – An agroecological perspective in the case of Alamata woreda in Tigray, Ethiopia.
Kompostering av det invasiva ogräset *Parthenium hysterophorus* L. – Ett agroekologiskt perspektiv i området Alamata woreda i provinsen Tigray, Etiopien.

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Summary

Parthenium is a serious weed threat in crop fields and grazing lands in Ethiopia (Tamado, 2001). In this study, the perception of farmers on parthenium and composting is explored using both quantitative and qualitative methods. A seed experiment was also carried out in order to assess the effect of composting temperatures on parthenium seeds as this could be a source of spread. Interviews were carried out with farmers in Alamata woreda, south of Tigray with groups and individual farmers. Even though the perceptions differed among farmers, all farmers were aware of parthenium. In the valley where parthenium was abundant many farmers felt that it was beyond their control, and they were not as active in their weeding. There was also a difference in weeding during seasons, with less weeding done in the dry season. In the highlands where parthenium had recently arrived, farmers were confident about removing the weed and viewed it as their enemy. Composting was more common in the highlands compared to the lowlands where only model farmers composted. This was associated with farmers in the lowlands considering their soils to be fertile and the fear of compost associated disease, *mitchi*.

In order for composting to be a possible control method, farmers need to see the benefits of composting. Current agricultural policies promote a top-down knowledge transfer. There is compulsory use of inorganic fertilisers that does not facilitate alternative practices. An agroecological approach is based on the use of several methods aiming to control parthenium in all seasons as well as making it more worthwhile to weed. Other control methods which could be useful for farmers is making silage from parthenium and planting competitive grass together with leguminous forage. This also has the potential to alleviate the lack of feed for animals in the dry season, which in part has increased due to parthenium. The introduction of biological control agents may alleviate the need for weeding in the wet season.

Foreword

This journey began over two years ago when I started the Agroecology programme in Alnarp. My background in Biology laid a ground for understanding things on a microscale and agroecology has given me a starting point to understand the whole. Getting the chance to do my thesis project abroad was very compelling; the chance to see a whole new culture and the chance to embark on a project that I thought was meaningful.

Things do not always turn out the way you thought and I had been made aware of it by several people before leaving. I had in mind that participatory methods would be challenging to use with farmers but I had not anticipated that the difficulties would be within the powers structures of the University. I have had to reflect heavily on my role as a researcher, the people I have worked with and the farmers I have interviewed. I have learned a lot, having to navigate through another culture, with the primary goal to explore the perceptions around a weed and composting, it is the surrounding subtleties that can give clues to how things work. I have learned that it is impossible to be an observer from the outside as I myself am observed when entering into the farmers world (and those helping me) and they will, consciously or not change their interactions upon their perception of the situation.

I have tried to present what I have done, what I have heard and seen so that the reader can understand the context in which the material was collected. I hope this thesis gives an idea of what predispositions there may be to a certain method to removing a weed, discussing it from different angles. In theory it is feasible, but in practice it requires several questions to be addressed.

ABBREVIATIONS

BoARD	Board of Agriculture and Rural Development
MoARD	Ministry of Agriculture and Rural Development
DA	Development Agent
TARI	Tigray Agricultural Research Institute
ISD	Institute for Sustainable Development (NGO)
FAO	Food and Agriculture Organization of the United Nations
REST	Relief Society of Tigray
FTC	Farmers Training Centre
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
UNDP	United Nations Development Programme
PSNP	Productive Safety Net Programme
HABP	Household Asset Building Programme, a part of the PSNP, aims to build assets with households to increase their economic resilience.
ITCZ	Inter-Tropical Convergence Zone

DEFINITIONS

Softnet (SOFTNET)	Reference to the PSNP by my translator.
Tabia	Area of associated houses, also village.
Woreda	Administrative area of several tabias.
Kebele	A smaller administrative unit, see also farmers' association.
Farmers' association (FA)	The lowest administrative unit in a settled rural area with its own jurisdiction. It is an association of rural dwellers formed by the inhabitants of a given area whose members are engaged either in agricultural and/or non-agricultural activities (CSA, 2007).
Development agent (DA)	There are generally three DAs in each kebele who have their own areas of responsibility (crop production, animal husbandry and household economics).
Inorganic fertilisers	Commercial Fertilisers, in this study a reference to Urea and DAP (Di- ammonium phosphate)
Mitchi	A beleif of sickness derived from opening a compost and being affected by the smoke or steam that results.

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Part I: Introduction

1. Background

"Agriculture is at a crossroads and business as usual is not an option" concluded the IAASD (2008) synthesis report following the question of what is needed to overcome persistent poverty and hunger. This was asked together with questions such as how this can be done with growing environmental problems and producing food for a growing world population whilst seeking a more fair, sustainable and resilient farming (see quote below). This is a relevant question in Ethiopia, a country that often experiences famines and receives international aid to alleviate its population from starvation (Kiros, 2006). Together with the UN, as part of the Millennium Project, they have set out to eradicating extreme hunger and poverty along with the 7 other Millenium Development Goals (UNDP, 2012).

> "What must we do to overcome persistent poverty and hunger, achieve equitable and sustainable development and sustain productive and resilient farming in the face of mounting environmental crises?" (IAASD, 2008)

The future holds many challenges to which agriculture has to adapt such as global warming (IPCC, 2013), resource shortages (Rockström *et al.*, 2009) and invasive weed species (Cassey *et al.*, 2005). One invasive weed in particular, *Parthenium hysterophorus* L. (referred to as parthenium hereafter) is an emerging problem in Ethiopia (Tamado, 2001). During a field survey by Tamado (2001) in eastern Ethiopia, the two most difficult weeds ranked by farmers were recently introduced and half of the recorded species were non-native. One of the two that were recently introduced is parthenium.

Weeds have always been a problem in annual and perennial cultivation and in developing countries about 25% of the yield is lost to weed competition (Akobundu, 1987). Agricultural practices keeps the successional stages of a plant community in its early stages (Altieri, 1995). They are also species that are best suited to survive and proliferate in the fields where we choose to grow a specific crop and interfere with our interests. If we do not remove them they usually compete very well and reduce the yield of our crops (Altieri, 1995).

The most common way to control weeds is to use herbicides, prepare false seed beds or mechanically destroy or uproot them through powered machinery, hand tools or by hand (Akobundu, 1987). Another approach to weeds is to make compost of them once they have been uprooted (Araya *et al.*, 2010), transforming a problem into an opportunity. Composting trials made with farmers in the Tigray region using parthenium have shown promising results, however the adoption of composting has not spread in the region from the original Kebele Selam Bekalsi (pers. com. Asmelash, ISD).

I decided to focus on the perceptions and attitudes of farmers with the aim to better understand the problem situation and to explore if composting of the weed is part of a feasible solution. I also looked at the perceptions of other stakeholders to see if they were different from the farmers. My aim was to use a holistic approach that is common of agroecology to get a rich picture. Getting the views of different stakeholders through participatory methods, composting can be put into a wider perspective of landscape and societal factors.

The following sections will give a brief description of the context and allow the reader to get an idea of the problem at hand. The research questions are then presented, followed by the theoretical background. This gives the context to the choice of methods and also the scope from which the work was done. The results are then presented followed by the discussion.

1.1. Ethiopia

Ethiopia is situated at the East Horn of Africa, bordering Eritrea, Djibouti, Somalia, Somaliland, Kenya, Sudan and South Sudan (see figure 1). Currently it has a population of 88,4 million people (see figure 2) most of which is rural and involved in agriculture, however the city dwelling population is growing. Being a mountainous country it is also very prone to soil erosion and with a large portion (45%) of it over 1500 m above sea level. The soil erosion has intensified with the growing population (Beshah, 2003, p 198).

Figure 1. Ethiopia is situated in the horn of Africa and is land-locked. The study area Alamata woreda is marked in red, in the southern most part of the Tigray region. Map designed on ArcGISOnline (ArcGISOnline, 2014).

Along with the variable topography Ethiopia has varying climates throughout the country and rainfall is dependent on the Inter-tropical convergence zone (ITCZ) that moves from the northern part of Ethiopia in July – August to the North of Kenya January – February (McSweeney *et al.*, 2010). The main rains in the north and central parts of the country falls when the ITCZ is in the north, which is when the south has its dry period (Leroux, 2001). The West of Ethiopia experiences only one wet season and dry season, whereas the east has two rainy seasons, the *kiremt* (June – September) and *belg* (February – May) (McSweeney *et al.*, 2010). The *belg* is also the main rain in the south, although it starts in March. The south has two dry and two wet periods, the second in September – November, corresponding to the movement of the ITCZ moving south (Leroux, 2001). This variation of distribution and amount rainfall across the country contributes to the variation of agricultural practices in different regions (McCann, 1995). The El Niño-Southern oscillation has been correlated to famine years in Ethiopia, where rains are delayed or do not occur as a result of it (Wolde-Georgis, 1997).

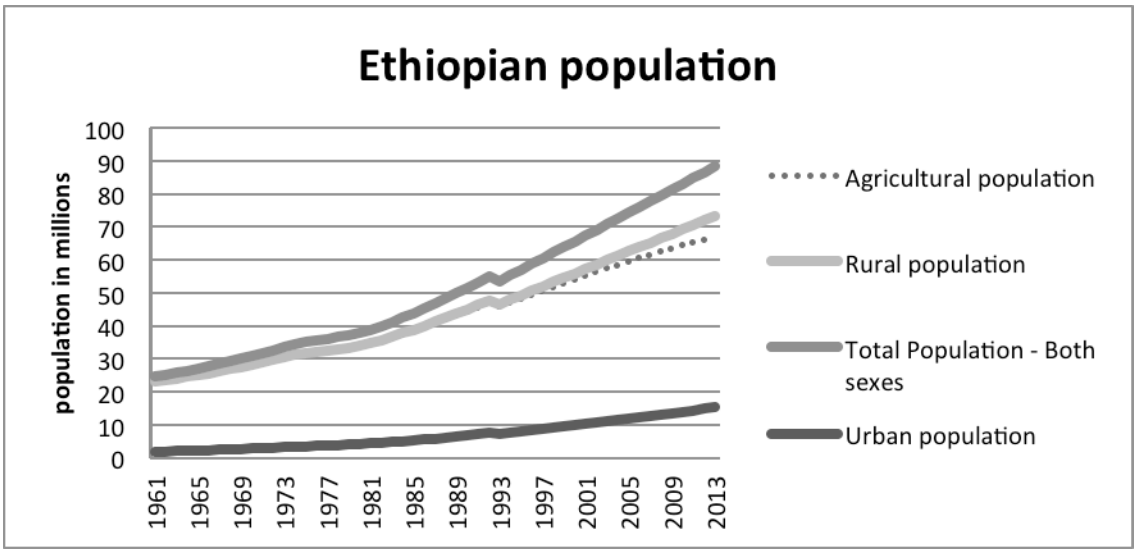

Figure 2. A population graph showing the total agricultural, rural and urban populations in Ethiopia. A large part of the Ethiopian population lives in rural areas, most of them are involved in agriculture, however in the last 20 years this is declining. The urban population has been steadily growing since the 1960s. The change in population around 1991 correlates with the time that the Derg were overthrown in Ethiopia. . Data from FAOSTAT (FAOSTAT, 2013).

1.1.1. Political history

Ethiopia has a long history of many empires, but the borders it has today were established around the beginning of the 20th century when emperor Menelik II united the many ethnic groups and also incorporated lands in the south from the Oromo people together with Somali in the East (Lindahl *et al.*, 2011). Menelik also fended off an Italian invasion at that time but the Italians later invaded in 1936, occupying the country for 6 years before British troops forced them out (*ibid*). Haile Selassie ruled Ethiopia from 1930 until 1974 when he was overthrown by the military council of the Derg, who came to power following unrest due to famine in 1972 – 1974 (*ibid*). The Derg proclaimed a socialist state, nationalising industries and agricultural lands. The Derg were hard on the opposition to the revolution, many were tortured or killed and many Ethiopians escaped to Europe or the USA (*ibid*). After the fall of the Soviet union and with the help of USA, the Tigray peoples liberation front (TPLF) and the Ethiopian Peoples Revolutionary Democratic Front (EPRDF) took power in 1991 (*ibid*). Ethiopia received military support from the Soviet union and food aid from the west during the Derg regime that changed to western development aid with the new government (Flores and The Oakland Institute, 2013).

Meles Zenawi, leader of the TPLF, was interim president until he was elected Prime minister in the first election in 1995 (*ibid*) and led the country until he passed away in 2012 (Gentleman, 2012). The border between Ethiopia and Eritrea have been disputed for a long time and in 1998 Ethiopia declared war on Eritrea after they proclaimed the city of Badme to be part of Eritrea (Lindahl *et al.*, 2011). A truce was agreed which is still in effect today, but the border is still in dispute (*ibid*). In 2002 and 2003 there was a severe drought primarily in eastern Ethiopia which led many to starve and be reliant on food aid (Lindahl *et al.*, 2011). The current prime minister is Hailemariam Desalegn (Gentleman, 2012).

1.1.2. Brief agricultural history of Ethiopia

Remains of agricultural practices have been found dated as far back as 9000 years ago in parts of Ethiopia (Lindahl *et al.*, 2011). Westphal (1975; cited in Beshah, 2003) has broadly summarized farming practices in Ethiopia to four different types:

- **The seed farming complex** is an annual cropping system (often lacking trees in the northern highlands) based mainly in the east, central and northern highlands where cereals (including tef (*Ergarostris tef* (Zucc.) Trotter) and sorgum (*Sorghum bicolor* (L.) Moench), pulses, oil crops and some tubers are grown from seed. Although vegetables were not common 30 years ago, with expanding markets they are now commonly grown in these regions. Land is prepared using oxen, however in the eastern highlands it is done using a combination of hand-hoeing and oxen ploughing. After harvest, cultivated land turns into common land for grazing and dung collection.
- **Enset-planting complex** is a mixed annual-perennial system including coffee (*Coffea arabica* L.) and khat (*Catha edulis* (Vahl) Forssk.) found in the South West.
- **Shifting cultivation** is practiced in parts of the west and south of Ethiopia. This system resembles a agro-pastoral production system, with crops similar to the seed farming complex with the addition of spices. However the main tools for soil preparations are hoes and sticks.
- **The Pastoral complex** exists mainly in the lowlands of Ethiopia (northeast) but livestock is essential to all farming in Ethiopia. Since the 1970's, the change in land use has increased the grazing pressure on these land complexes as well as limiting the mobility of pastoralists.

Land tenure in Ethiopia, from the early Axumite kingdoms up until 1974, when the monarchy was overthrown, has been based on a semi-feudal tenant-landlord relationship where the landlords were either the church or local elite (Beshah, 2003). During the 1960's, the Swedish foreign aid agency initiated a development programme to ”develop markets with fair prices and to use extension agents and model farmers to stimulate the target population to buy and use improved seeds and fertilisers” (Cohen, 1975). However, the project was not successful due to weak land tenure laws and difficulties with local government (*ibid*).

When the Derg came to power in 1974 a huge land reform took place. Each farming household was entitled to 10 hectares of land, however the land belonged to the state (Beshah, 2003). The redistribution of land was done by the newly started peasant associations (PA) and wereda administrations. However, there was a good deal of conflict, as farmers were not compensated for property lost in land redistribution or due to multiple claims on land (Beshah, 2003). Adamassie and Abebaw (2014) conclude that during the Derg ”Civil conflict and misguided economic policies [in] the 1970s and 1980s, widespread reliance on rainfall dependent subsistence farming and recurrent drought have condemned a significant percentage of the Ethiopian people to extreme poverty”.

Following the fall of the Derg regime, the land policies were not fundamentally changed, but farmers were now allowed to use hired labour, to lease land to or from other farmers (Beshah, 2003). In the new constitution (1995), the Ethiopian government has the sole right to the ownership of land and natural resources, however farmers and pastoralists have constitutional right to land for their farming practices without charge (Admassie and Abebaw, 2014). They are also protected against eviction from these lands and are allowed to own property built there (*ibid*). President Carter urged the new prime minister to have a look at Sasakawa Global 2000 (SG2000) plots which led to the government giving priority to the agricultural sectorzote and facilitating loans to small-holder farmers to acquire inorganic fertilisers and improved seed (Mann, 1997). SG2000 was started in the hope that it would replicate the green revolution that happened in Latin America 40 years earlier headed by the Rockerfeller foundation (Mann, 1997). The process does not encourage farmers innovation, although it claims to include peoples participation, it remains a top-down approach facilitating package solutions based on institutional research (Beshah, 2003).

1.1.3. Current agricultural policies and goals

Ethiopia signed the UNDP Millenium Goals, which constitute eight broad developmental goals[1] in 2000 at the United Nations Milennium Summit, and has developed medium term development plans linked to these goals over the last 10 years (MoFED and UN Country Team, 2004; MoFED, 2010a; IFPRI, 2013):

- Sustainable Development and Poverty Reduction Program (SDPRP), 2002/03-2004/05
- Plan for Accelerated and Sustained Development to End Poverty (PASDEP) - 2005/06-2009/10
- Growth and Transformation Plan (GTP) 2010/11-2014/15
- Ethiopia's Food Security Programme (EFSP) 2010–2014

The agricultural sector Policy and Investment Framework (PIF) 2010 – 2020 set out by Ethiopia (Chanyalew *et al.*, 2010), acknowledges that 95% of the agricultural production comes from small holder farmers and stresses that they need to move from subsistence to semi-commercial production of crops. The PIF is also connected to Ethiopia's growth and transformation plan (GTP) that aims to increase the annual agricultural growth by 8.1% (of GDP) (MoFED, 2010b). The GTP also opens up 8 million hectares (of the total 51.3 (Chanyalew *et al.*, 2010)) of land to commercial farm investors to increase the private agricultural sector (MoFED, 2010b). The growth is envisioned to come from three parts (*ibid*):

1. Technology adaptation, multiplication, distribution and use system which is explained as fertilisers, improved seeds, new breeds of livestock and machinery. The transfer of this technology is to be facilitated by councils of researchers, extensionists and farmers.
2. Protection of natural resources through community conservation practices. They also stress better water availability, ensuring more access to irrigation water on this point.
3. Increase farmers' income from high-value products in respect to the available and developable markets.

These aims are part of Ethiopias' aspiration to become a middle income country by 2015 (Flores and The Oakland Institute, 2013) and the UNDP Millenium Goals that aims to halve poverty and hunger by 2015 (UNDP, 2012). Following the plans of the GTP, large parts funded by foreign donors, many farmers are being displaced from their lands as part of a 'villagisation' plan where farmers are moved to villages to free up land and facilitate access to health and education facilities (Flores and The Oakland Institute, 2013). The Tigray, Amhara and Oromia are not as affected as other regions (*ibid*).

The productive safety net programme (PSNP) started in 2005 as a response to the chronically food insecure people, who in times of emergency had to sell their productive assets in order to survive (IFPRI, 2013). The PSNP was restarted in 2009, as a part of the EFSP, together with a new component, the Household Asset Building Programme (HABP), which aims to build assets in poor households through micro-financing to graduate them from the PSNP (IFPRI, 2013). One component of the PSNP is 'work for food', where local authorities implement conservation practices in the dry season, which are carried out by individuals who qualify for the programme in exchange for food or money (IFPRI, 2013).

[1] 1. Eradicating extreme poverty and hunger; 2. Achieving an universal primary education; 3. Promote gender equality and empower women; 4. Reduce child mortality; 5. Improve maternal health; 6. Combat HIV/AIDS, malaria and other Diseases; 7. Ensure environmental sustainability; 8. Develop a global partnership for development (UNDP, 2012).

1.2. *Parthenium hysterophorus*

Parthenium, a member of the Asteraceae, is native to the Americas, with the white flowered group occurring predominantly in the north and the yellow to cream coloured flower group in the south (Dale, 1981). It has spread to many other countries in East Africa, Asia and Oceania (Navie *et al.*, 1996). Parthenium grows as a rosette in its early stages spreading over the ground before it grows and takes on its bush-like appearance with many branches and prolific flower production (see figure 3). Parthenium also produces a long taproot which allows it to store energy for rapid re-growth when grazed and retrieve water deep down in the soil profile (Navie *et al.*, 1996). Parthenium is sensitive to shading and seedlings fail to establish in these conditions (Williams and Groves, 1980).

One of the reasons it spreads rapidly is that one mature plant can produce between 15000 to 25000 seeds (Navie *et al.*, 1996), however an Australian study showed that the amount of filled seeds varies between 35 – 67% with the climate (Nguyen *et al.*, 2010). Tana Tamado (2001) investigated the germination behavior of parthenium in eastern Ethiopia and found that it emerged between average temperatures of 10 and 25°C, that the seeds are sensitive to moisture stress and do not emerge unless there is sufficient water. The seeds were dormant for 60 days in field trials in both un- and disturbed sites suggesting that parthenium seeds have a dormant phase (Tamado, 2001). A lower dormancy at cooler temperatures has been found in Australia (Nguyen *et al.*, 2010), which was also found in Ethiopia by Karlsson *et al.* (2008). After 30 months of burial at two sites, more than half of the seeds were still viable suggesting that buried seeds could survive 6 – 8 years depending on the conditions (Tamado, 2001). In cooler climates it has been found to be 1 – 3 years (Nguyen *et al.*, 2010) and the onset of germination is prolonged with as much 10 times (Tamado, 2001). Seeds on the surface do not survive for very long (Navie *et al.*, 1996, 1998), experiments suggest about 6 months (Navie *et al.*, 1998) indicating that tillage increases seed survival.

Figure 3. (Left) Seedlings of parthenium showing the typical rosette stage. (Right) Mature parthenium plant growing by the roadside in February, with numerous white flowers.

Dale (1981) reported that dense parthenium stands occurred predominantly on dark, self-mulching, alkaline cracking clay soils and attributed the extensive stands to soil type. In Australia parthenium is present on all soil types but is most dominant on alkaline clay loam (DEEDI, 2011). A study of soil type on phenotypic variations found that soils with high clay content promoted higher growth and fewer but larger seeds, suggesting that seeds are better equipped for longer survival (Annapurna and Singh, 2003). Disturbed soils are common place for parthenium, as are roadsides, cultivated soil, building sites and grazed areas (Dale, 1981).

Parthenium also has allelopathic properties. 10 days into the seedling life it is already exuding allelopathic compounds that could inhibit the growth of other plants (Belgeri, 2013). An investigation by (Belz *et al.*, 2007) found that parthenin is not the only allelochemical responsible for inhibition of germination and growth but suggested that it may play a leading role. Belz *et al.* (2009) found that in laboratory conditions parthenin is broken down within 3 days, even faster in soils taken from field sites, indicating that parthenium does not inhibit germination of other plants after it is removed. The presence of seeds in the soil may have inhibiting effects similar to leaf extracts (Msafiri and Tarimo, 2013).

The distribution of parthenium in Ethiopia is concentrated to the rift valley between Arba Minch and Dire Dawa, stretching up along that road from Addis Ababa to the Eritrean border (McConnachie *et al.*, 2011). A survey by TARI showed that parthenium was present throughout most of Tigray but with higher infestations in the south between Alamata and Mekelle (Abriha and Abebe, 2012). In the same report they identified the following reasons for spread of parthenium in Tigray: Run-off water; Animal ingestion and movements; Heavy vehicles moving between regions; Transport and use of seeds/grains (mainly tef and onion) (*ibid*).

Quite a few studies have been done on parthenium in Ethiopia. A study on the South-Eastern Ethiopian rangelands found that parthenium has a high impact on biodiversity (Ayele *et al.*, 2013). Both herbaceous and grass species have been reduced significantly, which has a huge impact on the carrying capacity of the lands (*ibid*).

In sorghum the yeild reduction due to parthenium can be as high as 97% if it is not weeded (Tamado, 2001). In tef, aqueous extracts of parthenium give different responses depending on the concentration and origin of the extract (flower, stem, shoot and roots) (Tefera, 2002). At higher concentrations of flower and shoots, seed germination of tef was completely inhibited while stem and root extracts had a stimulative effect on shoot growth (*ibid*).

Not all grasses are outcompeted by parthenium, some indigenous Ethiopian species have been found to be able to compete with it (Mersie *et al.*, 2010) and some non-native species have been found in other countries(Khan *et al.*, 2013) (see table 1). Over-grazing of grass species in the dry season lowers their ability to compete with parthenium (DEEDI, 2011).

Table 1. Native and naturalized species of grass that compete well with parthenium.

Native species	Common name	Reference
Bothriochloa radicans (Lehm.) A.Camus	Stinking grass	(Mersie *et al.*, 2010)
Chryspogon aucheri (Boiss.) Stapf.	-	
Cenchrus ciliaris L.	blue buffalo grass	
Panicum coloratum L.	blue panic grass	
Naturalised species*		
Setaria incrassata (Hochst.) Hack.	Purple pidgeon grass	(Khan *et al.*, 2013)
Panicum maximum Jacq.	Guinea grass	

.*As described by Ethiopian Flora Project *et al.* (1989)

1.2.1. Contact dermatitis and toxicity

People who are repeatedly in contact with parthenium can develop contact dermatitis (Towers, 1981). Interviews done with 64 farmers in Ethiopia showed that almost all of them reported parthenium related hay-fever (90%) and almost a third had skin problem (Wiesner *et al.*, 2007). By contrast, a study in India found that out of 300 people who had been in contact with parthenium, 56% had been sensitized but only 4% developed contact dermatitis to the weed (Rao *et al.*, 1977). The compounds that cause the allergic reactions are sesquiterpene lactones, mainly parthenin and coronopilin, and are found mainly in the trichomes on stems and leaves (Towers, 1981). The probability of developing dermatitis from sesquiterpene lactones is highly individual (Warshaw and Zug, 1996). The sesquiterpene lactones have not been found to be phototoxic as is common on other *Asteracae* species (Towers, 1981). In a study on the parthenin content of parthenium at different sites and altitudes in Ethiopia, they found that water availability was the largest factor related to parthenin content (Ulrichs *et al.*, 2012).

Animals tend to avoid parthenium, however livestock will consume it if other feed is not available which in worst cases can cause death with prolonged periods of ingestion (Navie *et al.*, 1996). Tainting of cows milk has also be reported after they have ingested parthenium (*ibid*).

1.2.2. Control methods

The most common methods of control are either mechanical removal or herbicide application. Alternative methods have appeared in the last 30 years which focus on either controlling it through biological control, use of competitive grass species and removal before flowering (Navie *et al.*, 1996). A trial carried out in the Hluhluwe-Mfoloze Park found that herbicide treatments favoured the establishment of native grasses while manual control through hoeing and pulling up plants by hand favoured alien forbs (Goodall *et al.*, 2010). In all control methods, the regeneration density a year later was the same as prior to any treatments (*ibid*). In countries where parthenium is not native, very few or no natural enemies are present, which has led countries such as Australia to seek out possible candidates to release (Navie *et al.*, 1996). In Australia many species have been evaluated and released for their ability to limit parthenium growth and seed set: the stem-galling moth *Epiblema strenuana* Walker; the stem-booring wevil *Listronotus setosipennis* Hustache; the defoliating beetle *Zygogramma bicolorata* Pallister; the larvae of *Smicronyx lutulentus* Dietz feed in parthenium leaves; the stem-galling wevil *Conotrachelus albocinereus* Fiedler; the leaf mining moth *Bucculatrix parthenica* Bradley; the stem boring moth *Carmenta* nr *ithacae* Beutenmüller [2] (parthenium clear wing moth); the winter rust *Puccinia abrupta* Dietel & Holw.; and the summer rust *Puccinia melampodii* Dietel & Holw. (DEEDI, 2011). Of these, *Z. bicolorata* and *L. setosipennis* have been considered for release in Ethiopia (Mersie *et al.*, 2010). In Ethiopia one species is about to be introduced and two species are currently present. These are described in more detail below.

Varigated ragweed beetle

Zyogramma bicolorata (Coleoptera:Chrysomeldae) feeds on both leaf and shoots which reduces the growth and spread of parthenium (Navie *et al.*, 1996). It is native to Latin America and has been present in Australia since 1980 when it was introduced as a biological control agent (*ibid*). It is being considered for use as control agent in Ethiopia and has been evaluated for its impact on other native species (Mersie *et al.*, 2010). It is dependent on sufficient rainfall to establish a good population which was the case in Australia where one site only had significant change due to *Z. bicolorata* in one out of four years (Dhileepan, 2007). It also enters into a diapause for which the exact reason for its initiation is unknown. It may be connected to photoperiod, temperature or the senescence of host-

[2] Due to its host specificity, this moth is believed to be different from the *C. ithacae* commonly found on a wide range of asteraceae species in North America (Dhileepan *et al.*, 2012).

plant foliage (Jayanth and Bali, 1993). In a study in Bangalore (India), the break of the diapause came with the monsoon rains, partially due to the need for moist soil in order to burrow out (Jayanth and Bali, 1993). The beetle was present during the warm rainy half of the year and in diapause during the other drier, cooler half of the year (Nov – May), which could also be induced in laboratory conditions with higher temperatures (*ibid*).

Parthenium leaf rust

Puccinia abrupta Dietel & Holw. var. *partheniicola* (Jacks.) Parmelee is a rust fungus from Mexico which reduces plant size, biomass and seed production in parthenium (Taye *et al.*, 2004). It produces all spore stages on parthenium and it is its only host (macrocyclic and autoecious) (Evans, 1987). Parker *et al.* (1994) found that in order for *P. abrupta* to be successful in infecting parthenium, there needs to be dew for more than 6 hours and a temperature below 20°C. An inventory of it's presence around Ethiopia by Taye *et al.* (2004) showed that it was present in sites between 1500 to 2550 m altitude, however it was not found in Kobo, close to Alamata, indicating that it is not present in the lowlands of the region.

Phyllody in parthenium

In a study by Tessema *et al.* (2004), the incidence of phyllody[3] on parthenium and its causing agent were investigated. They found that the causing agent was a phytoplasma similar to that of faba bean (*Vicia faba* L.). The closest site to Alamata, Kobo, showed a phyllody incidence of 6 -20 and 21 – 50 in Jan-Feb and Oct-Nov respectively (*ibid*). They were not able to identify the vector but suggested that with further research it could be possible to use as a biological control agent (*ibid*). The authors point out that the similarity to the faba bean family of pytoplasmas might pose a threat to other crop species which are susceptible if intentionally spread (*ibid*).

1.2.3. Composting

The main benefits of composting according to Araya and Edwards (2011) are:

1. Release of nutrients throughout the growing season.
2. Improved soil structure.
3. Improved capacity for water retention in the soil.
4. The composting process helps remove pests and diseases (including weeds such as parthenium).
5. Less soil and wind erosion due to better soil structure.
6. Improved productivity for farmers through the higher yields. There is no need to take loans for fertilisers, however the authors stress the need for hard work.

The use of compost in the Tigray region can increase yields significantly, even more than inorganic fertilisers, according to trials done by Edwards *et al.* (2007). The sufficient amount of compost that needs to be applied in order to get good yields are between 3,2 and 6 tonnes per hectare (Araya and Edwards, 2011). However, the ability to apply such quantities depends on the availability of resources (*ibid*).

The ISD performed a composting trial using parthenium between May and October 2006 at the Selam Bekalsi FTC in Alamata woreda after being approached by the Tigray regional BoARD (Araya *et al*, 2010). They tested four different combinations of compost components: only green parthenium (no water); only dry parthenium with water added; a mix of green and dry (no water); 75% of mixed dry and green parthenium with other compost materials. The dry and green mixed with other

[3] Phyllody is the development of leaf instead of floral structures.

materials was found to mature the quickest and contain the most nutrients equivalent to compost normally prepared by farmers. A field trial showed that a local maize variety grew best with this compost (2.7t/ha, 9 t/ha straw) followed by the green parthenium compost (2 t/ha, 7 t/ha straw). Germination tests of seeds found in the dry parthenium compost (none found in the other preparations) did not germinate for 6 months indicating that parthenium seeds may be destroyed if composted using their methods.

Trials with composting have shown that the allelopathic properties are reduced after composting and mixed with other materials at a ratio of 1:2, growth inhibition is also reduced (Wakjira *et al.*, 2009). Kishor et al., (2010) found that seeds are not destroyed when composted and suggested that it is best to avoid parthenium plants that have gone to seed. The seeds germinate when exposed to the heat in compost, however at temperatures around 60°C the germination rate is 10% (and viability 15%), indicating that higher temperatures might destroy the seeds (Kishor *et al.*, 2010).

Optimum moisture content of a compost is 40-60%, particle size plays an important role and C:N ratio of 25 gives rapid decomposition (Bekunda *et al.*, 2010). Long-term experiments have shown that crop yields from treatments consisting of inorganic fertilizers without accompanying organic inputs can decline over time as a result of (i) soil acidification, (ii) rapid depletion of non applied nutrients, (iii) increased loss of nutrients through leaching, and (iv) decline of soil organic matter (*ibid*).

1.3. The study area

1.3.1. Alamata woreda

The town Alamata is situated in the Raya-valley, but the woreda itself also includes a highland region part of the livelihood zone (defined by MoARD) Tsirare catchment (The Livelihoods Integration Unit (MoARD) and FEG, 2010). The area around Alamata is known to be a parthenium 'hotspot' in the Tigray-region (Fitiwy, 2013, pers. Comm.). The main road from Addis Abeba to the Eritrean border runs through the valley and Alamata Town itself. There are 12 kebeles in the woreda and three were visited in this study (see figure 4). It takes about 3 hours to get to Alamata from Mekelle. Soil profiles tested by Relief Society of Tigray (REST) show that pH in the valley bottom ranges from 7.4 to 8.5 and increases with depth (IPMS, 2007).

Farming is very dependent on rainfall availability, there is one main rain in July to August (*kiremti*) which corresponds to the main growing season (*meher*) and one short (*belg azmera*) in January to February (IPMS, 2005). Recently the short rains have been inconsistent (*ibid*).

Farming in the Alamata area is roughly divided into two different farming systems, one in the highland and one in the lowland (IPMS, 2005): In the highlands barley, wheat, pulses are mainly grown as they are better adapted to the cooler temperatures; In the Lowlands teff, sorghum and maize are grown; In both locations livestock are held.

Both are concurrent with the **The seed farming complex** mentioned earlier (sec. 1.1.2). The woreda office of agriculture and rural development supplied agricultural extension to the region through three different focuses: crop production, animal production and extension (household economics, supervision of FTC and PA) (IPMS, 2005). In each tabia there are development agents (DA), although the exact number may vary, they hold similar areas as at the woreda level (*ibid*). There are FTCs in most tabias, however none of them were equipped in 2005 (*ibid*).

The rainfall in the region is bimodal (Leroux, 2001, p 353), with the main *kiremti* rain during July – September and the shorter *belg azmera* rains from March to April (DPPA, 2007), which is reflected in the rain and temperature chart in figure 5. The occurrence of rain is highly variable in Alamata, and rain is not evenly distributed throughout the months when it rains (Hadgu *et al.*, 2013).

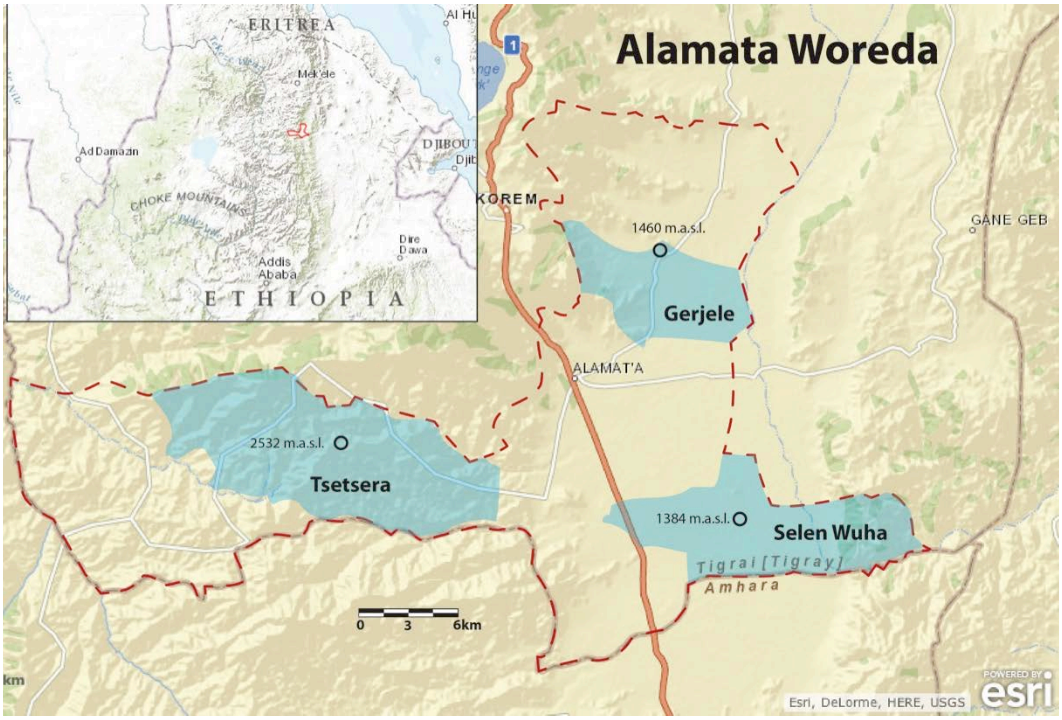

Figure 4. An overview of the Alamata Woreada, which is situated in the southern-most part of TIgray, bordering with the Amhara region. The visited kebeles are highlighted in blue, Gerjele with the highest parthenium infestation, Selen Wuha with a little less and Tsetsera with a low presence of parthenium. The rings represent the villages visited during group and individual interviews (altitude from own GPS readings). Map compiled in ArcGIS Online (Map images ©ESRI).

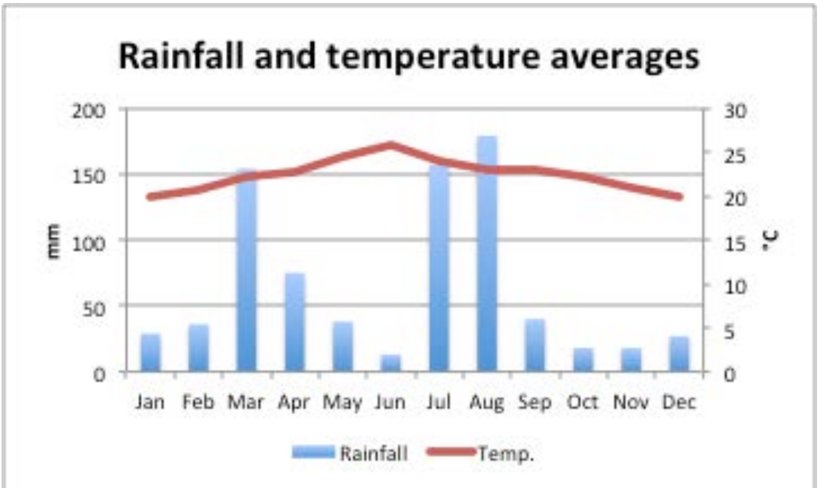

Figure 5. Average rainfall from Alamata based on data from climate-data.org (AmbiWeb, n.d.). The two peaks in the rainfall correspond to the bimodal rainfall the region gets (Leroux, 2001), however the presence of the March – April rainfall is highly variable (Hadgu *et al.*, 2013).

1.3.2. Mekelle

Mekelle is the regional capital of the Tigray region. As I was living here for most of the duration of my stay in Ethiopia I had time to make observations in and around the Town.

2. Research questions and objectives

This research aimed to explore the possibilities of composting parthenium in the Alamata area as a means to control it. I wanted to find out what local knowledge can reinforce its use and if there are any objections to composting a noxious weed. The focus of my research questions are on parthenium and composting. In order to understand the situation at hand I have sought to get a rich picture through qualitative methods.

My initial research questions are based on discussions with the ISD, their work on composting (particularly parthenium) and Dr. Emiru Seyoum (Addis Abeba University) in the months preceeding my time in Ethiopia. They evolved when I arrived to Mekelle and after my first visit to Alamata.

Research questions:

1. What is the overall attitude towards parthenium and composting?
2. Is there any knowledge of, and active practices of composting?
3. Are there any limitations towards composting of parthenium?
4. Are the health hazards of parthenium a serious limitation to composting?
5. Do the seeds survive the composting temperatures?

Objectives:

- Get an insight into the context in which the composting of parthenium would be done to get a richer picture of the situation at hand.
- To listen to some of the perceptions amongst farmers towards parthenium and composting.
- Understand what factors may be limiting in the use of parthenium as compost material.
- To see what temperature, if any, is limiting to the survival of parthenium seeds.

3. Theoretical framework (methodology)

3.1. Agroecology

Agroecology has many different definitions depending on whom you ask, where you are and what literature you look at. Earlier literature focuses on a description of Agroecology and associated methods (Conway, 1987; Vandermeer *et al.*, 1990; Altieri, 1995) whereas newer literature (with some exceptions, e.g. Gliessman (2007) has gone into discussing the definition, origin and evolution of Agroecology (Dalgaard *et al.*, 2003; Wezel *et al.*, 2009; Méndez *et al.*, 2012; Sevilla Guzmán and Woodgate, 2013). Different sources on the definition and evolution of Agroecology are summarized in Table 2, but can be broadly defined as: A discipline that uses basic ecological principles for the study, design, and management of productive and natural resource preserving agroecosystems with the aim to be economically viable, culturally sensitive and socially just (Altieri, 1995).

Early literature from before the 1960's that mentions agroecology, focuses on applying ecology (the organism, plant interactions with their environment) within agriculture (Dalgaard *et al.*, 2003; Wezel *et al.*, 2009) has been described as a 'hard' agroecology (Dalgaard *et al.*, 2003). The alternative view of this is the 'soft' agroecology that also includes humans and society in this approach (*ibid*) and an example of this is Altieri (1995). Wezel *et al.* (2009) points out that agroecology has evolved differently depending on the country or regions agricultural and social contexts. The environmental movement of the 1960's – 1970's influenced agroecological thought and introduced a more critical voice towards production oriented agronomy (Altieri, 1995), which tailors individual solutions to isolated problems (in a reductionistic manner, see sec. 3.2) instead of understanding the rich complexity of an ecosystem (Vandermeer *et al.*, 1990, p 342). At this time agroecology also expanded past ecology of the agroecosystem to include social and economical issues in the USA (Wezel *et al.*, 2009). In Latin America, agroecology has been part of a political movement from the start, based on the adoption and development of agroecological practices by farmers which has empowered them to change the way they farm (Altieri and Toledo, 2011). In South-East Asia the agroecosystems analysis was developed by Conway (Conway, 1987). He looked at both biophysical as well as social aspects within farming and developed several methods that were adopted into PRA (see section 3.4). In Germany agroecology has been seen more as a science focused on farm field ecosystems (Wezel *et al.*, 2009), a 'hard' agroecology as defined above.

Sevilla Guzmán and Woodgate (2013) have questioned the separation of agroecology into science, practice and movement by Wezel *et al.* (2009) and argue that it is not possible to partition agroecology. It is clear however that there are different ways to see agroecology and use it, and Méndez *et al.* (2012) has contrasted scientific research grounded in Western tradition with an action-oriented research inquiry done in participation with farmers. This is also highlighted by Altieri (1995) who contrasts dominant and alternative premises in modern science (ie. Atomism versus holism, objectivism versus subjectivism). Systems thinking (discussed further on in this thesis, sec. 3.2) challenges the cartesian perspective by reversing the understanding of the whole by its parts to understanding the parts by the whole (and their connections) (Capra, 1996). This is a central concept inf agroecology (D. Rickerl and C. Francis, 2004).

When trying to identify the epistemological (knowledge/understanding) and ontological (existence/being) ideas behind agroecology it is important to understand the context in which it appeared. Ecology is a science in which ecosystems are understood through the interactions of its parts. At the time when Odum (1969) presented his ecological theories the green revolution was underway. When Rachel Carsons' book "Silent Spring" (Carson *et al.*, 2002) was published, it created public awareness of the side effects of pesticide use. Both Altieri (1995) and Gliessman (2007) have a background in agricultural extension in the Americas and are both in a sense forefathers of the agroecology of today.

A critique of the systems thinking within agroecology was voiced by Bland and Bell (2007) where they warned of an over-connected understanding over boundaries and change. They suggest that agroecology practitioners be aware of the "consequences of those understandings, with all their conflicts and asymmetries"(*ibid*, p292). They suggest a holon approach where the researcher "flickers" between different boundaries and areas, something I find very close to the multi-dimensional thinking discussed by Rickerl and Francis (2004)[4]. Reflexive thinking and learning is a part of agroecology, especially when working with participatory methods and qualitative methods.

[4] Multi-dimensional thinking in the case of Agroecology could be looking at different levels of environment ie. landscape, farm/field, plant. It could also encompass biophysical or biological factors, sociocultural background, economic forces, available technologies and ecological soundness (D. Rickerl and C. Francis, 2004).

Table 2. Summary of important literature that defines agroecology in the last 30 years.

Reviewer	Definitions	Typology
Conway (1987)	"[The agroecosystem is a] complex agro-socio-economic-ecological-system, bounded in several dimensions[…]" (p. 96)	• Multidiciplinary analysis of different levels of an ecosystem • Cybernetic systems, observer considered outside.
Vandermeer *et al.* (1990)	Application of a deeper understanding of ecological processes to modern agricultural practices	• Multidisciplinary problems characteristic of agroecosystems
Altieri (1995)	"[A]groecology [is a] discipline that provides the basic ecological principles for how to study, design, and manage agroecosystems that are both productive and natural resource preserving, and are also culturally sensitive, socially just, and economically viable." (p. ix)	• Focus in bottom-up approach working with farmers perception and knowledge • Resilient agroecosystems mimicking natural ecological systems
Dalgaard *et al.* (2003)	"[A]n integrative discipline that includes elements from agronomy, ecology, sociology and economics" (p. 39)	• "Hard"-agroecology • "Soft"-agroecology
Francis *et al.* (2003)	Ecology of food systems	• Ecological, social and economic dimensions • Interdiciplinary
Buttel (2002)	Does not give a definition, but Identifies most with the multifunctional approach.	• Integrated assesment of multifunctional agricultural landscapes • Ecosystems agroecology • Agronomic agroecology • Ecological political economy • Agro-population biology
Gliessman (2007)	"The application of ecological concepts and principles to the design and management of sustainable food systems" (p. 18)	• Study of ecological processes in agroecosystems • Change agent for complex social and ecological shifts that change agriculture to a sustainable paradigm
Wezel *et al.* (2009)	"Agroecology as a Science, Practice and Movement" (p. 503)	• Time (pre and post 1970) • Geographical (different developments in different countries)
Méndez *et al.* (2012)	Agroecology as a Transdisciplinary, Participatory, and Action-Oriented Approach	Two dominant perspectives: 1. "[A] framework to reinforce, expand or develop scientific research, firmly grounded in the western tradition and the natural sciences" (p. 5) 2. "[D]eepens conceptual inquiry within specific sub- fields while expanding and redefining a broader agroecological perspective" (p. 6)
Sevilla Guzmán and Woodgate (2013)	"promotes the ecological management of biological systems through collective forms of social action, which redirect the course of coevolution between nature and society in order to address the "crisis of modernity." This is to be achieved by systemic strategies . . . to change [the] modes of human production and consumption that have produced this crisis. (Sevilla Guzmán and Woodgate 1997, p 93–94)"	• Origins of Agroecology from sociological thinking (Marxist thought and the Metabolic rift which led to the Agrarian question) • Environmental sociology another input into agroecological thought • "Understanding nature as an active participant in processes of change" (p. 40)

The type of agroecology prevalent in Ethiopia is based in the bio-physical bounds focused on what crops are suitable to grow based on their requirements (for examples see MoA (2000) and Kassie *et al. (2009)*). It differed from my perspective of agroecology and it influenced the result of this thesis due to the different views on methodology associated. The Agro-ecological zones often referred to (or agroecologies in short) in Ethiopia, have their origins in work started by IIASA and FAO in the 1980's (Fischer and IIASA, 2002). They use GIS maps and collected variables (eg. moisture retention of specific soils) to make maps showing suitability for growing specific crops. They say that socioeconomic data is used to formulate constraints or suitable policies, suggesting that this methodology is strictly a top-down approach and close to the physical-agroecological thought (Fischer and IIASA, 2002).

However, as Méndez *et al.* (2012) argues "An agroecology-as-natural science perspective tends to privilege positivist science and Cartesian reductionism[5] over other ways of knowing (e.g., indigenous or local knowledge), and, thus, risks producing research that is not appropriate to local contexts which ignores the larger power structures that impact farmer livelihood strategies" (p. 12). Interestingly, this is one of the arguments in (Fischer and IIASA, 2002) that indigenous knowledge was seldom used by researchers when developing new practices and is therefore not useful, but the question arises from what perspective the indigenous knowledge was assessed. Therefore, it is important to put the problem and farm in context of the surrounding ecological, socio-economic and political environment, to get a complete picture.

This paper takes on an Agroecological perspective, inspired by Gliessman (2007), Altieri (1995) and Conway (1987). The aim is to view composting of parthenium from a holistic perspective, understanding the context to parthenium and composting taking in to account socio-economic factors, biological factors from both the farmers perspective and my own.

3.2. Systems thinking

Systems thinking is a fundamental part of agroecology as problems often cannot be solved by individual solutions but require a systems approach. The general idea of systems thinking is that the interactions between the component parts matter as much as the functionality of the parts themselves and therefore the properties of a system has to be understood as a whole (Capra, 1996). This stands in contrast to Cartesian thinking where the whole is sought to be understood by studying individual parts and therefore ignoring their interactions (*ibid*). Cartesian thinking, stemming from Descartes (Capra, 1996), is a positivist approach to inquiry where truth is based on verifying hypotheses to establish facts or laws (Guba and Lincoln, 1994).

Systems thinking has its roots in several disciplines (Biology, Ecology, Gestalt psychology, Quantum physics) and emerged during the 1920s, but was institutionalized in the 1940s through Ludvig Von Bertalaffnys work (which came to be known as General Systems Theory [GST]) (Capra, 1996). The hard systems thinking emerged from systems engineering, which is part of GST, where a system is considered to be independent of the observer, and belongs to the world 'outside of them' (Checkland, 2006), much like positivist science (Guba and Lincoln, 1994). Out of the critique of hard systems thinking grew the soft systems thinking (SSM) which acknowledged the human factor within the system and that the observer is an unextractable part of it. Instead of the world as the system, the process of inquiry is systemic and the observer navigates the perceived real world (Checkland,

[5] Cartesian refers to the philosphy of Descartes, which reduces a whole to its parts and is the norm within natural sciences.

2006). Soft systems in inquiry are constructivist, where knowledge is based on the reconstruction of information from individuals (Guba and Lincoln, 1994).

Critical systems thinking (CST) emerged as an approach as systems thinking evolved, partly as a reaction to the dichotomy between hard and soft systems thinking. Hard and soft systems thinking are seen as complementary, often viewing hard systems as part of larger soft systems (Hofny-Collins, 2006). Without the specific bounds of either hard or soft systems thinking, the researcher has to find the appropriate methods according to the problem context (Jackson and Keys, 1984). CST is also more sensitive to boundaries, especially when stakeholders view system boundaries differently (Midgley, 2000, p 143). Agroecology often identifies system boundaries through an agricultural perspective (field system and livestock system as part of household system, in turn part of land-use system (village), which falls under a regional landscape system, part of a larger national system (e.g. Altieri, 1995, p 12). Considering the context of the farming system in multiple-dimensions allows for the use of ecological principles to be used to study agricultural systems (D. Rickerl and C. Francis, 2004).

In this thesis I have chosen to follow a CST approach, mixing both hard and soft systems thinking when choosing methods. By probing farmers perceptions this allows for a picture to be constructed from their perspective. A part of the farming system is also the knowledge possessed by the farmer as it is a basis for his decisions concerning it. The seed experiments are of a more hard systems approach.

3.3. Farmers knowledge

In Agroecology, local or indigenous knowledge is often thought of as essential to understanding the way the agroecosystem works, and as a solution to a problem is often sought, new practices need to take local practices into account (e.g. Altieri, 1995). There are many definitions of farmers knowledge, indigenous knowledge, local knowledge, indigenous technical knowledge and their uses are multiple, from extractive purposes by researchers to empowering exercises to use this knowledge (Thrupp, 1989).

Midgley (2000) defines knowledge in the broad sense of 'any understanding', be it through imagery or language, including perception. Perception being "a complex construction by a sentient being in interaction with its environment" (Midgley, 2000, p 81). This bears resemblance to Kolbs' learning cycle where the learner reflects upon an experience (Kolb, 1984), usually in or with their environment. The creation of knowledge occurs when an experience is transformed into knowledge, also known as experiential learning, a process which is a continuous recreation with and between individuals (Kolb, 1984). The sentient being is a knowledge generating system but is not exclusive to the one individual; the 'sentient being' can for instance be a group of beings embodied in an organization, social class or ecosystem based on the boundaries that we set (Midgley, 2000). In the context of Ethiopian farmers, McCann (1995) argues that "The peoples who evolved agricultural systems in this setting [of varying soil types] had to learn to read the meanings of the variation on a field-by-field basis" (p26), indicating that experiential learning is part of their farming.

In order to use farmers' knowledge, their participation is sought to involve them in the process, ideally the results are owned by them and reinforces/builds on the knowledge they already have (Pretty, 1995; Guijt and Shah, 1998). One of the objectives of this thesis was to draw on farmers knowledge in order to understand if composting of parthenium was feasible.

3.4. *Participation in the context of this thesis*

Discussing participation in this thesis is important as the decision to remove parthenium ultimately ends up with the farmers and their decisions to manage his or her land. In table 3 there is a summary of different levels of participation in development projects where decisions are being made to come about change. Within the methodology of participatory rural appraisal (PRA), the researcher often takes on a role of facilitator, in order to empower people by letting them take an active role in analyzing their problems and reaching their own solutions (Sontheimer *et al.*, 1999). However, PRA has its origins in activist participatory research, agroecosystem analysis, applied anthropology, field research on farmingsystems and Rapid Rural Appraisal (RRA) (Pretty, 1995). One main difference between PRA and RRA is that in RRA the results belong to the researchers, whereas in PRA the participants should also feel that they own the results (Rennie and Singh, 1995). As the interviews and participatory methods were consultative in nature (see table 3, point 3), my methods are closer to RRA. Of the methods I intend to use, transect observation and seasonal calendar has its origins in agroecosystem analysis as described by (Conway, 1987), the ranking done during interviews was not done in a participatory manner.

Table 3. Typology of participation in the context of development projects. Adapted from (Pretty, 1995)

Typology		Characteristics of each type
1	Passive participation	Participants are told what will or has happened where the responses are not taken into consideration. The shared information belongs to the external professionals.
2	Participation in information giving	Participants answer questions from extractive researchers from questionnaire surveys (or similar approaches). Participants cannot influence the process and the results are not shared or checked for accuracy.
3	Participation by consultation	Participants are consulted by external professionals who define the problems and solutions, and may change them after considering the responses (but are not obliged to do so). The consultative process does not allow for sharing in the decision process.
4	Participation for material incentives	Participants provide resources (such as labour) in the exchange for food, money or other material incentives. An example of this is on-farm research where the farmer supplies land but are not involved in the experimental or learning process and have no incentive to prolong activities when the project ends.
5	Functional participation	Participation occurs through group activities to fulfill predetermined objectives related to the project where social organization is promoted from the outside. The involvement occurs in later stages of the project when major decisions have already been made. The participation is dependent on external facilitation in the beginning but may continue and become self-dependent.
6	Interactive participation	Participation leads to action plans, formation of new or strengthening existing institutions through joint analysis. Interdiciplinary methodologies are usually involved to reach multiple perspectives and utilize a systematic and structured learning process. The participants take control over local decisions and people have a say in keeping the practices or structures.
7	Self-mobilisation	People take initiatives without the influence of external institutions to change systems. Participants initiate contact with external institutions to get the resources or knowledge that they need and decide how to use them. This collective action may change the inequitable distribution of wealth and power.

In their critique on participatory methods, Cooke and Kothari (2001) state that it facilitates a form of tyranny, exercising illegitimate and/or unjust power. They highlight three areas of concern: Undermining existing legitimate decision making processes; Group dynamics reinforce the interests of the already powerful; The possibility that participatory methods shut out advantages of other methods for which it cannot provide. Indeed it is important to be aware of what participatory methods will lead to. Since the participatory level in this thesis is quite low, this is not an issue.

4. Methodology, methods and some materials

4.1. Research design

The intention in this research was to get an idea of the issues at hand regarding parthenium and explore them with the help of both qualitative and quantitative methods. With the focus on parthenium and composting it is necessary to explore associated factors that a qualitative approach allows. The outcomes in this thesis are based on an exploratory case study in the Alamata area. The Alamata area was suggested by Dr Fitiwy at Mekelle University as it is considered a parthenium hotspot and has a good potential for use of parthenium.

The use of qualitative methods were chosen as it is a means to understand and explore the meaning groups or individuals give to a human or social problem (Creswell, 2009). The underlying rationale is constructivist, seeking understanding by listening to the participants' views of the situation at hand and recognizing that the researcher is trying to interpret views through his/her own background (*ibid*). The qualitative aspects of the research were not as prominent as I wanted them to be as quantitative methods were the norm at the university.

In this thesis parthenium is ascribed a problem by the farmers as well as academics and government officials. I arrived in Ethiopia with an initial set of questions. Some were adapted as the research process went on. I have worked to view my results inductively, being sensitive to emergent themes that arose during interviews (Bernard, 2011), which led to themes I had not thought of before I arrived in Ethiopia and in the study area. My aim was to get a rich picture of the parthenium and composting, and by using a qualitative approach identify associated factors the farmers take into consideration and practices they employ.

I decided to use convenient and informant based sampling methods (Bernard, 2011) as I relied on the help from my co-supervisor and translator to help me find respondents through appropriate channels. The tabias to visit were suggested by the woreda expert when asked about what sites represented a high, medium and low infested area. The farmers themselves were arranged by the DAs in respective village. The research was carried out in Alamata during three days in February, followed up by four days in March.

The quantitative aspect to this thesis, are in the seed experiments that I performed was a suggestion by the ISD following their composting trials in the Alamata area as it was unclear if the seeds survive the composting or not. The seed experiments were ongoing during March and institutional interviews were carried out February through March. I also explored the possibility to acquire seeds that had been composted at TARI to test for their viability although this was abandoned due to time constraints.

RRA/agroecosystems analysis metods

Initially I aimed to have a higher level of participation by using PRA methods, but due to the limited level of participation (as mentioned earlier), the methods used were closer to RRA and agroecosystem analysis (Conway, 1987; Pretty, 1995).

4.2. Methods

4.2.1. Interviews

Two visits were made to the Alamata region, the first in the third week of February (3 days) and the second (4 days) in the second week of March. Differences between the first and second time was a market day in Tsetsera on the second visit including people other villages in the region and in Selen Wuha we met with a different DA visiting two villages in the tabia to find farmers. Interviews with institutions were carried out during February and March in the study area, Mekelle and Addis Abeba (see appendix for a complete list). The interview guides were all constructed to give a rich picture of the farmers practices and factors that influence their farming by reading literature on parthenium (e.g Navie *et al.* 1996), composting (e.g. Araya and Edwards, 2011) and looking at other master thesis from Ethiopia (e.g. Gebeyehu, A. K., 2008).

4.2.1.1. Interviews with institutions

Semi-structured interviews were carried out using an interview guide. Most interviews were done in English, however some parts of the interviews with DAs were clarified through translation. Notes were taken during the interview and if the interviewee consented the interviews were recorded to be transcribed later. Semi-structured interviews are well suited for situations when there is only one chance to do it (Bernard, 2011). It gives the interviewer the chance to follow leads that come up during the interviews (*ibid*).

4.2.1.2. Farmer group interviews

I had drawn up some initial questions for individual interviews that I had made into a semi-structured interview guide based on reading other studies conducted in Ethiopia (see appendix). The group interviews were held using the interview guide that had been prepared for the individual interviews as individual interviews were not possible at the time. The interviews were held in respective village with respondents facing myself and translator. Because of the language barrier, the questions were asked by Dr. Fitiwy from Mekelle University (plant protection department) who acted as translator for all three tabias. The number of farmers interviewed are summarised table 4. The group meetings were recorded and notes were taken during the interview.

Table 4. The number of participants in group and individual interviews with the number of males (M) and females (F). In the lowland sites no women farmers were present, whereas a quarter of the participants in the highland site were women. For the individual interviews one female farmer was interviewed at each site.

	Participation in group interviews (M/F)	Individual interview
Gerjele	12 (12/0)	4 M (2 model*), 1 F
Selen Wuha	7 (7/0)	4 M (1 model*), 1 F
Tsetsera	18 (13/5)	4 M (1 model*), 1 F

* Model farmers are awarded their title by village officials for adapting new technologies.

4.2.1.3. Farmer individual interviews

After my first visit I decided to confirm the information I had from the group interviews by speaking to farmers individually (as farmers left during the group interview, apparently due to its length). It was suggested by my co-supervisor and translator to make a questionnaire for my second visit and have it translated to Tigrinia as this would make it easier for my translator. I designed the questionnaire to have both open-ended questions and set answers based on the group interviews. I employed an external translator to translate the final questionnaire. My translator asked the questions in the questionnaire/structured interview guide and translated the answers to me. The interviews were recorded, notes were taken as the interview progressed and questions that arose during interview were asked in the spirit of a semi-structured interview (Bernard, 2011). The participants of the interviews are summarised in table 4.

4.2.2. Own observations

Observations were made during the travel to and from Alamata, the visited kebeles and to the farmers' fields. It was my intention from the beginning to visit the fields of each farmer I spoke to, however it became evident that this was not so easy as many farmers fields were far away (and not accessible by road) and there was not enough time to travel. I did get the opportunity to visit two sites with the farmer himself and ask site specific questions as well as to do the questionnaire. Direct observation is a common tool used in RRA and PRA (Pretty, 1995).

4.2.3. RRA tools

Transect walk and field observation. The farmers showed us to their field and on the way there relevant questions were asked. I also made observations on the way there and on site as we walked around. The questionnaire questions were asked on site. Strictly speaking these were not transect walks as I did not walk in a predetermined straight line, but rather more of a guided farm walk.

Year calendar. In order to get an idea of what farmers did at different times of the year I wanted to use a year calendar with each individually interviewed farmer. However, due to lack of time during the visits to the villages and for explaining its use to my translator it was only used once.

Ranking in interviews. Farmers were asked to list interactions or limitations and rank them according to specified criteria.

4.2.4. Seed experiment

4.2.4.1. Seed collection and heat treatment

Seeds were collected around the Mekelle University area from parthenium plants and on the ground around them. 25g of seed and flowerheads were weighed and put in paper envelopes for heat treatment. They were put into an oven with an electronic temperature gauge for 72h at the temperature intervals of 40, 50, 60 and 70°C. The seed experiments were performed at Mekelle University.

4.2.4.2. Tetrazolium (TTZ) assay

The methods are based on the Tetrazolium Testing Handbook (The Tetrazolium Subcommittee, 2000). 50 whole seeds were collected from the heat-treated material and imbibed on moist toilet paper overnight. The seeds were then cut longitudinally with a razor blade and put in a glass petri dish. Empty seeds were discarded. 5 - 10 ml of 0.1% (w/v) TTZ was added to the petri dish with cut seeds, covered with a lid and tin foil to obscure any light. The seeds were subsequently incubated at

35°C for 16h (+/- 1h) together with a control sample of 20 seeds prepared in the same way but not exposed to any heat treatment. The seeds were visually assessed under a stereomicroscope. Parthenium seeds which were red upon removal of seed coat were marked as viable, white seeds or seeds with white cotyledons were marked as dead.

4.3. Analysis and presentation of data

In order to make it easier for the reader to follow the origin of the information presented in the results I have added a comment after any information that is not from the individual interview e.g.: Group interviews in short GR followed by the Kebele (G – Gerjele, SW – Selen Wuha and TS – Tsetsera); Institutions TARI, BoARD and ISD followed by the interview location or person, see table in appendix for further details. In the quotes I have put my own words in italics beginning with (R) eg. *(R) What happens if you don't take it?*

The interviews that had been recorded were transcribed and coded according to emerging themes, as is commonly done in qualitative research (Creswell, 2009), such as grounded theory (Bernard, 2011, p 492). Parts of the interviews were then sorted into different documents according to the different themes, which emerged during the transcription process. The information from the questionnaires were also summarized in an Excel sheet to get an overview of the more quantitative information collected.

In order to make it clear when I had made my own observations these are presented in boxes titled **Observation**, and appear within the results.

4.4. Validity, reliability, bias of data and other world views

This study was not intended to be representative but rather to give an insight into the different views regarding composting and parthenium in the study area.

The sites were visited twice in order to gain a broader understanding of different views, both from the groups and individuals. The intention was that following up the first visit (group interviews) with individual interviews in the second visit, would allow to probe for more silent voices that had been present in the group interviews. However as the selection of farmers was done by the DA (and not randomly) it is hard to say that this was fully successful. There was a dominance of male farmers during interviews for instance.

Combining my own observations from Alamata with farmers' perceptions as well as questions that arise when in the field I hope to allow for a degree of triangulation on what they have said (Bernard, 2011). As visits to fields were not possible in most cases, triangulation through observation was limited. The observations that were made in the field did lead to new questions and follow-up questions with the farmers, Taking on a constructivist approach allows for the reader to follow the farmers perspectives in the way the data was collected, which was through the translators and my own interpretation (subjective) of what they have said.

Part II: Results

5. Interviews and own observations in Alamata woreda

The following section presents the perceptions and information gathered during interviews with farmers and institutions, grouped into the main themes identified. The general themes that were found are: **Rainfall, Water shortage and conservation**; **Soil fertility and improvement** (through the use of manure, inorganic fertilisers, composting and crop rotation); **The phenomenon of *mitchi* during composting**; **Parthenium** (arrival and spread, its control, health issues, impacts and composting); **Gender**; **Resource availability**; **Perception of change**; and **Knowledge and adoption of 'new technologies'**. A detailed list of the interviews carried out can be found in the Appendix (sec. A). In the results when referring to lowlands this is a reference to the Raya valley and the two kebelles Gerjele and Selen Wuha, whereas the highland is a reference to the kebele Tsetsera.

In order summarise general observations when visiting the three kebeles, the setting for the interviews are given in Observation I.

Observation I – A rich description of the surrounds in each Kebele

Gerjele (Lowland site, high parthenium infestation)

It is clear that there was a parthenium infestation in this area, parthenium was present along the road to Gerjele from Alamata, and fields along the way were a patchwork of parthenium. Upon arrival all the farmers had met up in the shade of a house facilitated by the DA and the group interview was carried out here. There was no parthenium in this area. After the interview a transect walk was done in a field 100m from the main road. The fields here were all infested with parthenium, some with very dense stands. Some fields around had less parthenium, plants spread more sparsely. In one field *Argemone mexicana* L. grew next to parthenium and areas around them were not as populated with parthenium.

At the second visit, the interviews were carried out at the FTC, where the area around it had many small parthenium plants that looked as if they had been cut and new growth had begun. There was also an onion-drying house, currently empty. Parthenium along the road in the village showed evidence of being grazed. However, if this was from animals in the village or those passing through the village was unknown. The Raya valley is all farmed apart from areas covered by communal forests or flood plains where farming is not possible.

Selen Wuha (Lowland site, medium to high parthenium infestation)

The group interview was carried out next to the pump house, the warm water flowing out of a large pipe into a small water canal which led into fields being cultivated (about 50 ha). The area around the pump house showed no evidence of parthenium (not even small rosettes) but other unidentified weeds were present. The nearby village (1 km) was void of parthenium apart from one plant growing in a hedge.

On the second visit we met with a different DA and travelled to a different village further away from the first one with the pump house. In this village parthenium was present in the same amount as in Gerjele. Parthenium also grew along a large dried out stream, but only along the edges and in islands in the stream. In this area we encountered a farmer who was slashing parthenium in his field.

Tsetsera (Higland site, low parthenium infestation)

A long windy road led to the village with the FTC, uncultivated hills were green with bushes, whereas the cultivated hills were clearly marked with the lines of terraces. Some sites which had direct access to streams were green, but most land was bare and dry with no crops growing. The first time we arrive the group interview is done outside of the FTC, and as the hour progresses some farmers left with about half remaining at the end. Outside of the FTC there was a huge pond which was dry. We took a walk into the fields without the farmers to see a compost pit. The fields were mostly clear of vegetation with the occasional plant. I passed a small parthenium rosette which was gone upon the second visit. In the field margins there was grass growing and a woody plant with pink flowers. Chickpeas were grown in one field close to a stream, and seemed to be in the process of being harvested.

Upon the second visit there was a market day in the village and some of the respondents come from a village further away. The interviews are carried out in the DAs office with the DA present for most of the interviews.

5.1. Shortage of water and conservation

The farmers were also asked when it rains in their region. Most farmers responded that the heavy rains come in July and August, with less heavy rain in June and September (see figure 6). A slight difference in timing was observed with perceived earlier rains in Tsetsera and Gerjele, where as in Selen Wuha the rain came later (See figure 6). None of them mentioned the small belg azmera rains, possibly one woman in the highlands referred to it (See figure 6). In the group interview, the farmers in Selen Wuha said it rained one month between 15th of July to 15th August, whereas in Tsetsera they said it rained June to September with high rainfall in July and August. This may be due to the relative position to the mountains.

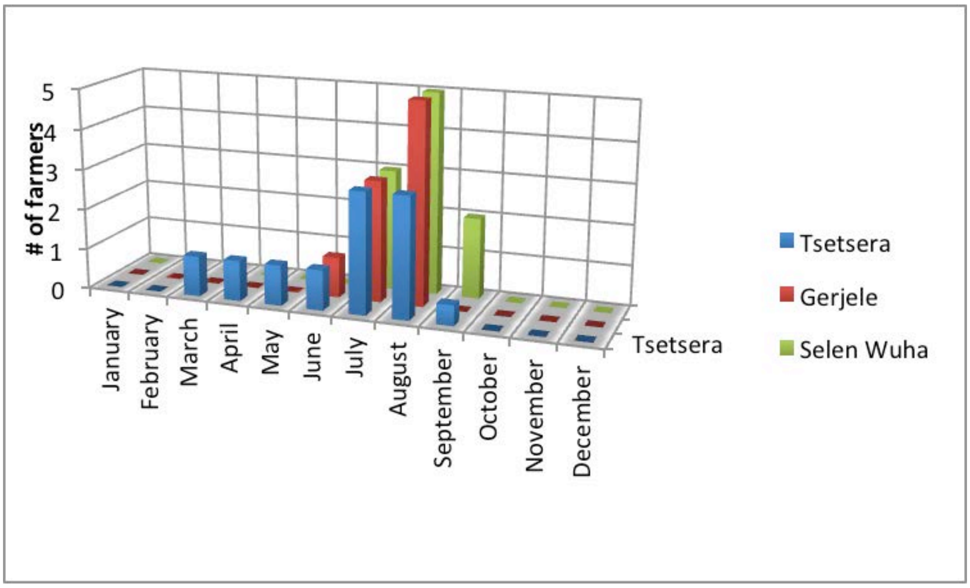

Figure 6. Difference in rainfall patterns according to what farmers said in the three tabias. One farmer in Tsetsera said that the rain came during the time we were there and three months forward (Feb – Apr), however there was no rain at that time. The farmer may have been referring to the belg azmera rain which comes at that time but did not make any reference to any rains later on.

Farmers said that there is a variation in rainfall with good and bad years (G:1, T:3). The main factor which affects their crops is the shortage of water (see figure 7), and during the group interviews in the lowlands water shortage was said to be critical. One farmer in Selen Wuha said that rain was critical in order to cultivate his lands:

> "It is difficult to put a rank for the source of income because if there is no ox there is no production *(R) Oh.* If there is no land there is no production. There is I think a mixture of

animal and farm he said like this. *(R) Depends on how much water or?* Yeah yeah. *(R) Or the availability of...* Priority, yeah, priority it is depend on water, if there is no water then we cannot plough our lands he said like this" - Male Farmer Selen Wuha

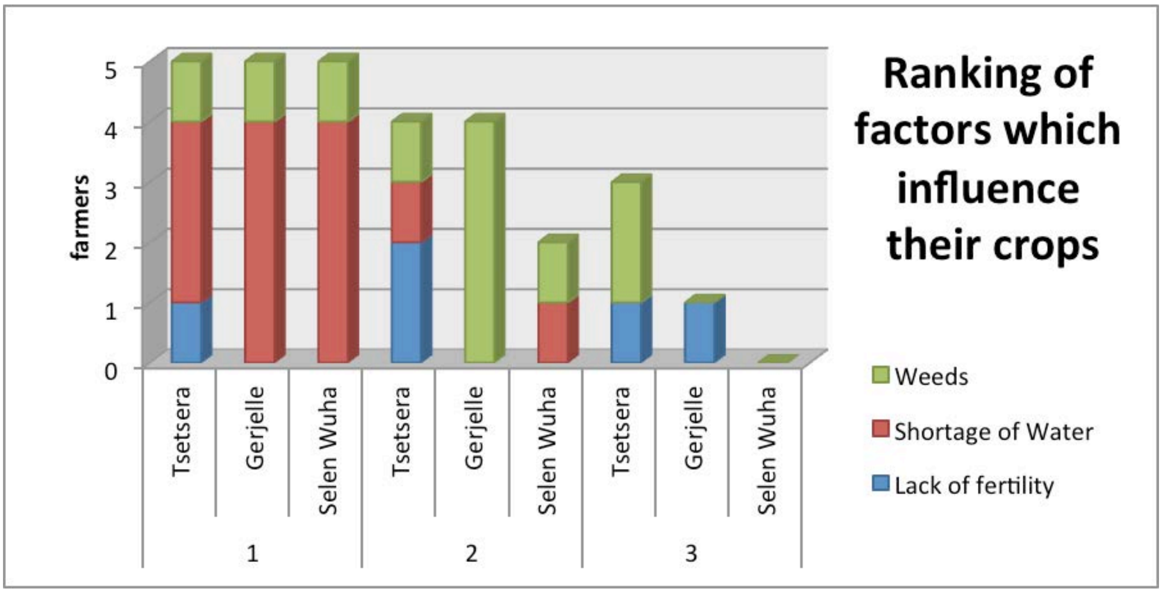

Figure 7. Farmers were asked what factors influence their crops and were asked to rank them in relation to each other of importance. The declining numbers in the ranking is due to farmers only mentioning 1 or two factors that influence their crops. Most farmers ranked water shortage as the primary factor influencing their crops.

In Gerjele one farmer said that they depend on the rain even though there are underground sources available, but the water is expensive to extract:

> ”There is a shortage of water only, the reason why this is there are no other opportunities to use. *(R) To get water*. Only we dependent on the rain. *(R) On the rain*. There is water und... ground water available somewhat but it is costy to ... what you call it? *(R) To extract it, to dig?* Yeah, yeah, have to dig it and that all, I know it is costy.” – Male farmer Gerjele

At all sites diverting water from rivers was common, as was using trenches to trap water in the fields to increase infiltration. In the highlands most fields were on terraced hillsides. In the highlands model farmers had dug ponds which they used to irrigate favabean and tomato, whereas in Gerjele model farmers dug shallows (a couple of meters) or holes (10 meters deep) (TS-G,G-G).

Water conservation group activities are common, also referred to as SOFTNET-programme[6] (however I found that I never really got a straight answer what they were).

5.2. *Soil fertility and soil improvement*

There was a difference in perception of the soil fertility between the highland and lowland sites. In the lowlands the soils were said to be naturally fertile as one farmer says:

[6] I have not been able to find any references to a "softnet" programme, however the Productive Safety Nets Program (PSNP) is implemented in this area and is described in the same manner as "SOFTNET".

> ”[…]the land is, the land is or my farmland is, not only my farmland of the area around this is fertile, it is not what, there is no problem for the nutrient availability or others for the crop growing,” – Male farmer Selen Wuha

Whereas the highlands were:

> "They learned in the area, local area is somewhat unfertile but now we are on the way of improvements and managements like adding manures or compost or others, even artificial fertilisers. But the main reason is naturally, it is the sandy soils, it is not fertile." – Male farmer Tsetsera

The crop specialist at TARI did not agree with the lowland farmers that their soils are fertile and said that small-holder farmers do not know the true potential of their land and that it needed to be demonstrated to them. He also implied that it was hard to get them to use composting and fertilisers because of this:

> ”Of course they have some proofs [that the lands are fertile], but you know they don't know the potential of that area, in order to know that area some experimentation by part important, we should show the farmers that the yield that they obtain from the given land is the maxiumum or minimum. They simply use their traditional way of cultivating the land and the harvest they get from that land. So it is not due to that, because they didn't show any difference in yield, because before they didn't use any compost, even it is difficult to make them use the chemical fertilisers too, not only the compost but also the chemical fertilisers too.” (TARI-SP)

The most common soil improvement practices, manure, inorganic fertilisers, crop rotation and composting are covered in the following sections.

5.2.1. Manure

Manure was used by all farmers at all sites visited, and is collected from animals kept by the farmers. The most common animals are: oxen (*Bos primigenius* Bojanus), cow (B. primigenius), goat (*Capra aegagrus hircus* L.), sheep (*Ovis aries*), chicken (*Gallus gallus domesticus* L.) and camel (*Camelus dromedaries* L.). In the highlands two farmers used their manure exclusively for their composting practices. One farmer in Selen Wuha said that from his experience it was not preferred to use manure on rain fed lands as they cannot tolerate the lack of moisture. Manure produced around the home is transported to the farmland. One farmer said one benefit of using manure was that the effect was there for 2 or 3 years after application.

Of 12 farmers that answered the question of where they learned about using manure, five said they learned from their DA, five from neighbours or relatives and two from NGO’s.

5.2.2. Inorganic fertilisers

Most farmers stated that they use inorganic fertilisers, the most common are diammonium phosphate (DAP) and Urea. Many of the lowland farmers said that they were forced to take inorganic fertilisers by the DA, village leaders or farmers association (SW:3, G:3). As one farmer said:

> "Those farmer networking as you if he is the leader then he comes from the farmer association and put under your house, [...] imagine how it is difficult to them to turn back the fertilisers" – Male farmer Selen Wuha

They also said that if they do not take inorganic fertilisers they are not permitted to be part of the SOFTNET programme and receive those benefits (usually money or grain): "For SOFTNET programme said, if he not take the [fertiliser] there will be no gain for the profit" – Male farmer Selen Wuha.

Some farmers mentioned that there were more disadvantages than advantages of using inorganic fertilisers, particularly during years without adequate rainfall (and then especially if the rain is intermittent). Farmers in the lowlands said that they knew the benefits of using inorganic fertilisers to increase their production, but the water shortage makes it difficult (GR-SW, G:2). They said this would produce burning effects on the crops, which was also confirmed by one lowland DA. A TARI specialist thought that this was due to the farmers not applying the fertilisers properly: using the wrong dosages; and broadcast spreading leading to evaporation or leaching of the UREA. One farmer said that his yields were not larger with inorganic fertilisers, but the interest on his loan to acquire them grew. The DA also said that they had pressure from above to make sure that new technologies are adopted by farmers (including inorganic fertilisers), and failing to do so would give them a lower ranking and not allow them to go on special trainings.

One farmer said he would only use organic fertilisers next year and refuse inorganic fertilisers. Another said he thought he could match his yeild using organic fertilisers to that of inorganic fertilisers and SOFTNET combined. I asked if there would be repercussions:

> "*(R) What happens if you don't take it?* [Tigrinia] During the meeting there will be, somewhat, discussions regarding why don't you take, what is this? So this may also take something. In front of those peoples there is some discussions, some panel discussions regarding the fertiliser, so for that matter then maybe he will come." – Male farmer Gerjele

At the woreda level the woreda expert said that they had reduced the recommended inorganic fertilisers use from 50kg, to 12kg per ha. The farmers in this study said they used 50kg of DAP and/or urea.

5.2.3. Composting and mitchi

Composting is more common in the highland area where most farmers compost. One farmer in Tsetsera said that they make compost in February and remove it in June. In Gerjele it was said that only the model farmers compost and in Selen Wuha it was said during the group interview that they compost. In contrast to this, during the second visit none of the individuals interviewed stated that they compost. Most farmers who did not compost said they did not have any information about it. The materials used for compost were dry and green plant materials, manure, ash and water. Parthenium was only used by farmers in the lowlands. Most farmers compost in a pit. However one farmer in Gerjele (GR-G) said during the group interview that he used a heap method.

> "They use heap system as it is easier, previously pit (1,5m) but was too labour intensive. USAID marshall introduced this technology. Have not seen seeds in compost as they use parthenium before flowering." (GR-G)

The extra labour was also mentioned as a constraint by the specialists at TARI: "They tell you it is a fertile, it is burning so also for this, they may think that you tell them to make a compost then they have to wait, they are making area and so on, therefore extra work, they don't like that one." (TARI-SP)

A similar statement was made by the BoARD representative in Mekelle: "I think you have seen but most of them would not [compost], especially in Raya, was not take that activities for parthenium and for the milks because they didn't believe to, they know that their soil fertility, fertile. *(R) ok.* They understand that. And Zenebe[7] also is takes us as a problem, labour costs and others. I think that was a problem." (BoARD-MK)

During the group interview in Selen Wuha one farmer spoke about his experiences of composting and he said that due to lack of support from the DA he had abandoned it (see quote below). Another DA working in that area said that the farmers were not interested in composting.

> "The farmer what he is telling us is that, from the very beginning, yes we got how to prepare the composting and then in between I heard something smoking, but there isn't, fermentation is coming out, and then came, I phone, I asked that DA, the extensionist to come and show me to open, you know. Because I was in doubt of that smoking, could result in some diseases on me on my health, that is the perception of the farmer anyway. The extensionist no answer, I don't have time, you just go ahead with your, what I have already told you and then please go what I already told you lesson what happen. Ok, if you don't come with me there will be some problem with my health because of such smoking I see, I heard the smoking. Yeah, smoking, then he refused to come then I couldn't work, and then why, because then I would be on risk of my health. Then it is just left there," (GR-SW)

One farmer in Selen Wuha said he used to compost, but had stopped:

> "[...] in the previous I have already used compost preparation but now I am not proceed *(R) Ok, how come?* [...] We have seen some peoples are sick due to the, due to participating on the compost those and others are cause me to left, to leave the preparation of compost he said like this." – Male model farmer Selen Wuha

This is also known as *mitchi*:

> "You know, it has some effects, it is known especially around the locals so for the composting we are on the way of removing just from the pit early in the morning or at night [...]. It is not allowed for no one to take compost at the day. And, also he said, you can open in the morning, and you can take at the day.[...] Yeah, it is sickness problems. He says locally, mitchi." – Male model farmer Gerjele

Another farmer in Selen Wuha said he had been told by the DAs to compost but had not tried it yet as he had observed two people getting sick from composting and was waiting for a solution to this (SW2).

When describing the problem of Mitchi to the BoARD representative in Mekelle he said the DA probably told them to stop for another reason and that there really was not anything dangerous with the smoke as it was most probably water steam. One of the DAs said that he did not allow his farmers to take the compost unless it was nighttime or in the morning (as a solution to *mitchi*). My own observations of compost pits can be found in Observation II.

Observation II – Compost pit placements
During a field walk after the group interview in Tsetsera, I observed two compost pits, both placed closest to the upper border of the field. The model farmer in Gerjele we visited also had his compost in the field, close to his water source in the middle of his plots.

[7] Zenebe was not present at the interview but has in the past done a survey with farmers in Alamata, however these results were never published (pers. comm. Z. Abraha, Mekelle University).

5.2.4. Crop rotation

All but one farmer stated that they grew leguminous crops in rotation with cereals in order to increase soil fertility in Tsetsera. During the group interview the farmers said that no tilling was necessary after legumes, they sow directly onto the land and get good results. In the lowland sites, Gerjele and Selen Wuha chickpea was also stated as a rotational crop with tef and sorghum. One farmer in Selen Wuha stated that he no longer grew chickpeas but did not say why:

> "He says earlier that use cropping systems, for teff and sorghums. *(R) No chickpeas or legumes?* [Tigrinia] In the previous yes but now eh... *(R) But not anymore?* Yeah." – Male farmer Selen Wuha

5.3. Parthenium

As stated in figure 7, weeds are considered to be the second ranked problem in the lowlands, but third in the highlands where lack of soil fertility was considered more important. According to the TARI in Alamata, 60 000 hectares of farmland are infested with parthenium. (TARI-AL) Parthenium is also locally known as "kinche", which is also the name for porridge made with cracked wheat (TARI-DR). Declared noxious weed in Ethiopia in 2001 by Ethiopian parliament (TARI-D), it was discovered by accident in 1982 [1989 EC] by an Australian expert who was in Ethiopia for another reason (BoARD-AA). The TARI director said that parthenium could be found in most of Tigray (24 of 32 woredas) (TARI-D).

When farmers were asked what properties they were aware of with parthenium (see table 5), the most common answers pertained to the effects it had on their production.

Table 5. Properties given on *parthenium* by farmers. The bolded reasons are ones given as alternatives in the questionnaire when farmers were interviewed in the individual interviews.

What properties are they aware of?	# of farmers (15)	Group interviews
Taints milk + milk products	9	Yes
Reduces production	7	Yes
Leaf morphology	5	-
Spreads easily	3	Yes
Stains hands	3	-
Difficult to remove (tap root)	3	-
Leaves bad taste on hand	3	-
Bad smelling	2	-
Flower and others	2	-
Water competition	2	-
Prolific seed production	2	-
Quickly growing	1	-
Easily characterised at seedling stage	1	-
Easy to see *parthenium* seeds amongst tef seeds	1	-
Do not know	1	
Alellopathy	0	Yes in Tsetsera
Quick to set seed (2 months)	0	-
Health drawbacks*	0	Yes

*During this particular question, health drawbacks were not mentioned.

Most farmers said that it was easy to distinguish by its leaves or flowers, or that it was simply easy to recognize. The more physical properties mentioned were the fact that it is hard to remove due to its taproot, produces many seeds, grows quickly, and competes for water. A summary of my own observations on parthenium can be found in Observation III.

Observation III

Flowers even when small in growth but number of flowers are reduced.
Undisturbed grows dense stands where it is not weeded or grazed upon, often in wastelands or field margins.
Grows less dense stands in presence of *Argemone mexicana* when present in farmers fields.
Used as cushioning in tomato-boxes (see figure 8a), which would facilitate spread of seeds over longer distances and into cities.
Occurs in disturbed land in cities by building sites, riverbanks and roads.
Occurs in "islands" along the road between Alamata and Mekelle. One example of this was observed after travelling back to Mekelle. After a long time of not observing parthenium we passed two fields covered with the weed. Here it was also growing along the side of the road. Some farmers we gave a lift told us they had been trying to urge the farmer who had the fields to remove it.
Phylloidy in one farmers field (see figure 8b), the flowers remain green and no seeds are produced, rather another set of flowers. It was present on two of the plants in the field, showing that spread was low.
Patchwork of parthenium **stands in the Raya valley,** some tall and dense, some sparse and lower while some fields had no visible parthenium infestation.

Figure 8. **(a) Parthenium used as cushioning in tomato box.**

(b) Parthenium plant with phylloidy disease found in Selen Wuha area.

5.3.1. Arrival and spread

In table 6 is a summary of the arrival and spread at the three sites in the Woreda. Gerjele has had parthenium the longest, which is consistent with it being situated on a busy main road. In Tsetsera the spread is mainly coupled to animals whereas both Gerjele and Selen Wuha also included flooding as a cause for spread. The late introduction of parthenium to the highland area could indicate that flooding is a quicker mode of spread than through animals. According to the farmer in Selen Wuha whose field was visited, there was more parthenium on his land due to diverting water from the community woodlands where parthenium grows:

> *"(R) Ah. And does he divert the water ... from the floods?* [Tigrinia]This is the reason why parthenium is more here, the rows try to come all the water here from thus [wooded area] and to this site there is this looks the more parthenium comparitavely [to] that one must, he said like this." – Male farmer Selen Wuha

My own observations of the area around this farmers' field can be found in Observation IV. It seemed as if the parthenium in his field was more mature than in the woodlands.

Table 6 illustrates the farmers perception of the year that parthenium came to their area and how it spread. There are differences in perception between the three areas as well as between group and individual interviews. The date arrived upon in the individual interviews is the average of five farmers.

		Gerjele	Selen Wuha	Tsetsera
Year	Group	From 1987	1991 – 1992	2008
	Individual average (range in parentheses)	1990 (1984 – 1996)	2002 (1990 – 2008)	2007 (2004 – 2011)
Spread	From where (group interviews)	Food aid, maybe EU	Food aid to Amhara region 3, then water	Cow, camel and donkey ingesting seeds
	How does it spread? (individual interviews)	Flooding, birds, contaminated seeds, do not know	Animals, Flooding, Do not know	Food aid, animal manure
	How does it spread? (group interviews)	Flooding, wind, cow dung	Flooding	Donkey and camel primarily

Observation IV

Figure 9 (a) The farmer had diverted water from the community woodlands (in background) and the neighbouring field has less parthenium. The size of the parthenium in his field was larger than those found in the woodlands and the neighbouring fields.

(b) In the community forest in the shade of large trees there were small parthenium rosettes growing, the soil otherwise quite bare.

(c) In the border between the community forest and the fields were many small parthenium rosettes.

5.3.2. Control

The BoARD representative in Addis Abeba said that they tell farmers to cut the parthenium before flowering and burn it (BoARD-AA). In the Alamata area, the farmers from the highland spoke more generally about parthenium: in the group interview they said they hand weed it before flowering, then burn it and have group activities to remove it on common lands. In the highlands they do not use herbicides any more due to the apiculture in the area as there is a perceived shortage of flowering plants to support it (T-GR). This was repeated in the individual interviews. The farmers who came from a village further away said they had little practical experience with parthenium and that it did not exist at their location or that it was no longer present. It did not seem to take much extra time, they said they remove it when they see it. In the highlands the farmers seemed confident that they could control parthenium.

In the lowland sites they use both hand weeding and herbicides (according to the woreda expert this is 2,4-D, none of the farmers knew what they were using). The soils are prepared by ploughing using oxen, which is also a form of weed control (GR-G). Most farmers preferred hand weeding, two however preferred chemical control although most farmers used a combination of both. Two farmers said they had burning effects on the crops from herbicides, one said specifically in tef but that this was their only chance to control parthenium because handweeding destroys the crop. Half of the farmers in the lowland area said that they control parthenium through group efforts, especially outside of their lands. In the highlands parthenium control was part of the PSNP activities:

> "Have you seen some places there where doing water conservation programmes? In the same manner for removing purpose also they allowed us to remove for that parhenium, especially even 3 to four hours per day. This is through the soft-net programmes. After that they will get some wheat or moneys I think." – Female farmer, Tsetsera

There appeared to be a reduction in the coverage of parthenium at the time of the second visit (See Observation III), which prompted me to ask farmers why there was a difference between fields. As one farmer said:

> "It varies from one person to other persons, it is not common that the one who naturally comes active and controls his lands, farmlands again and again, the others ones what becomes carelessness for that matter. But for the nextes, since the sowing day or the summer will be after the one months, think even after two months, what you call March, April and after will be one. Every farmer will be look like the same on the April months, and even though now there is a parthenium there, but they will be removed and controlled he said like this. Because the sowing date it will become nearest at that time on the June or May. But thus depends upon, it varies one person to another" – Male farmer Selen Wuha

I understood his comment as: Weeding is not common in the dry season, some are active, others are careless and it will all look the same when farmers prepare their fields in April for the growing season. This would indicate that weeding is not commonly done in the dry season by farmers. In Selen Wuha during the group interview one farmer said they were very quick to remove the parthenium in the wet season, but not at all in the dry season:

> "Still during the off seasons the attention given is very very less *(R) Ah.* During this time now, for example if someone sees there, nobody is taking care off. That is a problem he said." (SW-G).

In Gerjele, one farmer said that he was too old to weed in the dry season while another had given it up since he saw no results of his weeding efforts and perceived it was beyond his control:

> "But nowadays it is beyond us, we cannot control. Even the government knows how it is difficult to control. So now I think everybody, just everybody now is not active for the control because rather than to waste the time no activities are here because it is.. finally there is no results, so that he said like this." – Male farmer Gerjele

Half of the individually interviewed farmers in the lowlands said that the control of parthenium was beyond them (G:3, SW:3), and that it was hard enough to control it just on their lands. Even though there was no large problem with parthenium in the highlands similar attitudes were present there as one farmer in Tsetsera said that if a problem was beyond them it was better to tell the government and wait for help. One farmer explained that the variation in parthenium in different plots was due to the lack of knowledge or attitude (lack of faith for the future):

> "I also encouraged other people just to remove, to control partheniums, since partheniums is an anti-human. So just I am giving advice for those who are not ..., who are careless peoples. So that still I just... In my opinion I am well on participating on the control of parthenium. *[…] (R) Yeah, why are people careless? I mean, is there something that stops them from removing it?* [Tigrinia] This is their lack of knowledge especially, and also their attitudes also. *(R) Attitudes.* Because they think lessly, they don't give more for the future he said." – Male farmer Gerjele

One farmer said they would not change their farming practices since parthenium would be everywhere:

> "*(R) Did you ask about the, if the parthenium has changed their way of managing their land?* Yeah, yeah, yeah, she said there will be no reduction, there will be no production *(R) No production.* But they're not going to change it, they are not changing their way of farming because if it? Still there is a reduction of productions but it is not so more because this is gone happen on the all the similarly on around this areas so even there means no so, even it is beyond us to control it she said like this. It is tedious crop she said like this." – Female farmer Selen Wuha

A specialist at TARI said that "[…] if you visit the existing areas of the Raya valley at this time (February/March) all plots are covered with parthenium. That they don't work, they don't care about the weed". (TARI-SP)

The local government had given the farmers instructions to give priority to their own farmland. Several farmers said they were waiting for the government to help them with the parthenium infestation as it was beyond their control. Help from the government is supply of herbicides and the organization of group efforts to remove the weed on common land. However, most farmers said that they thought that the main responsibility was with the individual rather than the government and that they felt a responsibility to stop it from spreading to the wild surroundings. One farmer said that he felt responsible but had not done it practically and another said he did not feel responsible, as it was enough work just trying to control it on his own.

According to the regional BoARD there is a law on parthenium, which requires anybody with a land or house to remove all parthenium around it, however this law is not "functional" as they are more focused on preventing the spread. Most farmers were not aware of any law, some said they followed the recommendations by the DAs or local government. Some replied that they did not know of any law but that they followed it. During the group interview in Selen Wuha, it was said that the tabia unit would fine any farmer who was seen ignoring parthenium on his land, however it was unclear if this was all year round or just in the wet season.

All farmers in the lowlands said that they required extra labour to control parthenium and most said they needed extra time (see table 7).

Table 7 Farmers in the lowland and their replies to if parthenium management incurred any extra costs. All numbers in Ethiopian birr except numbers in parentheses, which are the number of labourers salaries of 50 birr. Farmers 1 – 5 in Tsetsera said they had no extra expenditures for parthenium.

Farmer	6	7	8	9	10	11	12	13	14	15
Extra labour	2000	2000 (40)*	85 (chemicals)	Yes	150	2000	550	560	3-400	1000 (20)
Extra time	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-

*Said he could not afford to control outside of his land due to lack of funds to pay labourers.

Prior to parthenium arriving in Gerjele, they used approximately 10 mandays p/ha, now they use in the order of 20 - 30 mandays p/ha and this is really not enough. They cut it and the parthenium regenerates quickly again. They use hired labour, family, household family for weeding (GR-G). One farmer Selen Wuha said that parthenium, unlike other weeds did not add to the soil fertility:

> "You know this, this is very important, during your ploughing if you plough this one [*Argemone mexicana* L.] it turns the soil and they include what, additional nutrients, add nutrients for the soil he says. *(R) Uhuh*. But not kinche." - Male farmer Selen Wuha

None of the farmers I met said they slashed parthenium from their lands. However, one farmer in Selen Wuha said "Assume this one is a parthenium, then it is difficult even to plough, under this site *(R) ok*. If unless you slash it or cut it, remove it" (See also Observation V, next page). Almost all farmers in Tsetsera and Gerjele said that the best way to remove parthenium was to hand weed before flowering, whereas in Selen Wuha only one farmer mentioned it.

5.3.3. Composting of parthenium

In Tsetsera the farmers said they would not compost parthenium as they would be letting the enemy into their compost and it provides a way for it to spread (GR-TS). In Gerjele one model farmer said he composted it regardless of development stage (with or without seeds) and another said that he did not compost it this season as he had not weeded it before flowering and it would have been a means of spread (G:2). The one farmer in Selen Wuha who used to compost said he had not got information from the leader or DAs to use parthenium for compost. During the group discussions in Selen Wuha one farmer said he used parthenium for compost before flowering and that it was useful.

At TARI the specialists said that if the farmers believe that it is beneficial for them they will weed parthenium and make compost out of it. They have been doing field-trials using t-compost, a compost where the materials are ground and effective microorganisms (EM) are added to get a quick decomposition into a good compost, which they said takes about a month. They recommended that the parthenium be harvested when ¾ of the flowers were flowering. They were conducting experiments to see if the seeds are able to germinate or not after this composting treatment. The EM comes from an American company, however they did not have any current information on the cost as they had received the EM free of charge.

Observation V – Control methods
The farmer in Gerjele, whose field I visited, had slashed parthenium in his field, however it was still under preparation and piles of parthenium laid around the edge of the field and it may be that this part had not been completed yet. I observed one farmer in the Selen Wuha area slashing parthenium on his land (see figure below), he also said he would plough it down once he was done slashing. When asked why he had left it growing on his land, he responded that he was alone and had been busy on infested lands he had elsewhere. He also said that that field was only fit for sorghum and onion (Farmer Selen Wuha area). As I only have one active observation of weeding it is hard to say which techniques are more common. However both appear to exist.

Figure 10. The farmer is slashing parthenium on his land in order to prepare it for ploughing.

5.3.4. Health issues

Most farmers response to health problems related to parthenium was that there was none or that they had no experience of it but had heard of it. Those who said yes reported itching, sneezing or something resembling the common cold:

> "She says common cold *(R) Common cold?* common cold, itching, itching you know? *(R) Yeah.* Itches, itches. *(R) So is that more common when there is that powder or is it from the fresh plant?* [Tigrinia] She says it varies from the situations sometimes, eh, but morly [more] it is at young stage." – Female farmer Selen Wuha

The farmer whom I observed weeding in Selen Wuha (Observation V) said that he experienced common cold symptoms from the dust that comes off the mature plants. Another farmer in Selen Wuha said that he had been told not to touch the parthenium when it dusts, but he had not experienced any heath problems from it. Bitter taste related to green stains on hands after weeding was also mentioned as a health problem, however none of them said that they experienced any itching or common cold symtoms. One farmer said he paid no attention to health problems, and that removing parthenium was more important:

> "Yeah, even he says during the burning is our aims are we are only looking no more other side-effects but only to remove all the parthenium, we are focused on the

> parthenium, even though the burning side may have other effects but our aim is to remove.” – Male farmer Gerjele

Another farmer said there was an effect during composting and the burning of parthenium:

> ”You know it has the skin problems, highly burning on the compost, and answer later the parthenium, during the burning have also somewhat burning effect *(R) so the smoke has some effect.* Yeah yeah. Like sneezing. Itching or such kind of thing.” – Male model farmer Gerjele

The TARI director said that there are asthmatic effects and the crop specialist said that health reasons contributed to the lack of attention to weeding:

> “Of course they know the allergic effect of parthenium, if you go to Alamata and ask why they don't pull this weed, 'ah, this is very difficult for hand', yeah, 'it has some burning effect with it so I don't want to touch that weed'” – *TARI specialist Mekelle*.

None of the farmers interviewed gave any indication of this; the closest thing would be the bitter taste left on their hands after weeding.

5.3.5. Gender

In the group interview with farmers from Tsatsara, they said only men were allowed to plough. In Selen Wuha they said that women were not to work in the fields according to their culture but that nothing stopped them from coming there. A female farmer we spoke to in Selen Wuha confirmed this later:

> “She says on that matter, on the production systems on the increasements I don't have any full information, it is better to ask for those, guys the men, she said like this” - Female farmer Selen Wuha

The same woman said that she used a sieve to separate the parthenium seeds from the teff, and this was a womans task:

> ”She said during the marketing days assume a teff have weed the parthenium from the teff they use a sieve *(R) Ok.* A sieve so that they will not be any change for the price, this is what she said. Even though it is tedious we do like this especially the females do this one *(R) Ok.* So us to increase the cost of weed decreasing.” – Female farmer Selen Wuha

During the group interview in Tsetsera a woman was specifically asked about the weeding in general and she replied that it depended on the ploughing (only done by men) and the type of weed seed. The men who did not plough repeatedly, there weeding could become a problem.

In Gerjele, it was said during the group interview that the women collect parthenium around the house and use it for cleaning (GR-G). During the group meeting in Selen Wuha, it was said that the use parthenium for cleaning purposes was forbidden (sweeping and preparing the threshing land) (SW-G).

5.3.6. Impacts

When asked what will happen if they do not manage parthenium on their land, most of the individual farmers in Tsetsera I spoke to said that it will reduce yield, one said they did not know, “only knows that it is the enemy” (T:1). In the highlands most of the farmers had heard of parthenium before from the lowlands, as one farmer expressed himself:

> "We have heard so bad news about kinche and therefore we just, we are also organise group making to avoid that one". – Male model farmer Tsetsera

In the lowland areas they said that it reduces yield, while others said there would be no production or land left, that it was a question of their life and two replied that “God knows” (G:1, SW:1).

Two model farmers said that parthenium also competes for water with the other plants (G:2). During harvesting, parthenium has been used to sweep the fields when threshing in Selen Wuha. It has also been used for sweeping around the house (GR-G). These practices have, however, been stopped (GR-SW). When the seed is threshed and collected, parthenium seed is mixed in with grains. When it is ground (tef and sorghum in lowlands, sorghum, wheat and barley in highlands) the flour becomes bitter and several farmers said that visible parthenium seed lowered the market price of tef. Two farmers said they used a sieve to separate the tef while others said the only chance to remove it from their grains was to prevent having parthenium growing within the crop. It was unclear if there was a larger effect on certain crops, however two farmers said that sorghum was not affected by parthenium, while one said there was a reduction of yield.

One farmer in the lowlands said that during the dry season there are no other feed for their animals:

> “You know nowadays parthenium becomes important especially for animals, there is no grass, there is no water, we are in the area where there are no waters, so that animals can use as a source of feed. Even though its milk and milk products are bitter, but there is no other opportunity, he said like this. *(R) Did they have grass before this, or has the grass disappeared because of the parthenium?* Parthenium, ok. [Tigrinia] But before 3 or 4 years there was no parthenium more here, this area is known by the availability of the grass, so that is the reason why we said parthenium now becomes as a feed for the animals”. – Male farmer Selen Wuha

Two farmers said that parthenium was the only feed available in the dry season. One said he accepted bitter taste of milk while the other said there was no more dangerous weed to their animals but that there was no other opportunity (G:2). In all group interviews the bitter effect on milk and milk products was mentioned.

5.3.7. Policies and actions taken to remove parthenium

An exercise was held in Alamata 2005 (1998 EC) with policymakers, researchers and investors where three possibilities were discussed for parthenium control: Compost; Biological Control; and hand weeding (TARI-SP). No official policy for parthenium control came out of the meeting as it was hard to get all stakeholders to agree on one (BoARD-AA). There was also some frustration voiced over that potential solutions were not being adopted by the BoARD and that researchers were not passing on results:

> "The focus should be given to develop alternative practices, not only for development, they should also show the policy makers that it is effective. If the policy makers didn’t believe all that management tactics, they didn't take any action. That is a big problem not only from the policy makers or from the administration side but also from the researchers side, simply they are trying to develop the best management practices but they put with their hands simply.” (TARI-SP)

The ISD in Mekelle said that the BoARD there had not adopted parthenium composting after sharing their results from Alamata. The BoARD representative there said they promote composting in general and said that farmers in the Raya valley did not generally adopt composting.

The main focus of the regional BoARD is to limit spread of parthenium through quarantine programmes, which focus on limiting the transport of building materials, are being implemented. They also promote co-ordinated weeding after the main rains.

The two projects they have ongoing to reduce parthenium are creating awareness through farmer research groups (FRG) and compost production using EM (which is currently being developed by researchers). According to the DAs there are common activities for parthenium removal organised at kebele and woreda levels. The TARI director in Mekelle said that he believed that biological control with *Z. bicolorata* and composting of parthenium were two promising ways forward to control the weed TARI-DI. According to the BoARD representative in Addis Abeba, *Z. bicolorata* has been released in the Nazreth area (also known as Adama) in the Oromia region, approximately 100km south east of Addis Abeba (BoARD-AA).

5.4. Resource availability

The impact of parthenium on animals are becoming more important for farmers as animals have become more expensive (and also more profitable), but finding feed for them is difficult as one farmer says:

> ”And also the main source of income is from the agriculture, that means from the farm, but also nowadays production of animals becomes, what, profitable, but there is a problem for those, for the provision of feeding, the water accessability, for the .. , he said like this. Now animals become costy, tana five thousand or birr one oxen or something.” Male farmer Selen Wuha

Even in the highlands, lack of herbaceous matter is a problem as one farmer said that there was a lack of foliage for composting:

> “He says on the preparation of compost I am well and take informations but for the others problems maybe shortage of lands and also some materials are not available for decompositions, some leaves and such he said like this *(R) Shortage of eh..* components, yeah, for composting.” – Male farmer Tsetsera

The opposite was said at the group interview in Tsetsera, where farmers said there was not a shortage of composting materials. A variation in available composting materials throughout the highland region may therefore exist.

5.5. The perception of change

The question “Has there been any change in the last 10 years?” was asked in relation to rainfall, but was often interpreted as general change by farmers, often related to their quality of life or yield. Several farmers in the highlands said they had an increase in income due to the use of inputs and compost.

In the Gerjele the model farmers spoke of a positive change due to new breeds of cow and use of inputs (G:2). However, other did not share the same view and said there was a reduction from year to year mainly due to water and parthenium (G:1). In Selen Wuha one farmer also spoke of negative change, but he said he did not know what caused the decline in soil fertility. One farmer mentioned an improvement from the time of the derg regime, that it had become more democratic:

> ”Do you know the main things specially in the previous ten years he says just I have got some information about the ways of the increasing production. I have started, status, what you call ... also there is some democracy also maybe, he says like this. The most .. *(R) The democracy of eh...* Yeah, to use your land just as own, to own you know. Maybe the land is with the farmer yes? *(R) Hmm*. I think in the previous, there is during the derg region [reign] there is what, half is for the government, half is for the farmer. He said like this.” – Male farmer Gerjele

5.6. Knowledge and new practices adoption

5.6.1. Origin of knowledge (preferences)

During the individual interviews the farmers were asked whom they prefer to receive new practices from and just over half of them said they preferred to get them from the DA. However, it should be noted that the DA was present during some interviews. The other half said they preferred them from another farmer or model farmer.

> “Yeah, priority we give for the, to see our neighbour having such new technology then after we request the government to supply such kind of that. First of all we should have to see , it is practically he said like this.” – Male farmer Selen Wuha

The geographical availability of practices also seemed to play a part in adoption of practices as one farmer expressed:

> “She says she doesn't have any information about composting, even I didn't have seen in my neighbours, I don't have any knowledge about composting she said like this.” – Female farmer Gerjele

Most farmers stated that their main contact with institutions for information was with the BoARD, where as some model farmers in Gerjele had been in contact with NGOs (Unicef, USAID [G-GR, G:1]).

5.6.2. Adoption of "new technologies"

There was a consensus amongst the DAs, woreda expert, TARI specialist and regional BoARD representative that farmers do not adopt new technology easily, as one DA said:

> “[… farmers] cannot easily accept the new technology. So that makes more difficult to forced us to take the artificial fertilisers, but for the next I think they will be a change of generations, maybe they will be educated farmers so that they can accept new technology easily.” - DA in Alamata woreda

The DA seems concerned with the lack of knowledge amongst the farmers, where as the TARI specialist stressed that the farmers need to see the benefit of a new practice:

> “That is the main issue, anyone should concered on that issue, not forcing the farmers, as you force a farmer, the farmer also creates some [counter production,] this means, ah, everything should focused on the awareness creation and the capacity of farmers to

> believe that this activity is beneficial for them. […] it is better to do at ground level with farmers to increase their knowledge and to capacitate their skills, how they manage their families, how they challenge the weeds" (SP-TARI)

The woreda expert said that farmers were different and could be divided into early and late adaptors of new practices, and that the model farmers often were early adaptors. According to the regional BoARD, the flow of information comes from the regional BoARD where the woreda experts receive information and training who in turn train the DAs. All the Kebeles I visited had a FTC, but it was unclear how often there were activities. The wereda expert said that the government experts had given advice on compost preparation and that it had not resulted in any knowledge exchange (experience sharing) between kebelles on composts. Since it is only model farmers who compost in Gerjele and Selen Wuha, little exchange is apparent within kebelles. The Woreda expert said in Tsetsera group interview that composting knowledge was not spreading between tabias.

When speaking to the TARI specialists (TARI-SP) about farmers who abandoned composting after the DA would not come and assist in unearthing the compost pit (open it), they commented that there are good and bad DAs and that their background matters. They also said that farmers help each other through farmer networks, and that rich farmers are the head of farmer groups to whom the DAs can speak directly:

> "Therefore every farmer [the DA] supervise to produce compost and have at least one pit of compost and water conservation mechanism also in addition to that one. Therefore some farmers even help each other, now to rich farmers it is not a problem, they have a network. 5 farmers one group, they have a leader, other 5 years on there are around 30 come thirty farmers in one development group. By the way, the DA only can talk to the leaders, he can talk them. Not every household he [DA] didn't visit, but some days may not want to, some of them they came from towns, they don't know about farming, they may not have explains or they maybe fed up also. They may have remains more than 10 or 20 years, they have different reasons. There is a problem of flow of every, every year you find different DAs."

According to one of the DAs in Alamata, the workload was very high and with over 2000 farmers in the tabia it was difficult to reach all of them. There are expectations on the DAs and the BoARD from the farmers. Some said they were waiting for irrigation to come to their area, many said they were waiting for assistance with parthenium, and one farmer said he was waiting for more information on beehives.

6. Seed experiment: viability of heat treated seeds

Testing the fate of heat-treated seeds was done to assess if compost temperatures have any impact on *P. hysterophorous* seeds. Figure 11 shows the viability of different temperatures assessed using the TTZ assay. There was no significant difference between the control and any of the other temperatures. The biggest difference was seen at 50 and 80°C where the average of two replicates (of 50 seeds each) was 15% lower than that of the control samples (5 replicates of 20 seeds each).

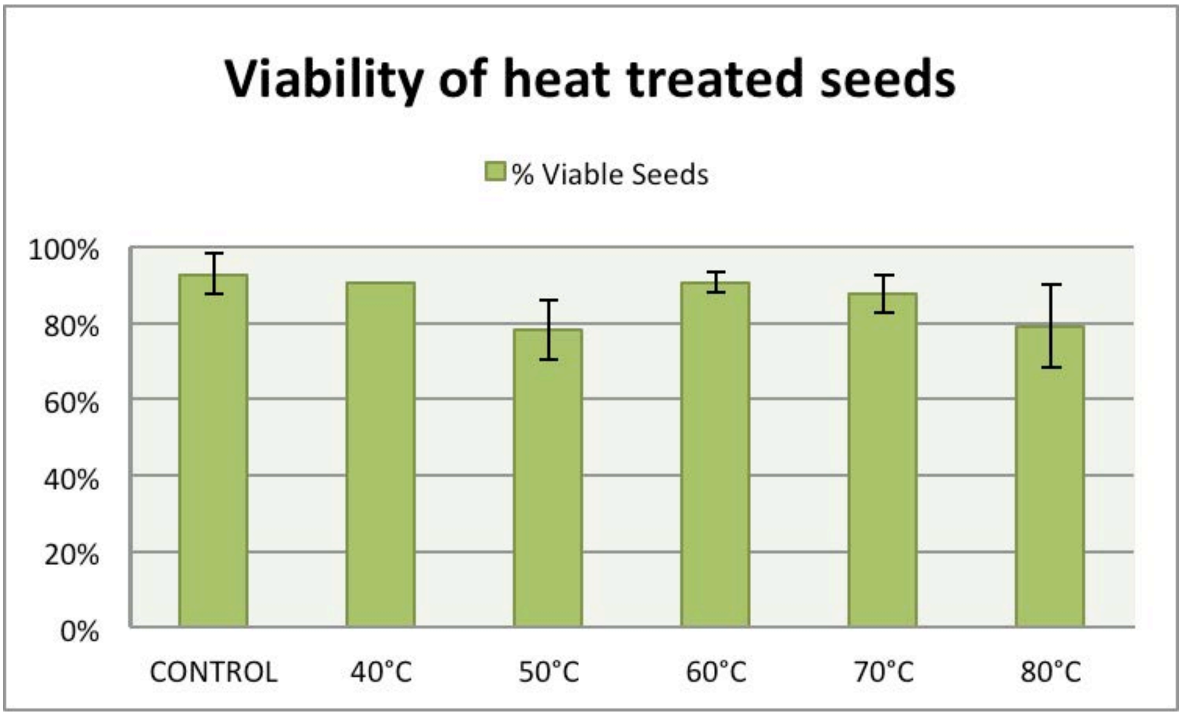

Figure 11. Percentage of seeds found to be viable after 72h heat treatment at respective temperatures and tested with TTZ assay. Viable seeds were found at all temperatures tested, 80°C being beyond normal composting temperatures. Empty seed coats were omitted from results and only one replicate was made at 40°C due to time constraints.

PART III: Putting into context and formulating an approach

7. Discussion

7.1. Parthenium in Alamata

The firm establishment of parthenium in Alamata suggests that conditions are very favourable for it. As many other weeds, it is prolific in disturbed soils which the heavily cultivated Raya valley can offer. There was a clear difference in parthenium between the highland and the lowland sites caused by physical as well as management differences. The highlands do not receive floods as in the lowlands, which seemed to be the main form of spread. The difference in soils may play a part since parthenium seems more common on alkaline clay soils (see sec. 2.2: Dale, 1981; Annapurna and Singh, 2003; DEEDI, 2011). A local study in Kobo (Amhara region) found the opposite there, parthenium was more common on alkaline sandy soils (Wubeshaw, 2006). It is unclear if the soil type plays any major role in the rapid growth and spread of parthenium. In the Raya valley the soils are also alkaline (IPMS, 2005), the alkalinity of the soil seems to favour parthenium forming dense stands.

The concentration of cultivated fields (as well as main road to Addis Abeba), and therefore disturbed soils, are much greater in the Raya valley compared to Tsetsera, giving parthenium better of a chance to spread quickly and establish here. The difference in elevation also gives a different temperature range with cooler temperatures in the highlands. Therefore, the cooler temperatures may slow the spread of parthenium as the seeds are less viable, show loss of dormancy and long onset of germination in these conditions (Tamado, 2001; Karlsson *et al.*, 2008; Nguyen *et al.*, 2010). The increased access to markets for farmers in recent times (IPMS, 2005) may also increase the spread to other regions.

Diversion of floods are common way to safe guard against longer periods without rains in the lowlands of Tigray (Assefa *et al.*, 2007) but is also a quick avenue of spread for parthenium. The rigorous ploughing needed to prepare and grow tef (Ketema, 1997) could also benefit the establishment of parthenium, as it prefers disturbed soils. It is clear that if parthenium is to be removed from Alamata, the seed bank present has to be depleted which would require weeding all year round by all farmers for the next 6 – 8 years. How this could be achieved is unclear with the associated costs of labour. The best one could hope for is to keep it under control.

7.1.1. Perceptions of parthenium

The difference in management practices are connected to the perception the farmer has on parthenium. Farmers were aware of the impacts of parthenium on their crops and livestock. However some farmers only weeded in time for the growing season, and the lack of weeding in the dry season can have many reasons.

Seasonality. The variability of weeding practices through out the year could be connected to earlier pastoral practices, as the dry season is a time when they herd their animals to find feed for their animals (pers. Comm. G, Tesfay 2013). It is perhaps natural to not pay any attention to the fields in the dry season when nothing grows there. Weeding is commonly done when fields are prepared, which is variable depending on the crop, but usually in April (IPMS, 2005; this thesis). Their labour can yield more direct results elsewhere and the dry season is a time when income is generated elsewhere through PSNP or sales of livestock (IPMS, 2005). The soils are only ploughed when rain falls since they are easier to work (Haile, 1996). One farmer said that parthenium was difficult to remove due to its deep root system, which may be even more difficult when the soil is dry.

***Knowledge and observation**.* At the same time farmers had not observed any differences from their weed practices and have stopped weeding (new seeds come with floods and soil seedbank is large). They may not have enough understanding of the biology of parthenium and that it can produce plenty of seeds during this time to motivate them to remove it. A few farmers have found it necessary to use it as a source of feed for their animals due to lack of alternatives partially caused by parthenium.

The carelessness expressed by some farmers to the lack of weeding may be contained within the reasons mentioned above. Poor farmers sell their labour in the time of critical food shortage in local communities which coincides with weeding in time for the main growing season (Wondimagegn, 1996), the variability in weeding seen in the fields may be a direct result of farmers access to labour (their own or others). A contrast to the carelessness is that farmers said that they did feel a responsibility to stop it from spreading.

The farmers in the highlands had heard of parthenium from the lowlands before it came to them which may have given them a head start on control, since parthenium establishes quickly once seeds have been shed. Herbicides used in the lowlands may also allow farmers to be more relaxed with their hand weeding, whereas the highland farmers have to be more vigilant as they do not have that option as government has banned chemicals due to beekeeping in the area. A study in Eastern Ethiopia (Tamado and Milberg, 2004) found that herbicide application gave variable control of parthenium in *S. bicolor,* and the best control and yield was obtained when had-hoed twice during the crop. Some farmers mentioned that *S. bicolor* could resist parthenium in competition. Tamado (2001) found that under moisture stress, *S. bicolor* would germinate normally while parthenium was completely inihibited at higher temperatures and around 30% at 20°C. He suggested that *S. bicolor* would get a competitive advantage over parthenium and is supported by the farmers observations.

From a gender perspective there was no difference between male and female farmers, rather a difference in awareness with those sporadically or not actively involved in farming activities, e.g. women using parthenium to sweep around the house. A stronger focus on gender and higher participation of females in interviews could have revealed a deeper insight into any differences.

7.1.2. Health aspects

Very few farmers said they experienced health problems associated with parthenium. These findings differ from another survey in Ethiopia where most farmers reported problems due to parthenium (Wiesner *et al.*, 2007). Rao *et al.* (1977) reported a 4% incidence of contact dermatitis which is close the findings of this research (7%, 1 out of 15). This may be due to lack of associating symptoms to parthenium, that the farmers themselves do not do the weeding or they are not susceptible to any immune reaction (as dermatitis from sesquiterpene lactones is highly individual (Warshaw and Zug, 1996)).The level of secondary metabolites also vary with rainfall in parthenium (Ulrichs *et al.*, 2012). During my time in Ethiopia I got the impression that health problems are not something you speak of in public and this may have influenced the farmers to answer the way they did. Likewise, as one farmer replied that their only aim was to remove it and that any health problems that might be were secondary. Even though not many farmers reported of health problems from parthenium (apart from *mitchi*), it should still be considered as a potential threat to farmers livelihoods. In order to increase weeding and use of compost, the issue of protection to parthenium would need to be addressed. Farmers in the Rift Valley south of Addis Abeba used plastic bags for weeding parthenium in order to protect themselves (Gebeyehu, 2008).

7.1.3. Dependency on rainfall

The farmers spoke about the main rain season in July and August but it is unclear why they did not mention the smaller rains (bimodal rainfall) that is common in the Tigray region (Leroux, 2001). It is possible that they do not perceive the rainfall to be reliable enough for growing crops and therefore do not mention other rain events. There was no difference in perception amongst those farmers who had access to a reliable source of water (river or dug pit). As parthenium is less dormant in the dry season and germinates after sufficient rainfall (Tamado, 2001; Nguyen *et al.*, 2010), the lack of weeding at this time can increase the seedbank if they go to seed before farmers begin to prepare their fields in April.

It was unclear if majority of farmers were aware of actively bringing more seeds onto their lands through their spate irrigation as one farmer was. Being dependent on the floods for water to manage the variability in rain this may be a trade-off they make, as farmers said that the rainfall was the factor which decided if there was any production at all.

7.2. Perceptions on soil fertility and composting in Alamata

The difference in the perception of soil fertility between Tsetsera in the highlands and the two lowland sites was clear in their choices of soil improvement. In a qualitative study by Corbeels *et al.* (2000), they found that Ethiopian farmers assess soil fertility by crop yield and performance as well as soil factors affecting its growth. Use of composting and inorganic fertilisers were common in the highlands. In the lowlands however, very few composted as they considered their soils fertile and did not need any additional nutrients. It was the variable rain that led many farmers to question the suitability of inorganic fertilisers in the lowlands and to prefer manure as a soil improver. This has been noted earlier in central Tigray, where farmers found that application of inorganic fertilisers during unreliable rains was destructive to the crops (Haile, 1996). The suitability of inorganic fertilisers in a region, which does not receive a reliable amount of rain, is questionable. The farmers' perceptions of soil fertility and use of inorganic fertilisers does not fit with the perception of other institutions that yields could be higher with inorganic fertilisers. Since those who make the policies are not present in the region to make the same observations as the farmers, there is a conflict of interest. Perhaps a focus to increase the moisture retention e.g. through adding more soil organic matter would be a better focus in order to increase yields. The farmers' perception that their soils were already fertile, can be seen as a constraint to compost and increased control of parthenium. It would require farmers to feel a need to fertilise the soils, perhaps from observation of the effects of compost on crop yeilds.

The government policy which greatly encourages DAs to disseminate inorganic fertilisers to farmers, provide a method to add nutrients to their soil which is less labour intensive than compost preparation and use. It can be very labour intensive to move compost or compost materials to the fields due to the distances the farmers have to travel to their fields (pers. Comm. G. Tesfay, 2013). The extra labour need for compost is also a constraint, especially with inorganic fertilisers available which do not require the same amount of labour. It may be that they don't see the full benefits of composting, such as yield increase from added nutrients and lower competition from parthenium.

The threat of sickness from composting was enough for farmers, who spoke of *mitchi* in Selen Wuha, to find it disadvantageous. It is unclear what mitchi is, but there is reason to be cautious when handling composts, the bioaerosols that are released when turning can contain many live or dead microbes as well as toxins or other allergenic compounds and cause health problems (Harrison, 2007). The farmers solution to open it when it is cooler outside may reduce aerosols being released but there is not evidence of it in literature. Ensuring the right moisture content in the compost can help reduce the bioaerosols (Harrison, 2007). It would be interesting to see if health problems or labour requirements are the largest constraints for keeping compost. In the highlands the use of parthenium as a compost material was limited by the view of some farmers that they would be inviting the enemy into their compost pits.

Farmers also need feed for their animals, and the fact that some farmers were using parthenium due to the lack of other materials, suggests that there may not be enough resources for both livestock and composting. As livestock are an important asset to households, they are likely to prioritise feed for their animals over compost materials.

7.3. Composting of parthenium seed

If the seeds survive the composting process this could be another avenue of spread as well as the release of allelopathic chemicals (Msafiri and Tarimo, 2013). Most farmers composted parthenium before seed setting to avoid spread, which was also common knowledge amongst BoARD and TARI representatives. The experiment I carried out shows that heat alone will not affect the seeds (at least not in the time frame used). However, when seeds are subjected to both moisture and heat this increases the seed mortality (Egley, 1990). Egley (1990) showed that several weed species, when subjected to temperatures at 60 and 70° C in soil containing less than 2% moisture, could survive the whole experiment period of 7 days, including one weed from the Asteraceae (*Xanthium spinosum* L.). When subjected to the same temperatures but in a soil containing 19% moisture only a few weed had viable seed at 60 °C, and at 70 °C two grass species had less than 5% viable seeds. This could explain why the seeds from the ISD composting trials were not found or did not germinate (Araya *et al.*, 2010) due to the presence of soil moisture during the composting process. The difference in outcomes compared to Kishor *et al.* (2010), who observed a declining viability of seeds (lowest 15% at 60°C), may be due the seeds being at different development stages. The seeds used in this research were already mature and dry, whereas Kishor *et al.* (2010) used seeds still on the plant and may still have retained moisture, leading to the difference in results. Their control value of 75-80% viable seeds was also different from my 85 – 100 %. I selected only filled seeds compared to Kishor *et al.* (2010) who used whole plats and threshed seeds from these. Depending on growing conditions of *P. hysterophrous* the filled seeds vary (40% - 76%) (Nguyen *et al.*, 2010) and may account for the difference in viability between Kishor *et al.* (2010) and my control. As Mekelle has power outs from time to time, this may have affected the experiment if there were longer periods. This could have been verified with a maximum/minimum thermometer to identify temperature fluctuations.

Composting of mature parthenium that contain seeds does pose a potential risk to reintroduce parthenium to the fields if the seeds survive the compost environment. The closer to seed and the larger they are, the mature plants will contain more nutrients due deep to the tap-root that draws up nutrients from deeper in the soil profile (Navie *et al.*, 1996). This is something the seedlings will not have developed. In order to get nutrient rich compost it is better to use mature plants but if left too long will have set to seed. When weeding is done plants could be sorted into compostable and non-compostable depending on their development stage if the labour is available.

7.4. Power relations, knowledge transfer and adoption

It soon became clear that many hierarchies existed in the villages that I was not aware of before arriving. It is clear that communities are not homogenous but faceted with different power relations related to different positions within a community (Guijt and Shah, 1998). The nature of such power relations depend on the context and people involved (*ibid*).

In the lowlands some farmers 'complained' of feeling pressured to use inorganic fertilisers. The repercussions of not doing so were penalties such as not being allowed to plow their land or not being part of the SOFTNET programme (PSNP) or having to explain themselves in front of the officials. This is typical of top-down dissemination where adopting farmers are rewarded (e.g. with model farmer titles) and those who do not are penalized (Chambers, 1997, p 62). This is an example of where power relations influence farmers decisions. Top down dissemination limits learning to one way vertical transfer of information, promoting learning where a single view considered correct. This is opposite to a lateral learning cycles, where (farmers') knowledge generation occurs (Chambers, 1997; Guijt and Shah, 1998). In the case of parthenium the question is if the extension services and knowledge transfer provided make it easier for farmers to expect a solution from the government rather than find one themselves. Farmers have adapted to the presence of parthenium, many seem to have accepted that it is there to stay (until a new solution is found). In some cases they have no choice as with the lack of feed, parthenium is used out of necessity as other grass species have been outcompeted.

Farmers' beliefs are important in knowledge adoption, and observing a successful practice of another farmer will lead to adoption according to some farmers in this study. This was also observed by Corbeels *et al.* (2000) where one farmer who applied manure to his crops, lead the rest of the farmers around him to adopt the same practices after seeing the effects it had on his yields. Just like farmers may adopt a new technology or practice they preceive to be beneficial, they may cease an exisiting one if they feel it is not useful. In a study in Wolaita (South Ethiopia), Beshah (2003) found that the two main reasons for dis-adoption of soil bunds were: (1) the lack of information provided by research and extension to allow farmers to compare advantages and disadvantages; and (2) the farmers observations did not reveal any loss of soil fertility (valued high by the farmers) due to erosion as they had access to organic and inorganic fertilisers. The adoption of composting in Selen Wuha holds similar indications where extension does not supply enough information leading to the farmers believing that composting is dangerous. According to Beshah (2003) the key to getting farmers attention is to appeal to their soil fertility as this was the factor prioritised the highest by farmers in his study.

It seems evident that the farmers simply cannot just be told that their yield will be higher; they have to see it for themselves as several farmers expressed preference for. To want to see results of a certain practice shows of the farmers experiential learning (Kolb, 1984). As the specialist at TARI said, they can do anything if they believe it. The question is how easily the knowledge is transferred from a model farmer to other farmers is unclear. Is it a question of proximity to their fields, or being a member of their farmers group that enables them to observe and learn composting? It may be the power relations that limit the access to this information or the lack of interest and motivation to engage with composting. In Araya and Edwards (2011) experience, all involved stakeholders (farmers, DAs, woreda experts) have to be convinced that composting is useful and willing to work hard to get good results. It is clear that farmers decisions to use compost is complex, but they are not convinced and considerable work will have to be done to in order to convince them.

7.5. Farmers, natural and political forces

The seasonal cycles is something the farmers have adapted and their farming practices and life to (McCann, 1995). The natural variations in rainfall and extreme lack thereof has also led to some of the worst famines in both modern and old times (McCann, 1995; Viste *et al.*, 2012). This brings us back to the question asked by the (IAASD, 2008), what can be done to overcome persistent poverty and hunger? Ethiopia has come a long way from the fall of the derg regime (which was pointed out by one farmer) and the future solution envisioned by the Ethiopian government is to achieve a green economy by reducing its carbon emissions (EPA, 2011). This still focuses on economic growth through modern agricultural inputs and foreign investment (MoFED, 2010b). The question is if the whole approach is "equitable and sustainable" and will it "sustain [a] productive and resilient farming in the face of mounting environmental crises" (IAASD, 2008)? Perhaps with a stronger economy the government has the means to focus on the climate change vulnerable sectors such as agriculture and health (EPA, 2011).

In other parts of Ethiopia, parthenium has had a large effect. This is for example the case of the rangelands in the south-east (and already under pressure from land degradation), where the farmers depend on the grasses available in the dry seasons (Ayele *et al.*, 2013). Both farmers and DAs have spoken of the obligations to take and distribute inorganic fertilisers, which seem central to their goal to continue growth. With the problems of water shortages partially dependent on the natural climatic cycles (Wolde-Georgis, 1997; Leroux, 2001), the changing climate (IPCC, 2013) can be thought to exasperate the problem even more.

With no national policy on parthenium control and with other goals are pushed harder it is not strange that it is a growing problem. If a national policy was constructed it would need to need to be sensitive to local adaptation and allow for practices that can be multifunctional in their application. It is not only in and around farm fields where the challenge of parthenium exists, but also in the cities where awareness of the weed seems to be much lower and where it has the potential to affect the health of a much larger population.

7.6. Suggesting an agroecological approach

In order to suggest a good approach, practices have to be put into the context of what practices that farmers do at respective time of year and facilitate an all year round control of parthenium to reduce the seed banks. In order to do this I have looked at seasonal calendars from a livelihood study in the Alamata area done in 2006 by the Disaster Preparedness and Prevention Agency (DPPA, 2007). Timing different control measures and practices to farmers' normal practices could increase the application of them. Using methods that have other benefits such as fodder for animals or generating a good soil improver through compositing could also increase the adoption, strengthening the multifunctionality of the farming system (D. Rickerl and C. Francis, 2004). The future introduction of biological control through *Z. bicolorata* will, if it establishes well, alleviate the need to control parthenium during the wet season, as this is the time when it is normally active (Jayanth and Bali, 1993). Times when parthenium is not weeded such as the dry season require other practices to reduce its population. Preparation of silage could in theory be done throughout the year if farmers find time for it. Composting is normally done in February according to farmers in the Highlands, suggesting that collection of parthenium for composting use may initially be restricted to a month or two around this time.

As competition for space during the dry season is limited, establishing perennial grasses that are competitive with parthenium in communal or unused areas can help reduce the parthenium population outside of the fields where control is less common. It will also supply fodder or composting materials and act as a physical barrier for parthenium seed during flooding. The best suitable grasses (based on the ones mentioned in the introduction, sec. 1.2.2) for Alamata would have to be assessed with the farmers at the FTCs together with the availability of seed. Table E in the appendix (p. 63) shows the benefits and drawbacks of species found to be competitive, Buffelgrass (*C. ciliaris*) seems one of the more promising in terms of control and forage quality (Quattrocchi, 2006; Khan *et al.*, 2014). Many new questions would arise with the use of grasses on common land with the establishment, maintenance and use of the grass on the community level. This would require community action and the use of participatory methods if intervention was to come from the outside. The establishing of competitive grasses could also be combined with leguminous species to give forage with higher nutritional qualities, which is a problem in parts of sub-Saharan Africa (Thomas and Sumberg, 1995).

An illustration of different control practices together with rains and farmers normal practices can be found in figure 12. How successful a year round control of parthenium would be depends on the possibilities of implementing some of the suggested control methods. Certain practices are gender specific and seasonal. These include plowing (for weed control) or cleaning (sieve) and preparation of seeds for selling at the market. Gender sensitivity is essential to finding new ways to control parthenium. Farmers would have to find the new practices useful and planting of competitive species in communal grasslands would need the support of the community as well as a plan of how the grasses can be used.

In order to reduce parthenium, there also needs to be a focus on urban areas. City dwellers are unaware of its existence and earlier campaigns have not managed to raise awareness in the population, suggesting that more are needed (see appendix for observations made in the cities). The use of parthenium compost and silage in cities could greatly reduce parthenium populations and also facilitate awareness. Making use of parthenium compost in urban gardens could lead to a quick removal and better livelihood for those who use it, especially in the light of urban growth. Some difficulties that would need to be addressed are the health issues associated with parthenium, access to protection (gloves and facemask) and transport of collected parthenium to the compost site.

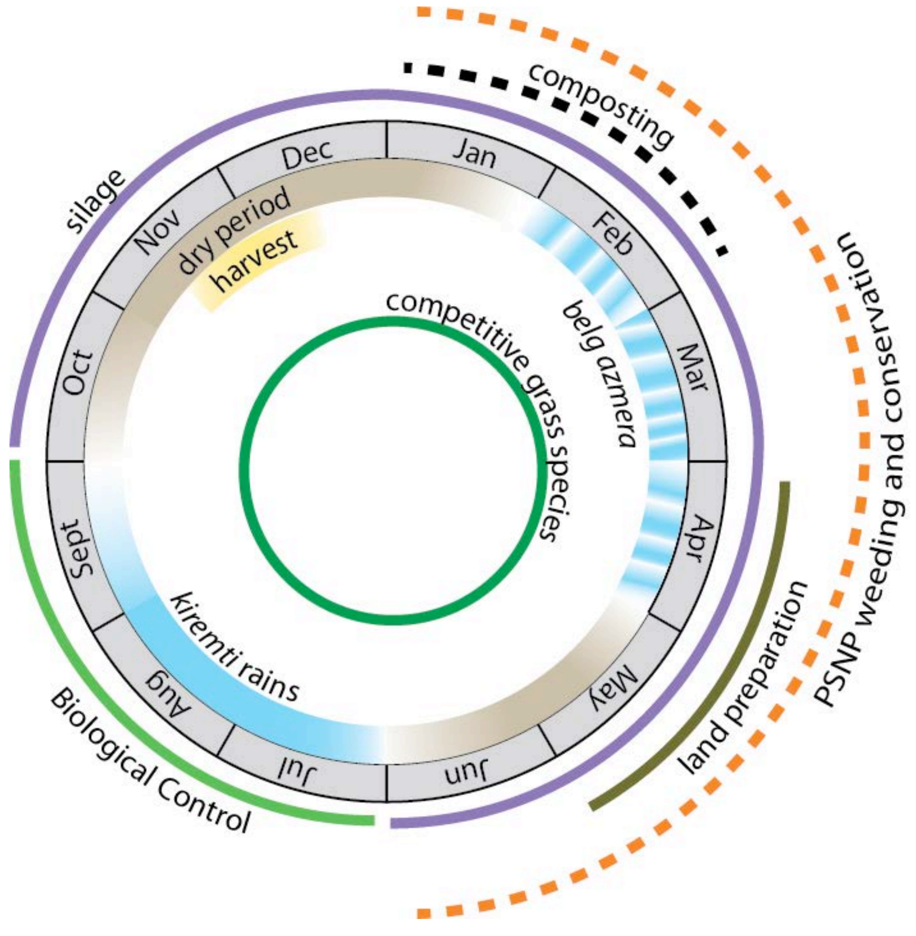

Figure 12. In order to better control parthenium control practices have to cover all months of the year as occasional rains may trigger germination. By increasing the number practices the chance of weed removal increases. The introduction of biological control could decrease the need for weeding during the *kiremti* rains. (Own illustration based on synthesis from following sources: farmers yearly calendar from IPMS (2005); *Zyogramma bicolorata* information (see section 1.2.2, p8); Rainfall accounts in results (figure 6**) and section 1.3.1 (p 10); parthenium silage (Narasimhan *et al.*, 1993) on times when feed is a shortage problem (dry season).**

7.7. *Reflections on the choice of methodology*

Things do not always go as planned. Upon arrival to Alamata there seemed to have been a misunderstanding, the interviews were planned to be done with individual famers but they had been gathered for a group interview. As the farmers were not going to stay around to be interviewed one by one we proceeded. I became aware of that certain individuals spoke more in the group interview, which is not uncommon (Bernard, 2011). This led me to follow up with individual interviews upon my second visit, to see if I could catch the more silent voices.

The qualitative aspect of this thesis did not become as pronounced as I had hoped. The difference in perceptions on agroecology had a role in this, with the view of agro-ecology as a set of physical parameters (and a positivistic approach) compared to my own of agroecology as a methodological approach including social, economic as well as participatory aspects (a more constructivist approach). The choice to use questionnaires for the second visit to Alamata was based on the recommendation by my contact at Mekelle University and my interpreter. The compromise to combine this with open-ended questions that would arise during the interviews with the farmers (which is what I wanted to use) is something I thought would be possible.

As the interviews often were quite long and the RRA methods, such as the year calendar and transect walk, were placed at the end of the questionnaire, the farmers were not too interested in staying longer. Even though it would have been wise starting with these parts and limit the number of questions in the questionnaire, I have learned that combining different methods can be difficult and requires more time than I had anticipated. It may be that the farmers did not see the point of travelling out to their fields when they were not growing anything (apart from perhaps parthenium). It did require more time when visiting the fields, and with the DAs recruiting farmers to the FTC all at the same time did not facilitate visiting the fields as the other farmers were waiting. *Mitchi* was something I didn't know about before going to Alamata and was not included in my guides or questionnaires. It is an example of how a more qualitative approach allows for a broader understanding of a situation and had I focused on a more technical approach to composting of parthenium the problem of *mitchi* may not have been identified.

In retrospect I think it would have been useful to have included a session where I familiarised those I was working with to participatory methods as to make it easier to carry them out (e.g. I may not be aware of constraints due to lack of knowledge on local customs, but they may have been able to tell me if we had sat down and planned it in detail). RRA tools are suited to the short time frame, however participatory methods are often long term, require careful planning if they will be useful and feasible but give more reliable results (Pretty, 1995).

I realised the effect of direct translation and communication can have on the research when interviewing in another language. Using a questionnaire for the individual interviews did not render much new information from the group interviews, it rather strengthened the information I already had. The qualitative information sprung up from additional questions or the farmer giving a longer explanation to a question. Coming from a different cultural and language background, some of my questions were not interpreted in the way I had intended as in the case of health problems, they were noted by few farmers, but is it that my understanding of health is different from theirs or a cultural question on openness of health? I realise that these are some limitations that can appear when not speaking the same language. Quite often during interviews there would be a minute or two of discussion in Tigrinia followed by a short answer from the translator, making me wonder what was said during this time. This is a limitation to my results, that what farmers have said has been translated and possibly condensed and/or interpreted. Since both translators have a background in agricultural studies I think they have a good understanding of what farmers have said.

The results I have decided to use are more qualitative in nature and I have omitted data that was quantified, (e.g. such as number of cattle) and focused on the perceptions. It is difficult to validate numbers, however perceptions are what the farmers have said and the validity is mainly based on the translation that I believe to be accurate. I was not able to triangulate as much as I wanted through my own observations and with more time this would have been possible. The geographic limitation to interviews with farmers was essential to keep the work possible during time I had in Ethiopia. As mentioned above (sec. 4.4), The results are not meant to be representative, but rather indicative of what issues are at hand.

I was unprepared for the issues of power structures which I had read of in the literature (Pretty, 1995; Guijt and Shah, 1998; FAO, 1999), perhaps since I had not spent enough time familiarising myself with them. In order to get a better picture of how this affects the presence of parthenium I would have needed to spend more than 6 days in Alamata and find good informants on how local power structures work. This was a good learning experience for me. I was asked in Gerjele upon my second visit if I had come up with a solution to the problem of parthenium, which I had not. I became aware of the danger of raising expectations when arriving as an outsider, which is often discussed in literature (Pretty, 1995; Guijt and Shah, 1998). This reinforced my belief that interactions with people as a researcher are not possible to keep objective and act only as an observer (at least on such a short timescale), but that it is a subjective experience where the researcher needs to be sensitive to his or her own impacts.

In order to stay true to the participatory methodology, I would like to communicate my findings to the farmers – however, it may be too late as I may already have reinforced an idea that outsiders who come and ask questions do not contribute anything in return. This also brings up the question of what role I take as a researcher in this process, and what level of participation was achieved using participation by consultation in this thesis. I had hoped that the degree of participation would have been higher, allowing the farmers to identify the problems around parthenium and being able to suggest solutions.

The time of visit from February to April provided me with some valuable observations to why parthenium is a problem. However, in order to observe and discuss with farmers active in the field it may have been better to do the study during a time when they are in the field. On the other hand, it is possible they would not have had the time to sit down and discuss parthenium with me as they did had I been there during the main cropping season. Time is a limitation that I mention often and is mainly tied to the short time I spent in the Alamata area. Overall the time spent in Ethiopia was enough to carry out the interviews and perform my seed experiments. More time would have allowed for longer visits and the possibility to visit more farmers fields. There would also have been the possibility to follow up or discuss my findings with the farmers, which would be in line with my intentions to have a more participatory approach.

7.8. Conclusion

This thesis set out to see if composting of parthenium was an option for control and to see if there were any large constraints in using it. Farmers said they would adopt practices they thought were useful, but they wanted to see it first. The farmers' perception that their lands were already fertile plays a part of the low adoption of composting and inorganic fertilisers. The variable rainfall also makes it hard for farmers to use inorganic fertilisers. Some constraints associated with composting were: *Mitchi* causing health problems; many farmers said they had no knowledge of composting; and to a small degree shortage of composting materials. It is unclear if the knowledge possessed by model farmers is accessible to other farmers, however it is clear that it has not spread from them. In order to use composting as a control measure, farmers would need to see the benefits of composting weigh up their time and labour investment. Farmers' perceptions and beliefs are important in their choice of practices.

If parthenium control is to be successful in the Alamata area it requires that control measures are not forced upon the farmers but that they see the benefits of controlling it. It is important that control measures are beneficial for farmers and that those which are promoted overlap and allow for control all year round to make sure that the seed banks are reduced. Apart from generating awareness of parthenium with farmers, awareness with city dwellers would reduce the spread to other areas, as they are places of great movement.

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Appendix

A. List of interviews

Table A. Number of individual interviews done with farmers using questionnaire (B).

Tabia	Site	Kushet origin	Type of interview	# of interviews	M/F
Tsatsara	DA office	4	Individual	4	3/1
	DA office	1	Individual	1	1/0
Gerjele	FTC	5	Individual	4	3/1
	Farmers field		Individual	1	1/0
Selenoi	FTC	3	Individual	3	2/1
	Farmer field	2	Individual	1	1/0
	Shade of trees		Individual	1	1/0

Table B. List of group interviews done with interview guide A.

	Interview site	Participants beginning (M/F)	Participants end
Gerjele	Shade of house	12/0	3/0 (1/4)
Selen Wuha	Pump house	7/0	7/0
Tsetsera	FTC	13/5	6/0 (1/3)

Table C. Semi-structured interviews done with institutions using interview guide (C).

Institution	date	Location	# visits	Interviews
TARI, Mekelle		Mekelle	3	1. Director 2. Researcher 3. Specialist
ISD, Mekelle		Mekelle	2	1. Representative
TARI, Alamata		Alamata	1	1. Director, Specialist
BoARD		Alamata	Field	1. 3 DAs (one in passing*) 2. Woreda expert*
BoARD		Mekelle	1	1. Representative
BoARD		Addis Abeba	1	1. Representative

*No interview was done with semi-structured interview guide, questions were asked in the field when they arose.

B. *Observations made in the cities*

Observation A

Alamata Town

Sporadic concentrations of parthenium in what seemed to be abandoned plots and building sites. One cart passed with tomatoes, they were cushioned with parthenium.

Mekelle

In Mekelle parthenium was present along roadsides, streams, buildingsites and houses. During a transect walk in the Ayder area (near to the hospital) cultivated fields had little or no parthenium, but in some fields there was a fair amount around the field margins. Fields not in use during the dry season had dense stands, in one area a man herding cattle was allowing his cattle to forage on the parthenium.

C. *Number of viable seeds from TTZ assay*

Table D. Results from TTZ assay with all the replicates on collected parthenium seeds for each temperature interval. Seeds which were found to be empty on inspection were omitted from the final result.

Temperature		Sample size	Total filled seeds	viable	Viable %	VIABLE (AVERAGE)	STDEVPA
40°C	1	47	43	39	90.70%	91%	-
	2	-	-	-	-		
50°C	1	50	27	19	70.37%	78%	0.078380706
	2	50	43	37	86.05%		
60°C	1	50	33	29	87.88%	91%	0.026515152
	2	49	44	41	93.18%		
70°C	1	50	29	24	82.76%	88%	0.04916986
	2	50	27	25	92.59%		
80°C	1	50	41	28	68.29%	79%	0.108536585
	2	48	40	36	90.00%		
CONTROL	1	20	6	6	100%	93%	0.053323667
	2	20	8	8	100%		
	3	20	14	12	85.71%		
	4	19	13	12	92.31%		
	5	20	18	16	88.89%		

D. *Suitability of grass species able to suppress parthenium*

Table E.Grass species found in Ethiopia that are able to compete with parthenium. In order for the grasses to be of use for farmers in Alamata, positive and negative properties of the grasses have been indicated. In order to actually use these grasses the farmers themselves would have to try them and see which grasses which are useful.

Species	Description	+ Alamata	– Alamata	Reference
Bothriochloa radicans (Lehm.) A. Camus (Stinking grass)	Unpalatable perennial, low grazing value, good for erosion control, grows on heavy clay soils	+ suitable soils and erosion control	- not useful as feed	(Quattrocchi, 2006, p 317)
Chrysopogon aucheri (Boiss.) Stapf.	Excellent perennial forage grass, Poor seeder, drought tolerant. Common in *Acacia* woodlands.	+ alkaline soils +drought tolerant		(FAO, 2005, p 34; Quattrocchi, 2006, p 493)
Cenchrus ciliaris L. (Blue buffalo grass)	Excellent perennial forage grass, withstands heavy grazing and occasional flooding. Common on nutrient poor sandy soils. Grows in association with *C. aucheri* in *Acacia* woodlands.	+forage grass +flooding + grazing tolerant	-Soil?*	(FAO, 2005, p 34; Quattrocchi, 2006, p 446)
Panicum coloratum L. (Blue panic grass)	Good perennial forage species; used for hay, pasture and silage; withstands drought; can grow on waterlogged clay soils	+ Drought tolerant and grows on sandy to clay soils	- photo-sensitization in sheep and goats	(Quattrocchi, 2006, p 1462)
Panicum maximum Jacq. (Guinea grass)	Several varieties with slightly different properties. A perennial pioneer grass, used for pasture in many countries.		- drought intolerant	(FAO, 2005, p 38, n.d.)
Setaria incrassata (Hochst.) Hack. (Purple pidgeon grass)	Perennial. Variable species with good forage properties that can withstand heavy grazing.	+ withstand heavy grazing		(FAO, 2005, p 36)

*In a study in both Pakistan and Australia, *C. ciliaris* successfully inhibited parthenium growth on a variety of soils types (Khan *et al.*, 2014). The fields were all prepared using a tractor and disc cultivator, no fertilisers were used (*ibid*).

E. *Interview Guides*

1. Group interview guide (2 pages)
2. Individual interview guide (4 pages)
3. Institutions interview guide (1 page)

Interview id#:____________ Date:____________

' 2 / 5 0INTERVIEW GUIDE FARMER VISITS

1. FARM

(1.1.1) Name: ________________________ (1.1.2) Sex: M/F (1.1.3) Age:____
(1.2.1) Village: __________________ (1.2.2) Tabia: _____________ (1.2.3) Woreda: ___________
(1.3) How long have they had it? _____ (1.3z)DRAW TIMELINE (?)
(1.4) How big is the farm? ____
(1.5.1) How many work on the farm? _____ (1.5.2) Are they family?
(1.6) Do they have livestock? (How many, which type)__________________________
(1.7) What are their main sources of income? (1.7z) *ASK IF THEY CAN RANK THEM.*

2. LAND and WATER

(2.1) Tell me about the/your land. ______________________________________
(2.2.1) Where do you get your water from? _______________________________
(2.2.2) Do you conserve water on your lands? _____________________________
(2.2.3) Do you have problems with water shortage?___________________________

3. CROPS

(3.1) Which crops do they grow? ____
(3.2.1) Do they improve the soil and With what? ___________________________
(3.2.2)Has it always been like this? _____________________________________
(3.3.1) What is the soil like?____
(3.3.2) Do they employ any specific management techniques for factors?__________
(3.3.3) Do they till the soil and Why?_____________________________________
(3.4.1) How much time do they spend weeding?______________________________
(3.4.2) Who does it?____

4. PARTHENIUM ("Kinche")

4.1 General
(4.1.1) How long have they had it? ____
(4.1.2) Where do they think it came from?___________________________________
(4.1.3) How?_____________________________ (4.1.4) When? ____________________
(4.1.5) How has it affected them?____

4.2 Management practices
(4.2.1) What management practices do they use for parthenium? _________________
(4.2.2) How and who does it? ____
(4.2.3) What benefits and drawbacks do they see with their current management practices of parthenium? ____

4.3 Biology
(4.3.1) Where or by who have they lerned the properties of Parthenium? ___________
(4.3.2) Where does it grow (transect walk?)? ________________________________
(4.3.3) When is it most abundant?____
(4.3.4) How does it spread? ____
(4.3.5) Which animals interact with Parthenium? _____________________________

4.4 Crop interactions
How does it affect the crops? ____

4.5 Health
(4.5.1) Has it affected their health? ____________________________________
(4.5.2)Do they know of anyone else who has been affected? __________________
(4.5.3) Is there any time when it is worse? ________________________________

5. COMPOSTING

(5.1) Do they compost? (If no, why not?) __________________________________

(5.2.1) How do they do it? ____
(5.2.2) How did they learn to compost? ____________________________________
(5.2.3) Do they compost with others? ______________________________________
(5.2.4) What resources do they use for composting? __________________________
(5.2.5) Which resources don't they use? ____________________________________
____
(5.2) Have they composted Parthenium? ____________________________________

Yes - (5.2.2) How does it compost? ____
(5.2.3) Have they seen seeds in the compost? ____________________________
No - (5.2.4) Why don't they compost Parhenium? ____________________________

6. INSTITUTIONS
(6.1) Which institutions do they have contact with? (NGO, Gov't, Agriultural office, Agricultural ext, companies) ____
____
(6.2) What do they provide them with? _____________________________________

(6.3.1) Where or to whom do they sell their produce? ___________________________
(6.3.2) Does parthenium have any effect on where they sell their produce? ___________

7. TRANSECT WALK

(7.1z) Estimate amount of parthenium
(7.1z) Amount of trees and bushes

(7.1) Additional questions..

....

....

....

....

....

Section A: Background

(a1)Woreda: ______________ (a2)Tabia: _________________ (a3)Village (Kushet):______________

(a4) Full name: ______________________ (a5) Sex: M [ ] F [ ] (a6) Age:____

(a7)Farmer income level: [ ] 1.Low [ ] 2.Medium [ ] 3.High (Established by DA)

(a8)How long have they farmed for? ________ (a9)How big is his/her farmland?______ ha

(a10)**Who works on their farm?** **Total # in household: ____________________**

Family: [ ] 1.Head [ ] 2.Spouse [ ] 3.Son/Daughter [ ] 4.Son/Daughter inlaw [ ] 5.Grandchild

[ ] 6.Non-household members (Neighbours) [ ] 7.Hired labour # _______ [ ] 8.Other: ________

(a11) **What is the current marital status of the household?**

1.Never married [ ] 2.Married [ ] 3.Divorced [ ] 4.Widowed [ ]

(a12) **Are you designated a model farmer by local government**? ....1.Yes [ ] ....2.No [ ]

Section B: Climate

(b1) Sources of water in	Dry season	Wet season	Comment(delivery etc.)
1. Rainfed	[ ]	[ ]	______________________
2. Resevoir/Dam	[ ]	[ ]	______________________
3. Pond	[ ]	[ ]	______________________
4. River	[ ]	[ ]	______________________
5. Underground source	[ ]	[ ]	______________________
6. Other:	[ ]	[ ]	______________________

(b2) How many months does it rain? _____

(b3)Which months does it rain? (add + for heavy rains)

J [1] F [2] M [3] A [4] M [5] J [6] J [7] A [8] S [9] O [10] N [11] D [12]

(b4) Has it changed in the last 10 years: 1. No [ ] 2. Yes [ ] (z) How:______________

(b5) Is water shortage a problem? 1. Yes [ ] 2.No [ ]

(b6) Do you conserve water on your lands?

1. No [ ] Yes: 2.Pond [ ] 3.Ditches [ ] 4.Other: ________

(b7)Does parthenium influence how you conserve water? 1.No [ ] 2.Yes [ ] (z)How:__________

____

SECTION C: FARMING SYSTEM

(C1)HOW MUCH LAND DOES THE HOUSEHOLD CULTIVATE? LOCAL UNIT AREA [____] HECTARES [____]

(c1)**Which crops do you grow? (1-**Sorghum, 2-Teff , 3-Maize , 4-Barley,5-Wheat, 6-Millet,7-Chickpea, 8-Fava bean,9-Field pea,10-Lentils, 11-Linseed, 12-Other: please specify**)**

Crop .	yield	ha	Affected by parthenium? How?
…………	………………	………………	……………………………………………………
…………	………………	………………	……………………………………………………
…………	………………	………………	……………………………………………………
…………	………………	………………	……………………………………………………
…………	………………	………………	……………………………………………………
…………	………………	………………	……………………………………………………

(c2)**Which factors influence their crops?** (Weeds, lack of fertility, water short., labour, other:_)

Rank.	Factor	Why + management approach?
…………	……………………………………………………	……………………………………………………
…………	……………………………………………………	……………………………………………………
…………	……………………………………………………	……………………………………………………
…………	……………………………………………………	……………………………………………………
…………	……………………………………………………	……………………………………………………

(c3)What Livestock do they have?		Purpose? *	Affected by Parthenium (How?)
Cow	[ ]	……………………………………………………………	[ ]
Oxen	[ ]	……………………………………………………………	[ ]
Camel	[ ]	……………………………………………………………	[ ]
Donkey	[ ]	……………………………………………………………	[ ]
Goat	[ ]	……………………………………………………………	[ ]
Sheep	[ ]	……………………………………………………………	[ ]
Chicken	[ ]	……………………………………………………………	[ ]

*(1 For sale, 2 draught power, 3 eating, 4 cultivating, 5 transport, 6 Other - specify)

(c4)Are any wild animals or plants affected by Parthenium: [ ] No [ ] Yes

Which?………

(c5)What are their main sources of income?

Rank.	Source	Affected by parthenium? How?
…………	……………………………………………………	……………………………………………………
…………	……………………………………………………	……………………………………………………
…………	……………………………………………………	……………………………………………………
…………	……………………………………………………	……………………………………………………
…………	……………………………………………………	……………………………………………………

(c6)Is the source of income changing? 1.No[ ] 2.Yes [ ] (z)How? ....

SECTION D: COMPOSTING AND SOIL IMPROVEMENT

(d1)Do you till the land? [ ] 1.Yes [ ] 2.No 3.who does?__________________ (d2)#Tillings______

(d3)What SFP† do they use?	Use	Don't use	Why?
1.Fallowing	[ ]	[ ]	....
2.Crop rotation	[ ]	[ ]	....
3.Applications of crop residues	[ ]	[ ]	....
4.Manuring	[ ]	[ ]	....
5.Incorporation of weeds	[ ]	[ ]	....
6.Terraces	[ ]	[ ]	....
7.Tillage practices	[ ]	[ ]	....
8.Other:___________	[ ]	[ ]	....

†Soil fertility practices

(d4)What soil improvement do they use?

1.DAP [ ] 2.Urea [ ] 3.Manure [ ] 4.Compost [ ] 5.None [ ] 6.Other [ ] ....

(IF 1 or 2 in d4)(d5) Where did you get chemical fertilisers last year? 1 [ ] Local government 2 [ ] farmers organisation 3 [ ] NGO 4 [ ] Market 5 [ ] Other: _______

(IF 1 or 2 in d4) (d6) How did you acquire the chemical fertiliser last year?

1. [ ] loan 2. [ ] Purchase w/ own money [ ] 3. Free (from whom) : ....

(IF 3 in d4) (d7) How did you learn to use manure? 1 [ ] Relatives 2. [ ] Neighbours 3. [ ] Government 4. [ ] NGO's 5. Other:_____________ (z) Comments: ....

(d8)How did you get manure last year? 1. [ ] Produced myself 2. [ ] Collected manure around home/village 3. [ ] I bought manure 4. [ ] Given by relatives

(d9)Do you compost, which way? Yes: 1. [ ] Pit 2. [ ] Heap 3. [ ] Other:_______ 4. [ ] No

(d10)If no, why not?... (➔**GOTO SECT V**)

(d11)**What materials do they use**?	Use	Don't use	Why?
1. Fresh matter (leaves, crop res.)	[ ]	[ ]	....
2. Dry matter (straw, sticks etc.)	[ ]	[ ]	....
3. Manure	[ ]	[ ]	....
4. Parthenium	[ ]	[ ]	....
5. Ash	[ ]	[ ]	....
6. Urine	[ ]	[ ]	....
7. Water	[ ]	[ ]	....
8. Other:___________	[ ]	[ ]	....

(d12)**HOW DO THEY PREPARE IT?** ....

(D13) HOW DID YOU LEARN TO MAKE COMPOST?

1. RELATIVES [ ] 2. NEIGHBOURS [ ] 3. THE GOVERNMENT [ ] 4. NGO [ ] 5. OTHER: ....

(d14)**DO YOU FEEL THAT YOU LACK KNOWLEDGE ON COMPOSTING? 1. NO [ ] 2. YES [ ] (Z)WHAT?**

..

SECTION E: PARTHENIUM AND ITS CONTROL

(e1)**Do they know what Parthenium is?** 1. Yes [ ] 2. No [ ] (e2)Names: _____________

(e3)**When did Parthenium first arrive at their area?** _______ (Y)

(e4)**How?** 1. [ ] Transport 2. [ ] Animals 3. [ ] Contaminated seed 4. [ ] Other:______

5. [ ] Don't know

(e5)**Had they heard of it before this time?** 1.Yes [ ] 2.No [ ] Where: ___________________________

(e6)What properties are they aware of?

1. [ ] Alellopathy 2. [ ] Prolific seed production 3. [ ] Easily spreads 4. [ ] Health drawbacks

5. [ ] quick to set seed (2 months) 6. [ ] Other:_______

(e7)**What control measures do you use for Parthenium**: .... 1. [ ]Uprooting 2. [ ] Slashing

3. [ ] Mowing 4. [ ] Grazing 5. [ ] Burning 6.[ ] Ploughing 7.[ ] Chemical 8.[ ] Other:________

(e8)If ploughing, is parthenium removed? 1. [ ] Yes 2. [ ] No

(e9)If chemical, Which type? (1)_________________________ what time of year?: (2) __________________

(e10)Which methods do they observe work the best?____

(e11)Does management of parthenium incurr extra costs?

1. Yes [ ] for: ....(a)[ ] Extra labour   % of income? _________________________

(b)[ ] Extra tim   How much?__________________________

(c)[ ] Other   Comment: ____________________________

2. No [ ]

(e12)Do they feel any responsibility to stop it from spreading to the wild surroundings?

1. Yes [ ] 2. No [ ] (z)Why: ....

(e13)Please rank who bears the largest responsibility to control Parthenium 1 high 5 Low:

(a)Individual [ ]   (b)Village [ ]   (c)Local Government [ ]   (d)Other [ ]: ___________

(e14)What will happen if they don't manage parthenium on their land?

....

(e15)Do they manage parthenium outside their lands? 1. Yes [ ] 2. No [ ]

(z)Why, why not? ....

(e16)Do they know of the law on parthenium control? 1. Yes [ ] 2. No [ ]

(e17)Do they follow the law on parthenium control? 1. Yes [ ] 2. No [ ] 3. Somewhat [ ]

(e18)If no, somewhat, is there anything that prevents them from following it?

....

(e19)What do they think is the best way forward to manage parthenium?

____

(e20)Have you had any ideas on how to manage parthenium? 1. [ ] No 2. [ ] Yes __________

____

(e21)Does it affected their health? 1. No [ ] 2. Yes [ ] (z)How?___________________________

(e22)Does the health effects increase over time? 1. [ ] Yes 2. [ ] No

(e23)Do they use any protection? 1. No [ ] 2. Yes [ ] (z)What? ___________________________

(e24) Is there any time when health effects are worse? 1. No [ ] 2.Yes [ ]

(z)When? ____

SECTION VI

(eI1) Which institutions do they have contact with? (1.NGO, 2.Gov't, 3.Agriultural office, 4.Agricultural ext, 5.companies, 6.local market, 7.Other-please specify)

RANK	INSTITUTION	What do they get/give from them
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

(eI2) Where or to whom do they sell their produce? ___________________________________

(eI3) Does parthenium have any effect on where they sell their produce? __________________

(eI4)Are they considering changing their farming practices due to parthenium or any other factors? ____

(eI5)Who do they trust most for recieving new practices?

Rank.	Source	Why?
....	1.Another farmer	....
....	2.DA	....
....	3.Woreda expert	....
....	4.NGO	....
....	5.Other:	....

Daily clock or year calendar

When is parthenium a problem? When do they do group activities with parthenium?

What are their cropping practices during the year?

What are their conservation practices during the year?

INTERVIEW GUIDE INSTITUTIONS

BACKGROUND

What is the institution mission?

Which other actors/institutions do they interact with?

How do they interact with farmers?

PARTHENIUM

When was Parthenium introduced into the area?

How do they work with Parthenium? Find out what projects are active.

What problems and possibilities do they percieve with Parthenium? ASK IF THEY CAN RANK THEM.

How does it affect the farmers?

What control measures management practices do they see as most effective and feasible? RANKING?

Do they enforce any laws concerning parthenium?

COMPOSTING

Do they think composting of Parthenium is a possibility?

Have they been involved in any such projects?

Do they know of any farmers practicing parthenium composting?

LOCAL KNOWLEDGE

How do they work with farmers and their knowledge?

ECOLOGY

Have they observed changes in the biodivesity or biomes?