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Environmental And Socioeconomic Importance of Cactus (*Opuntia ficus-indica*) Species in Gulomekeda District, Eastern Tigray, Ethiopia

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Environmental and socioeconomic importance of cactus (*Opuntia ficus-indica*) species in Gulomekeda District, Eastern Tigray, Ethiopia

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Abstract

Environmental and socioeconomic importance of cactus (*Opuntia ficus-indica*) species in Gulomekeda District, Eastern Tigray, Ethiopia

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The extent of food insecurity and lack of alternative livelihoods have resulted in large-scale environmental degradation and destruction of vegetation cover in Gulomekeda District in Eastern Tigray. The objectives of this study were to investigate the effect of cactus on species diversity and its socioeconomic contribution to household income. Vegetation data was collected from 60 sample plots of 100 m^2 plots from a cactus-free area and a cactus-dense area. Data on the socioeconomic contributions was collected from a total of 93 sample households using random sampling methods. A questionnaire survey was conducted to generate data on the perceptions of household heads of cactus owners and non-owners. A total of 2315 number of individuals were documented from the study area, out of which 756 were in cactus-occupied sites and 1559 in cactus-free sites. The result showed that regeneration of vegetation, and diversity was higher in cactus-free areas than in cactus-dense areas. Cactus production was the major source of human food, income source; livestock feed, fences, and fuel wood. Cactus owners' household income was higher as compared with those who do not have cactus, indicating the positive impact of cactus on the livelihood of the local communities. Price fluctuation, birds, insects, and diseases, high transport costs, and a lack of a specific market were identified as major problems for cactus production. Although cactus harmed local plant biodiversity, it was important for household income and animal feed. Therefore, there is a need for implementing interventions that would minimize its negative effect and enhance its socioeconomic uses.

Keywords: Beles, Cactus, Environmental importance, Gulomekeda District, O. ficus-indica species,Socioeconomic

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Abbreviations/ Acronyms

BOARD- Bureau of Agriculture and Rural Development

CAM-Crassulacean Acid Metabolism

CPPI- Cactus Production and Processing Initiative

CSA-Central Statistical Agency

DBH- Diameter at Breast Height

DM-Dry Matter

FAO-Food and Agricultural Organization

FGD-Focus Group Discussion

FIA-Foundation for Agrarian Innovation

HCDP-Helvetas Cactus Development Project

IAS-Invasive Alien Species

IVI- Importance Value Index

RD- Relative Dominance

RF- Relative Frequency

SAERT-Sustainable Agriculture and Environment Rehabilitation of Tigray

SPSS-Statistical Package for Social Sciences

UN-DESA-United Nations Department of Economic and Social Affairs

CHAPTER-ONE

1. INTRODUCTION

1.1. Back ground and justification

Climate change has caused frequent droughts and affected vegetation composition in Tigray National Regional State. Because of the high degree of drought and temperature endurance of the cactus pear (*Opuntia ficus-indica*), it has become well-liked and widely used in the area. It has good productivity and can tolerate infertile soil (Aliaga and Chaves-Dos-Santos, 2014). The plant uses water efficiently. *Opuntia* has greater water-use efficiency than C4 or C3 plants due to the CAM photosynthetic pathway. This is the key reason for which Crassulacean Acid Metabolism(CAM) species are the most suited plants for arid and semi-arid habitats.

Cactus (*O. ficus-indica)* invasions were among the first plant invasions to be detected and controlled. With management initiatives beginning in the 1800s, cacti were the first plants targeted for classical biological control (Winston *et al*., 2014). The cactus family (Cactaceae) is among the most widely introduced IAS (Invasive Alien Species) across the world due to its popularity in the horticultural trade (Novoa *et al*., 2015). This is why there is an increasing expansion of cactus pear in East Tigray, particularly in the back yards. Cactus pear has been evaluated as one of the most important species for crop production due to its role in promoting sustainable cultivation systems and landscape conservation, safe guarding both natural and cultural heritage (Chessa, 2010).

O. ficus-indica happens in nations where it has been developed and is obtrusive, including Australia, Eritrea, Ethiopia, South Africa, Hawaii, the USA, and somewhat in Somalia and Yemen (Hill *et al*., 2020), as well as in the tropical backwoods and rangelands of Kenya and Tanzania (Oduor *et al*., 2018). Furthermore, according to the report by Novoa *et al*. (2015), *O. ficus-indica* is the most common invasive cactus found outside of its native range in 22 nations. Fairly similar to the case in South Africa until late years, yet contingent likewise upon region and situation, the desert flora pear in Ethiopia is seen as both a gift and a revile. However, in Tigray, it is even more important than in South Africa to keep people and livestock alive during times of famine (Brutsch, 1997). The fate of bone-dry and semi-parched districts of the world to a great extent relies upon the supportable improvement of horticultural frameworks in light of the utilization of reasonable harvests for these areas. In order to supply poor farmers and herders with food and forage, suitable crops are those that can successfully adapt to climatic variability, such as a lack of water, high temperatures, poor soil, and simple management. According to FAO (2013), cacti can satisfy most of the aforementioned requirements. Cactus pear cultivation is primarily found on marginal lands in Tigray. It has flourished to become the most widely cultivated and naturalized plant in Ethiopia, particularly in the Tigray region, thanks to ideal edaphic and climatic conditions. Due to the continuous pressure of the invasion by cactus pear on the species composition and dry climates, further homogenization in the native species diversity is to be expected in the future for the highlands of Eritrea. Currently, cactus pear is playing a crucial economic role: it serves as a source of food, animal feed, and fuel wood; in some cases, it is a means of additional income, thereby increasing the efficiency and economic viability of small and low-income farmers (Brutsch, 1997). More recently, there has been interest in boosting the productivity of cactus-growing areas to provide higher-quality cladodes and fruit, and additional commercial areas could be planted (FAO, 2013).

More than 200 cactus species have been transplanted outside of their natural ranges for use as food, medicine, animal feed, and ornamentation (Novoa *et al*., 2016). Barbera *et al*. (1995) claim that the facility provides fresh and processed fruit and vegetables, as well as animal feed, for human use. The cactus pear is used to make a variety of traditional cuisines, including liquors, dried fruit, juice concentrates, syrups, and fruit-based goods including jams, juices, and nectars. Cladodes may be used to make pickles, juices, jams, and a variety of other minimally processed goods (FAO, 2013). Cacti are becoming more significant over time. According to previous study findings, the cactus pear has been assimilated into Tigrian culture and economy, providing seasonal family food income and employment, animal feed, and other environmental advantages (Fitsum, 1997; Mitiku, 2010). "Green gold", "fruit for the poor", "treasure under its spines", "world vegetable dromedary", "future plant", "sacred plant," and "monster tree" are just some of the epithets used for the plant and the fruit (Arias Jimenez, 2013a).

BELES, a kind of cactus pear, are grown in the Ethiopian province of Tigray, near the Eritrean border. Traditional melodies and proverbs highlight the crop's significant economic and cultural significance, such as "Oh, my **Beles**, you spare me this summer until barley has cheerfully come to rescue me." In Tigray, notably in the Hagere-Selam kebelle (Gulomekeda District) area, the sale of cactus fruit is seasonal and lasts for around three to four months out of the year. The connection between farmers and outside markets may help boost the fruit's economic yield during the growing season. As a result, growing cactus, or "**Beles**," as it is known locally, may allow farmers to capitalize on their distinct selling point in order to raise revenues and enhance quality of life. However, earlier research done in the area was primairly concerned with the crop's agronomic characteristics (Meaza *et al*., 2010). Animals and humans who inhabit these areas seek out plant species that can adapt, develop, and supply food and materials year-round (FAO, 2013).

Data on the level of cactus pear production, contribution to household income, and environmental importance in the region are limited, particularly in the study area. On the other hand, previous studies reported that there was no difference between cactus-invaded and un-invaded plots in terms of both species' richness and Shannon diversity index (Tesfay and Kreyling, 2021). However, based on some observations, there is a need to further investigate the impact of cactus on species diversity.

Therefore, this study aimed to fill these gaps with the overall objective of investigating the environmental and socioeconomic importance of cactus species and the effects of cactus on species diversity.

1.2. Statement of the problem

The amount of food insecurity in Hagere-Selam, which is mostly brought on by drought, over-cultivation, and deforestation, has led to widespread environmental degradation and the loss of plant cover, and the lack of access to and availability of food has become extremely frightening. The majority of those who are considered to be chronically food insecure have been enrolled in daily relief food programs year after year, even in years when weather and market circumstances seem to be good. This chronic status is usually exacerbated by unanticipated shocks. The study region is a significant example of a drought-prone environment with low and irregular rainfall and poor natural resource endowments. Hagere-Selam residents moved to regions with reliable food supplies. Working with cacti was suggested as the most practical way to address food security right now, particularly in regions that are prone to drought (Nafzaoui and Bensalem, 2001). In drought-prone areas, it is preferred over maize or dry beans while supplementing producers' revenue in marginally better locations (Jose *et al*., 2017).

To provide fruit for human consumption and animal feed, cactus was transplanted from the Irob District to the research region Bureau of Agriculture and Rural Development (BOARD, 2012). The *O. ficus-indica*, which thrives in dry and semi-arid climates, is known as the camel of the plant kingdom (Tadesse, 2010). The progress of society has been greatly benefited by the introduction of species to new habitats. The introduction of several crops outside of their natural areas has increased human welfare (Yibekal, 2012). According to Bureau of Agriculture and Rural Development BOARD (2012), the plant covers a large area in the district, covering naturally sloppy, hilly sites. Cactus was dominating and native species, but information on the extent of replacement was lacking. Only limited attempts were observed in planted cactus, in collective action during soil and water conservation activities on communal lands, and a few households. The household income was also low, and it was not enough to supplement the household income. Beyond this fact, there were no attempts to identify and quantify the environmental and socioeconomic important of the plant in the study area. It was necessary to study the contribution of household income and the effect of cacti on species diversity.

1.3. Objectives

1.3.1. General objective

The general objective of the study was to investigate the environmental and socioeconomic importance of cactus species in the Hagere-Selam kebelle (Gulomekeda District), Eastern Tigray, Ethiopia.

1.3.2. Specific objectives

The specific objectives of the study are:

- To explore the environmental influence of cactus plants with focus on species diversity
- To assess the effect of cactus pear as income source
- To evaluate the benefit of cactus cladode for animal feed

1.4. Research Question

The study has set the following research questions depending on the objectives of the study.

1. Does cactus have an impact on species diversity?
2. Does cactus improve household income?
3. Does cactus have any benefit as animal fodder?

1.5. Research hypothesis

1. Ho: The species diversities in cactus-free areas is not statistically different compared with cactus occupied areas.

2. Ho: the total income for households with more cactus plants is not statistically higher than the total income of households without cactus plants.

1.6. Significance of the study

The environmental and socioeconomic important of cactus was identified, and hence, a possible management option that would enhance the popularization and acceptance of the plant was recommended to the local people and policymakers as well. On top of this, the awareness level of the community about all aspects of the plant would be raised.

1.7. Scope of the study

The study is confined to investigating the environmental and socioeconomic importance of cactus production in Hagere-Selam because of the limited time and budget. Besides, being an empirical study, it helped to add to the knowledge base in the literature that uses a combination of both quantitative and qualitative approaches in assessing the impact of cactus on species diversity and household income. The effect of cactus plants and constraints on household income and species diversity has been determined. Therefore, the outcome of this study may serve as a source of additional information that may be of significant use to policymakers and planners when designing appropriate policies and strategies.

CHAPTER-TWO

2. REVIEW LITERATURE

2.1. CACTUS PEAR (*OPUNTIA FICUS-INDICA*); BIOLOGICAL CHARACTERISTICS AND GLOBAL DISTRIBUTIONS

Opuntia belongs to the genus of plants known as cactus (plural: cacti). The largest genus in the Cactaceae family, it has a wide geographic distribution and more than 360 species. There are many different sizes, forms, and developmental patterns for cactus plants. According to Novoa *et al*. (2015), they often have spine clusters that arise from areoles, which are deformed axillary buds. *O.ficus-indica* is found in countries where it is invasive and has been domesticated, including South Africa, Hawaii, the USA, Australia, Eritrea, Ethiopia, and, to a lesser degree, Somalia and Yemen (Hill *et al*., 2020). It is also found in tropical forests and rangelands in Kenya and Tanzania (Oduor *et al*., 2018).

Flattened stems, nopales or cladodes, and edible fruit are characteristics of cactus plants. Glochids and simple leaves on newly formed nopales are also present, and the seeds have a pale covering. Cacti have an extremely complicated root system because they have many different kinds of roots, such as tap roots, main roots, absorption roots, root spurs, and roots made of areoles, which grow as the plant needs them for survival and growth. Its fleshy, shallow tap root system extends horizontally around 30 centimeters into the deep earth. Sessile, actinomorphic, hermaphrodite, and solitary, the flowers often form on the cladode's upper margin. Large flowers resemble spines, and areoles give rise to branches. The fruit is an oval, elongated, fleshy berry with a regular number of hard seeds. It is known as tuna and varies in size, shape, and color. The fruits come in a variety of hues, including orange, yellow, green, purple, and red. Cladodes have two distinct kinds of spines, referred to as glochids, which can readily separate from the plant and pierce the skin. Numerous substances found in cactus nopal pulp, including as phenolic compounds, vitamin C, and dietary fiber, have the potential to offer significant advantages for hepatic, intestinal, and cardiovascular health as well as antioxidant activity and cancer prevention. According to Saroj *et al*. (2017), the young, fresh pads, also known as nopal, are a great source of vitamins and vital amino acids, among other proteins. Nowadays, worldwide, the most commercially used *O. ficus-indica* is for its large, colored, and sweet fruits. The fruits are of different colors, such as red, purple, orange, yellow, and green, which show the presence of various antioxidants. The high sugar and low acid blend of the fruit makes it delicious and palatable (Saroj *et al*., 2017).

Ethiopia's macro- and microclimates are very diverse. Its biodiversity is, however, at risk from invading species, habitat conversion, unsustainable resource use, pollution and climate change, population growth, poverty, lack of knowledge and coordination, and replacement of native breeds and variants. Cactus pears originated in Mexico and are now found throughout semi-arid and dry areas of the world, including Australia, Africa, the United States, the Mediterranean region, and Southeast Asia. Because of its broad adaptability, this species is considered a highly valuable resource for a variety of ecological zones (FAO, 2013). The *O. ficus-indica*, however, has an impact on species composition, and certain species are negatively impacted by its presence (Tesfay, and Kreyling, J., 2021). It has a minor impact on species diversity and richness.

2.2. Concept of Cactus Production

Its genetic diversity hub appears to be in Mexico, where the genus *Opuntia* is widely used as fruit, fodder, forage, and a green vegetable. *Opuntia* sp. are both beneficial weeds and feed plants (Russell and Felker, 1987). The genus has also spread over the globe, becoming established in Australia, Europe, and several African countries (Novoa *et al*., 2015). *O. ficus-indica* is a type of cactus that belongs to the Cactaceae family. It is sometimes referred to locally as "**Beles**." According to Tesfay (2010), the cactus pear and other plants in the same family were introduced from the New World when they were found in Africa and other parts of the world outside of Latin America. It was even considered the fruit of the dark days, as it matures during the times of the year when the stored cereals are almost exhausted. Cactus pear is also a livestock feed; prolonged drought, overgrazing, desertification of rangelands, and poor crop residue have forced animals to graze on cactus pear directly from the 1960s on (Zamra, 2001).

BELES has become the major income and food source, and it is very much part of the culture and livelihood of the people despite its limited uses. Today, it is fully integrated into the landscape of the highlands. Cactus pear has become dominant in many areas. Despite being an alien plant that can spread aggressively without the presence of any natural enemies, it is now accepted as an integral part of people’s environment and food security. The Tigray region of eastern Africa merits attention, as it has the biggest area of "naturalized" cactus pear in Africa and spans portions of both Ethiopia and Eritrea. It was introduced in the nineteenth century; Mondragon Jacobo and Tegegne (2006) report on efforts to describe the local diversity.

It is the easiest to find fresh fruit throughout the summer and gives both urban and rural households essential minerals and vitamins. Since it is taken from natural sources, all populations may pay the prices at which it is sold. Children sell the fruit to raise money for school expenses because the harvest season falls during the summer break. Large amounts of fruit are produced and consumed in their fresh state, but the excess is lost because people are unaware of how to fully utilize and prepare it. In recent years, there has been a notable surge in commercial interest in cacti. The country faced problems due to inadequate processing technologies, production techniques, and variety selection. The lack of management also led to a negative response because the crop would jeopardize some of the native plant genetic resources. Due to "**Beles**" primitive culture, a lack of local experience with full use, careful species selection, and appropriate farm management as stated in cropping systems, the government requested technical help from FAO to boost cactus output and utilization (Mafa, 2010).

With about 70,000 hectares, Mexico is currently the world's largest producer of cactus pears, according to the Foundation for Agrarian Innovation (FIA, 2010). Around the world, cactus pears are grown in many countries. In Mexico, it generates income and jobs in areas where few other crops can be cultivated, despite being a marginal commodity in the fruit market (Timpanaro *et al*., 2015b). Because the crop is often farmed by small and micro-farmers in areas with a high degree of "rurality," it is strategically attractive and should be carefully considered when formulating public policy.

The "Mum for Moms" recognized the potential offered by the development of cactus as a food crop and immediately internalized it into their activities. They started to promote it vigorously given that, because of its adaptability to low rainfall and poor soils, it does not enter into competition with grain production as it thrives in areas that would not normally be used for grain production. The moment the cactus was accepted as a food crop, it offered vulnerable populations an additional coping mechanism by stabilizing household food security and there by assisting them in absorbing the consequences of the cyclical shocks they face, which are all too common in Ethiopia (Mafa, 2010).

Utilizing the aerial components as feed creates a direct relationship with other agricultural value chains, including those for the production of milk, milk derivatives, meat, and hide. Because **Beles** may be grown on terrain with minimal potential for other crops to produce, none of these options compete with the existing crops for space or water (Mafa, 2010).

According to its botanical definition, *O.ficus-indica* is a domesticated cactus crop that is important to agricultural economics in arid and semiarid regions of the world. The biogeography and evolutionary origins of this plant have been obscured by long-standing, wide spread cultivation and naturalization (Griffith, 2004). The Cladodes fruit peel, or skin, is a botanical part of the plant that is consumed by animals. The spineless and spiny cladodes are eaten by livestock and other creatures. Most farmers mainly cultivate spineless cactus in their backyard and farmstead to rigorously control animal access and shield the plant from damage (Gebremeskel *et al*., 2013).

Spine cactus pads are a great source of feed, provided that the spines are removed beforehand, usually by the use of a propane weed burner (Shoop *et al*., 1977). Griffith (1905) discussed more steps. Chopping up the massive pads resulted in a significant increase in the quantity of cactus the animals ate. The spines were moistened using steaming. Claiming the same source, tools and equipment have been developed for these purposes. In North Africa, individual pads are burned and chopped into small pieces using hand tools or the appropriate cutting gear, however in some countries (the USA and Mexico) the entire standing plant is destroyed before grazing (Pérez-González, 2001).

One major barrier to the widespread use of *Opuntia* is the presence of spines on the pads. Since smooth-paddled plants do not thrive the naturally, it is believed that plants with spineless pads originated from human domestication. More aggressive and better suited for spreading are plants with spines. Grazing is the simplest and least expensive technique to use spineless cactus since it takes the least amount of labor. However, excessive grazing needs to be avoided, especially on young plants that sheep can easily damage. Overgrazing can seriously harm even older plants, and the resulting diminished yield will be felt for some time. The best method of grazing is to divide the plantation into small pad docks and graze each of them intensively for a short time (Pérez-González, 2001).

The availability of the grass layer between the cattle and the shrubs, along with its incredibly low cost, are the advantages of this management approach. a system that gains these two advantages and becomes more economically efficient. Spineless cacti are best used rotationally, with a new plantation being used every three to five years. In this way, a plantation can be cut or grazed periodically, rising one pad above the initial planting each time. This method of using spineless cacti results in rapid plant recovery, high-quality material being available, and plants being maintained at the proper height (Pérez-González, 2001).

A common plant on small homesteads is the cactus. Despite this, there have only been a few attempts to grow cactus in "communal" areas because of the contextual challenges associated with creating a supportive legislative and regulatory framework related to the use of marginal hillside lands. Because of this, the plant's commercial production was not possible because of the legal and regulatory support that was lacking, as well as the slopes that were easily accessible. Since the crop has been effectively promoted in recent years, the general public is fully aware of its potential. However, because of a lack of specialized knowledge, specialized regulatory and extension assistance, and deeply ingrained traditional and cultural impacts, the crop as well as the natural potential (hillsides) still go largely untapped (Tesfay, 2010a).

Many people consider cacti to be poor in nutrients (Curek, 2001). These days, animal forage experts have appreciated the multiple uses of cactus and started to develop an interest in this plant as a suitable fodder. The plant is now coming to backyards as a feed security resource. A large number of people are convinced of the use of cactus as dry-period animal feed, with some reservations about its nutritional quality. Cactus is an alternative feed supplied to animals during times of drought and is supplied to cattle in different forms. Farmers have utilized both thorny and spineless cactus as forage. Spineless cactus in the region is considered strategic fodder and encouraged by government policy to be planted with caution. Spiny cactus is, however, used for live fencing and biological conservation purposes in the region. Thorny cactus, on the other hand, is not recommended for feeding as it causes physical and mechanical damage (Tadesse, 2010).

Cactus is thought to have been introduced 160 years ago by Catholic missionaries through Irob District (Alitena town) (Fisseha, 2010). Since its introduction until the establishment of CPPI (Cactus Production and Processing Initiative), the attention given to the crop has been very low. It was the farmers who practiced a lot in the expansion of cactus to many parts of the region. The importance of cactus was limited only to life fencing and the fruits as poor men's foods during the rainy seasons. However, with time, when environmental degradation got worse, farmers started to use cladodes as food (mainly during the dry season) (Fisseha, 2010).

The region has recently received a lot of training and promotion work, especially following the intervention of the Bureau of Agriculture and Rural Development (BOARD) in partnership with other CPPI members. The Bureau of Agriculture and Rural Development has attempted to deliver millions of planting supplies to non-cactus-growing areas during the previous twelve years (2007–2008). Over 1,425,426 cladodes were delivered and planted on around 1419 hectares in 2007 and 2008. Nearly 9723 families were anticipated to get anything from this. More than 18 million cladodes were planted in several watersheds in 2009, mostly for soil protection. In 2008, 300 family-headed families, 150 primary school students, 1090 unemployed youths, 79 District experts, 243 development agents, and BOARD instructed them all in the preparation of cactus-based cuisine. A cactus variety collecting facility was also built in Agulae, about 30 km north of Mekelle, by BOARD and FAO. Around 42 different varieties of cactus cultivars have thus far been gathered at the collection facility. Additionally, 118 farmers and District specialists received training on the current management of cactus orchards. However, cactus promotion efforts are still insufficient in comparison to their potential and economic significance for the area (Fisseha, 2010).

The majority of cactus plantations in the region are discovered to be grown extremely thickly, exceeding height, in very steep places where there are not adequate walkways. Cactus fruit production was done traditionally in Tigray, and this resulted in a lack of skill in modern cactus orchard management procedures. Due to the previously noted farm issues, there is very little use of the potential resource; fruit harvest is projected to make up no more than 28% of the total. In other words, from 30,520 acres, only an estimated 128,660 tons could be collected (SAERT, 1994). In the fields, most of the produce is wasted. Because there is inadequate trimming and harvesting equipment to minimize losses, this also affects the quality of the harvest. In order to address these issues, 15 model cactus orchard sites were constructed in seven priority locations by the Bureau of Agriculture and Rural Development in partnership with the Helvetas Cactus Development Project (HCDP). Furthermore, BOARD and FAO introduced and provided roughly 2500 cactus fruit-gathering instruments to model farmers in the region's eastern and southern zones (Fisseha, 2010).

Cactus offers farmers in Tigray four main benefits: a supply of food for people and animals, a source of animal feed, a source of household energy, and a source of revenue from the sale of the fruit and its cladodes. Apart from the above-mentioned benefits, farmers can benefit from cacti by using them as a source of nectar for bees, fence material, and biological preservation. It is cultivated on terraces, bunds, and farms. Farmers can profit from cactus by selling their fruits and renting out their cactus gardens to short-term tenants, who mostly use the plant parts as animal fodder. People consume its fruits directly, primarily during June and September, and they frequently do so in place of other dietary staples. It offers a constant supply of feed for cattle and is accessible year-round. It is fully dependent on the majority of cattle and other animals in the area when there are feed shortages, which last at least five months of the year. As drought and land degradation persist in the area and elsewhere, there is a rising demand for cactus. Cactus are typically grown on rocky homesteads and muddy fields that can't support other types of agriculture (Tesfay, 2010).

2.3. Importance of cactus

Various studies show that cactus has economic and non-economic importance. For this study, economic importance, reducing desertification, and animal feed were briefly discussed.

2.3.1. Economic importance of cactus

Cactus (*Opuntia* sp.) has a substantial commercial significance in Kenya since it was introduced to the nation in the 1940s and 1950s and is currently employed for this purpose. The plant commonly used as a protective barrier for homesteads and agricultural fields is referred to as a cactus fence. This is especially true in places where there aren't enough natural or financial resources to construct a fence that will last. This is often found in warm, arid locations such as the Masai Mara in Kenya (Dena, 2009).

It is a grim estimate that the world's population will exceed 9 billion people by 2050 at the current birth rate. Among the world's fastest-growing populations are those of arid and semi-arid regions. In addition to being among the driest regions on Earth, these areas will have twice as little water by 2050 (UN-DESA, 2015). Climate change will change the amount of semi-arid terrain. Population growth is fastest in places where food production is most difficult. Therefore, whether or not their countries are now being impacted by climate change, governments need to be alert to its effects quickly and persistently.

Pastoralists also sun-dry the fruits and store them for several months. During the long dry season, the fleshy leaves in the Baringo District are cut, partially burned to eliminate thorns, and then fed to animals. As a drought adaptation strategy, more attention should be paid to the one remaining means of lowering hunger, even though it requires a great degree of expertise and caution to avoid getting pricked by its thorns. In addition to investigating any possible medical uses for this extremely useful and common plant, the Kenyan government and other research organizations ought to train the country's citizens on how to handle, gather, prepare, and cook the fruits and leaves (Dena, 2009).

Businesses involved in processing and distribution have been greatly impacted by the rising demand for fresh-cut cactus pears. In order to meet customer demands and logistics requirements, creative packing techniques and heightened attention to hygiene standards have been implemented (Timpanaro *et al*., 2015a).

Depending on the species, where, when, and how it is grown, as well as the intended audience, there is debate about whether a particular plant is beneficial or detrimental. Contradictory conclusions that hold in certain situations but not in others are derived from experiences in various ecological, economic, and social contexts. Various circumstances change based on the reality of the individual. Biological control, for instance, was utilized in South Africa and Australia to halt its spread and even eradicate it in some locations. However, after being introduced more than 150 years ago, nopal efficiently conquered thousands of hectares in Ethiopia and Eritrea, where the climate is favorable and there are no natural enemies. Whether the introduction of nopal was a good thing or a bad thing, the fact is that after all these years, people are economically dependent on cactus products and food, even though it may affect native plant genetic resources. Its potential for adaptation and rapid development in wilderness areas or in areas already impacted by human activity is another matter that requires further research. Dubbed "a crop that saves the lives of humans and animals" (Arias Jimenez, 2013b), the cactus pear is more than just a useful crop it is a vital one.

There are numerous reasons behind the diffusion of *Opuntia* sp. around the world, particularly of *O. ficus-indica*, including:

- ✓ Simple cultivation practices are required to grow the crop.
- ✓ rapid establishment soon after introduction in a new area;
- ✓ easy multiplication practices that favor rapid diffusion and exchange of material among users;
- ✓ ability to grow in very harsh conditions characterized by high temperatures, a lack of water, and poor soil;
- ✓ generation of income from the sale of much-valued and appreciated fruits;
- ✓ use of stems in the human diet and as forage for livestock;
- ✓ useful deployment of plants for fencing farms;
- ✓ nutritional value of juicy fruits;
- ✓ long shelf-life of fruit; and
- ✓ Production of a wide range of industrial derivatives from fruit

These and other factors have contributed to such a wide distribution, from the regions of origin in Latin America to remote areas, spanning continents, cultures, and traditions.

2.3.2. Use of cactus against desertification

Opuntia species can withstand extreme heat, long droughts, and erosion from wind and water. Due to their versatility and wide range of economic uses, they are the ideal option for agricultural expansion in areas affected by desertification and climate change, the two biggest environmental issues facing the planet today (Nefzaoui and El Mourid, 2008). Arid and semi-arid regions are delicate ecosystems with little to no plant cover and substantial soil erosion following rainy events. Nonetheless, native vegetation plays a critical role in controlling surface hydrological processes even in these circumstances (Vasquez Mendez *et al*., 2011). Land degradation occurs on all continents and affects the livelihoods of millions of people, including a large proportion of the poor in the dry lands (Nefzaoui *et al*., 2014).

You can stop desertification by using cactus. In North Africa, marginal lands are fragile ecosystems that suffer extensive degradation and loss of vegetative cover due to agriculture and irresponsible vegetation clearance. The depth of genetic and ecological losses is highlighted by the numerous plant species that have become rare or extinct. To stop desertification and restore vegetation cover in those areas, the appropriate integrated packages are used for rangeland monitoring, livestock conservation, and natural resource conservation. In Algeria and Tunisia, spineless *O. ficus-indica* is used to slow and guide sand movement, enhance the regeneration of the vegetative cover, and avoid erosion of the terraces built to limit runoff (Pérez-González, 2001).

In this method, cactus can operate as a windbreak, increasing the yields of cereals and grass. During the summer, animals can graze on the wide alleys' biomass strata or cereal stubble; low-quality stubble can be supplemented with chopped cactus pads for added energy (Nefzaoui *et al*., 2012).

Concern over Tigray's environmental condition is growing. Its current decrease is primarily due to human activities, especially those that include land degradation brought on by the careless use of natural resources. This is undoubtedly related to the historical pattern of land colonization that produced the high population density. The landform is frequently broken and uneven, and the soils are shallow, stony, and rocky (SAERT, 1994). We refer to these as marginal lands. Many of the hills are steep, which promotes drainage.

Owing to their easy vegetative propagation establishment, cactus is good for rehabilitating fields that were too steep, too stony, or too rock-like to be reclaimed using traditional agricultural methods. Only few plant species can boost land productivity, especially when it comes to marginal soils (Le Houerou, 1996). *Opuntia* can tolerate drought in open spaces by increasing and moving chloroplasts and avoiding drastic decreases in their osmotic potential (Delgado Sanchez *et al.*, 2013).

Large, steep, hilly areas in Eastern Tigray have been covered with natural cacti to prevent erosion and extreme runoff. Some of the spots are currently used for commercial forest plantings after the cactus were removed. Cacti convert marginal soils into more productive land, as evidenced by the successful growth of eucalyptus seedlings in cactus plantations. Furthermore, Mitiku *et al*. (2010) pointed out that cacti grown in stony areas produce more sugar and more socially acceptable fruits than those grown in deep, rich, and productive soils.

2.3.3. Animal feed

Opuntia sp. are widely available, inexpensive to cultivate, tasty, and drought-tolerant when used as animal feed (Shoop *et al*., 1977). Because of these qualities, they have the potential to be a significant feed supplement for cattle, especially in dry spells and low-feed seasons. The bulk of *Opuntia's* biomass is made up of cladodes, which can be stored as silage for future feeding or given to animals as fresh fodder (Castra *et al*., 1977).

In dryland rural villages, raising cattle remains the main source of income. It is a symbol of success and an essential component of strong manufacturing systems. Meal limitations and climate change are only two of the many challenges the sector faces. For livestock production systems, rangelands in semi-arid regions are essential, despite their decreasing contribution to animal nutrition. Dubeux *et al*. (2017) state that because rangelands often provide low amounts of edible biomass (1 tonne DM ha1 year1) and have low productivity (5 tons dry matter [DM] ha1 year1), they typically have limited carrying capacity (12–15 ha to maintain an adult cow).

Modified perennial plants can help improve the amount of fodder available in arid areas. The global cow population has been steadily increasing in recent decades, which usually results in rangelands degrading. Water scarcity is a major barrier in drylands that threatens the viability of livestock-based systems (Jose *et al*., 2017). Global projections indicate that within the next several decades, there will be less water available for agriculture and livestock production due to rising water demand. According to this scenario, cacti would rank among the most well-known crops of the $21st$ century. A cost-effective choice for watering animals is the cactus, a succulent and drought-tolerant plant that can generate > 20 tons of dry matter (DM) per year and 180 tons of water stored in its cladodes annually (Dubeux *et al*., 2013). At such levels of productivity, it is possible to produce sufficient forage to sustain five adult cows per year at least a 60-fold increase over rangeland productivity. With small, intensively cropped cactus orchards, it is possible to produce feed and reduce the pressure on overstocked rangelands. There are reports of the successful use of cactus as a feed source in countries ranging from Brazil and Mexico to South Africa and Tunisia, usually supported by strong research and extension programs (Jose *et al*., 2017*).*

The main feeds for cattle in Ethiopia are crop waste and low-quality rangeland grasses, which are either grazed or manually harvested during the dry season at over-mature stages. Crop waste is typically only accessible to a select few species. The feed crisis is especially severe in the country's semi-arid and dry regions, where moderate to severe droughts occur frequently and rainfall is erratic and unpredictable. These areas get erratic rainfall, which affects crop productivity and, consequently, the amount of crop waste the primary supply of feed for cattlethat is produced. Additionally harmed is the growth of grasses and other forages.

Cactus has been more and more significant in animal nutrition since the 1960s when they were the main source of standing feed that helped animals survive critical times of prolonged drought and the dry season (Mitiku *et al*., 2010).

2.4. Adverse impact of cactus

Opuntia cactus species can impact society, the environment, and the economy. *Opuntia* cactus hurt pastoral enterprises because they harm animals and make it more difficult to muster in afflicted areas. Dense colonies of *Opuntia* cacti can completely destroy grazing land. *Opuntia* cactus can also stain wool and cause skin irritation. In infestations, foxes and rabbits can find refuge in addition to fruit flies and other pests. This, aside from pastoral grazing, may be harmful to other sectors and production systems. *Opuntia* cacti can reduce biodiversity and the health of endemic species through competition, including in areas that support endangered species such as the yellow-footed rock wallaby. Infestations of *Opuntia* cacti also significantly degrade the aesthetic values of landscapes, affecting tourism use and values, especially in high-visitation outback areas. The plants can also cause injury to people, especially shearers handling stock, from the sharp spines and barbed bristles (Adrian, 2009).

The majority of wild fruits are dangerous and can occasionally cause fatal health problems, according to reports (Simitu *et al*. 2009). The largest obstacle to utilizing this species is cultural factors that make dietary changes challenging. Children eat most of these fruits, however adults prefer some varieties and discourage planting local fruit trees. These are only consumed during starvation and shortages of food. This has been connected to eating a lot of native fruit trees in arid areas (Simitu *et al*., 2009). (Kuria and Kedera, 2005)This species has sharp spines and is toxic. These spines hurt the skin and become invisible, making them difficult to remove from the fruit and causing pain and irritation. The species, which is categorized as invasive because of its disagreeable thorns, is commonly observed growing by itself in the wild, interfering with and competing with native plant populations (Githae and Nyangito, 2010).

2.5. Empirical Studies

2.5.1. Cactus was utilized for different purposes

feed for animals, edible fruit, a living fence to keep agricultural plots safe, and conservation of water and soil. Notwithstanding their great nutritional content, cactus fruits can cause constipation and glochid issues. Additionally, some believe the fruit could worsen malaria. This may occur because the pads have the potential to retain water for an extended period, which both promotes and fosters the breeding of malaria. Additionally, they might eat the fruits if they fall and get rotten. There have also been certain detrimental health implications from the widespread use of cacti as animal feed. These could be anything from physical harm from the thorns, including blindness, to death from feeding roasted cladodes at high temperatures. Such negative health effects are also manifested by delays in reproduction and death through worms associated with tender pads. Bloating is a form of indigenous disease marked by an excessive accumulation of gas in the rumen. Immediately after cattle consume feed, the digestive processes create gases in the rumen. Most of the gases are eliminated by eructation or belching (Habtu *et al.*, 2010).

Multipurpose indigenous plants like cactus pear (*Opuntia* sp.) may be included in the list of choice crops due to their drought tolerance and variety of potential uses as fruit, forage, or vegetable crops; they can also be used as living fences to protect family households in dry regions or to control erosion. (Mondragon Jacobo and Chessa, 2013).

Furthermore, for customers to get the most benefit from eating fruits and cladodes, several bioactive components must be preserved throughout processing. Cactus pears are versatile fruits that can be utilized for a wide range of purposes and byproducts. The cladodes are likewise covered by this. According to Rodrigues *et al*. (2016), there are various methods for preparing cladodes and fruits.

2.5.2. Economic importance of cactus pear production

According to data published by the Central Statistics Institute, Sicily accounts for the majority of the areas dedicated to cactus pear cultivation and the associated production that is obtained. It has been feasible to assess and understand the variations in the cultivation degree of civilianization, registered evolutions, and diffusion of the cactus presence in the nine regional provinces of Sicily. The surface area of the island devoted to intensive cactus pear cultivation has grown significantly even in the past few years, measuring approximately 3000 hectares as of December 31, 1998; traditional cultivation, on the other hand, has decreased, falling from 25000 hectares to 20000 hectares between 1989 and 1998a decrease of more than 20 percent. The three main production zonesthe San Cono Hills, the southwest Etna area, and the Belice Valleyaccount for the majority of the areas under intensive cultivation (about 80%), and all three have seen an increase in specialized facilities. On the one hand, this confirms the growing interest shown towards this Cactaceae, but on the other hand, if recent trends continue in future years, operators in this sector and public policy would necessarily have to face the problem of the so-called "locationality" of the cultivated areas and of the demand for capacity to absorb the ever-growing quantities produced (Basile, 2001).

Over five-year, Sicily's harvested output was found to have steadily increased, with corresponding average quantities growing from 35,000 tons in 1975–1978 to 55,000 tons in 1991–1994 and 63,000 tons in 1997–1999, respectively. Should this growing trend persist, by 2002 they will be producing more than 65,000 tons, mostly focused on the three sites this study looked at. Compared to the traditional large-scale method, cactus pear farming is intense, specialized, and modern andis becoming more and more popular. Particularly distinguishing characteristics of the former are the use of technical labor schemes, organizational strategies, and business management procedures that are similar to those employed in other fruit tree cultivations. The economic performance is outstanding and supports the recent area expansion, notwithstanding a slight reduction in real profitability over the past few years (Basile, 2001).

Regarding the plantation structure, a few characteristics set apart the three zones in the survey. The enterprises' modest economic dimensions (especially in the Belice Valley zone), the varying degrees to which businesses are cultivated, the various approaches to planting cactus pears and running the businesses, etc. When it comes to this final point, there are sometimes noticeable differences. For instance, the dry type of cultivation is more prevalent in the Belice Valley; the level of mechanization of the growing operations in relation to the length and regularity of the plant layout, with the southwest Etna zone in the worst condition; the use and methods of performing some "typical" operations (such as pruning, "Scozzolatura," and thinning out of the fruit), which are mostly present and more meticulously carried out in the San Cono Hills zone; the fertilization programs, regarding which it will soon be necessary to assess the effects of the recent agro-environmental measures outlined by EU regulation 2078/92 and later ones (Barbera, *et.al,* 1995).

It is clear that variations in cultivation methods have an impact on the expenses and income generated by a cactus pear plot, in addition to the associated earnings. Based on territorial surveys, it was found that "yellow" cultivars outnumbered "red" and "white" ones, and that "bastardoni" fruit production was greater than that of "August" varieties. Furthermore, there are noticeably fewer commercial structures and comparatively few associative market firms. Nonetheless, de-prickling techniques are being refined, and commercial operators are receiving the required equipment, especially in the area of the Etna (province of Catania) and the San Cono Hills. Ex-farm "astrasatto", ex-farm by weight, and ex-market sales are the three different categories of sales. The most common form is still the first, which suggests that the customer is paying for the product's harvest (Barbera *et al*., 1995).

Within the technical-economic analysis of the cactus pear industry (Basile, 1996), conspicuous degrees of activity emerge, which can be linked to the fact that many of the operations involved must necessarily be carried out by hand as they cannot be mechanized. The labor costs, which do not include harvesting and the successive operations (as much as the product degree of technical-economic preparation in which the agricultural phase finishes normally refers to the fruit hanging on the plant), are on average higher in the San Cono Hills in the southwest Etna zones than in the Belice Valley and range between a minimum of 130 hours per hectare and a maximum of 338 hours, of which over 70 percent are preferable to those growing operations characteristic of this Cactaceae (Basile, 2001).

In the San Cono Hills, land investment costs average about US$8000 per hectare; in southwest Etna, they are roughly US$6500 per hectare; and in the Belice Valley, they are little over US$5000. Approximately 66% to 85% of the entire investments are made up of cactus pear plot and installation expenses, which are the most prevalent kind and subtype of work included in these investments. The amount of land invested in different businesses varies greatly based on whether rural farm infrastructure with irrigation or water distribution systems is there or not, as well as the completion of projects before the cactus pear crop's development. Instead, this variation is better controlled for reserve investments, which are on average more expensive in the Belice Valley (approximately 1,200 US dollars per hectare) than in the San Cono Hills (US$750) and in the southwest Etna (US$650) (Basile, 2001).

In the regions under survey, labor and services makeup approximately half of the production costs; shares and other qualities come in second, and materials come in last. The businesses surveyed have average values of about US$ 3,100 per hectare in the San Cono Hills and southwest Etna zones and US$ 2,700 per hectare in the Belice Valley zone. There have been notable fluctuations in the first and second zones, ranging from US$ 2,200 to US$ 4,150 and US$ 2,250 to US$ 3,750, respectively, and most notably in the third zone, which has increased from US$ 1,900 to US$ 3,900 (Basile, 2001).

Gross production for sales appears to be higher overall in the San Cono Hills (US$ 4,550 per hectare) than in the Belice Valley (US$ 3,500) and southwest Etna (US$ 4,350); these discrepancies are primarily due to differing yields. Nonetheless, there is some variation in the total saleable production, more so in the first and third zones and less so in the second (Basile, 2001).

Note that production prices have been steadily declining in tandem with the growth in yields. Though these prices have stayed reasonable, they have actually shown a downward trend, and they are such that the recorded drops in production costs cannot be offset, even though they also seem to suggest that more product could be consumed. The enormous number of commercial operators currently in operation, the inadequate supply concentration, the poor commercial distribution and promotion of the product, and these factors all severely restrict the product's market potential. This Cactaceae could bring in new business in Italy and abroad if it is properly distributed and promoted (Basile, 2001).

Opuntias are characterized by the absence of leaves, succulent stems with a green cortex and the presence of spines. Multipurpose plants known as *Opuntias* are beneficial to soil and water conservation efforts. They yield a variety of products such as drinks, drugs, dyes, and cosmetics, as well as fruits and vegetables for human consumption, livestock feed, biomass for energy, live fences and wind breaks, and bee forage. Tesfay (2010) discovered that the majority of prickly pear cactus fruit is produced in the eastern and southern zones of Tigray, although cacti are grown almost everywhere.

Cactus is estimated to occupy about 379,338 hectares of land, or about 7.6% of the total rangeland of the region, with the largest proportion being found in Eastern Tigray. In Tigryi, there are about 80 varieties of cactus, as identified by farmers and by the Tigray Agricultural Research Institute (Nefzaoui and EI Mourid, 2010). Out of these, only three are preferred and provided with relatively good management by farmers. The remaining 77 varieties are kept as reserves when production are scarce. The cactus plant was mainly thought of as a famine meal that humans utilized to survive droughts. Thus, when famine and drought emerge, their significance grows. However, because of its growing susceptibility to drought and the rising unpredictability of other cultural crops in the area, its usage has overtaken this phenomenon over time (Tesfay, 2010).

Cactus pears are essential to subsistence farming in many places of the world. Whether they are produced in natural stands or on a small scale, cactus pears are a vital source of food (fruits and their derivatives) and cattle fodder or pasture for the rural poor. This is true not only in North Africa and the Horn of Africa (Eritrea and Ethiopia), but also outside of Mexico, the Near East, and the Americas. Northern Tigray, Ethiopia, provides an example of the importance of cactus pear notwithstanding the impossibility of putting an economic component on this phenomenon: during periods of severe food scarcity, natural cactus pear stands provide nourishment for an entire town.

2.6 Conceptual Framework of the Study

The literature reviewed by different scholars showed different variables on the environmental and socioeconomic importance of *O. ficus-indica* species, especially in Tigray. environmental important such as species and socioeconomic importance such as household income and animal foods from *O. ficus-indica.*The Primary problems the cactus owner households encountered were price fluctuation, birds, insects, and diseases, high transport costs, and no specific market. Therefore, this study focuses on the environmental and socioeconomic importance of *O. ficus-indica* species, analyzing their environmental and socioeconomic important.

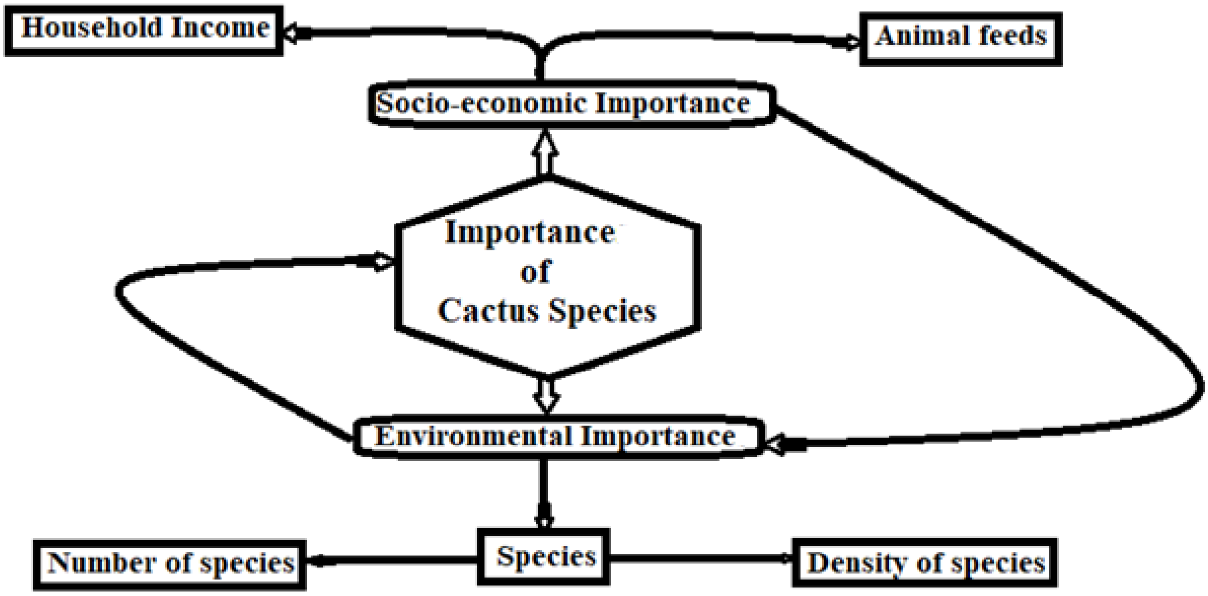

Figure 2.1. Conceptual framework for analyzing the Environmental and socioeconomic importance of cactus (*O. ficus-indica*) species.

CHAPTER-THREE

3. MATERIALS AND METHODS

3.1. Description of the Study area

The study area was in Hagere-Selam Kebele of Gulomekeda District, Eastern Tigray, Ethiopia. Gulomekeda is bordered on the south by Ganta Afeshum District, on the west by the Zoba Maekel (Central Zone) District, on the north by Eritrea (Country), on the east by Irob District, and the south-east by Saesie Tsaedaemba District. It is located between 39^0 23’11" E longitudes and 14^0 23'49" N latitudes, 17 km from Adigrat and 137 km from Mekelle. The District covers a total area of 591.438 km^2, constituting 19 kebeles. Hagere-Selam kebele had an area of 3436 ha. The present study was in one kebele and three Kushets (villages), which were cactus-rich areas.

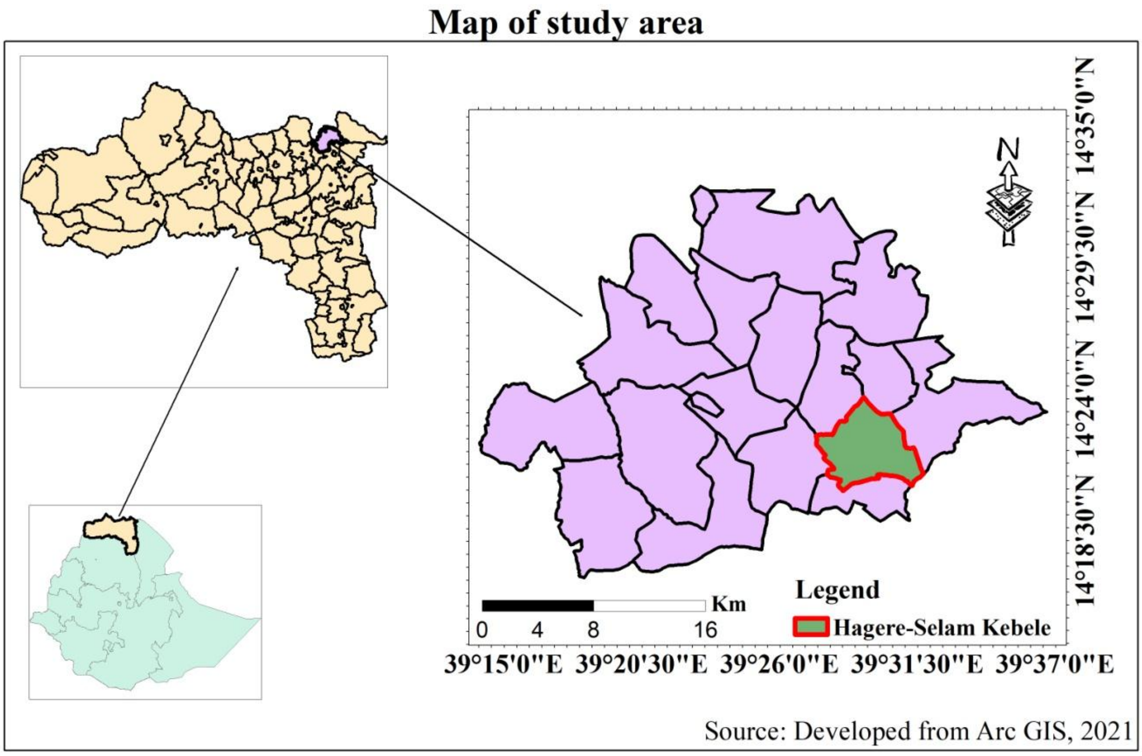

Figure 3.1.Map of Gulomekeda District and the study areas

3.1.1. Climate

The average monthly rainfall during the year varies from 2.5 mm to 500 mm, with the average minimum and maximum rainfall recorded by the National Agency Fatsi, and the average minimum and maximum temperature recorded ranging from 6.5 C° to 25.5 C°, respectively. The mean annual temperature for the same period was 16 C^o, (Fatsi Metrological Station, June, 2020).

3.1.2. Topography and soil

According to the Bureau of Agriculture and Rural Development (BOARD, 2012), the District has two agro-ecological zones: high land, which covers 12,032ha (20.34%) of the area at an altitude of 2300–2866 meters above sea level; and mid-high land, which covers 47,111.8ha (79.66%) of the area at an altitude of 1393–2300 meters above sea level. Based on its geographical location, the Gulomekeda District has different types of soil. The plain area has clay soil in the majority and sand soil to some extent. The rest of the slope and river area also have both silt and sandy soil.

3.1.3. Land cover and vegetation

The District is classified according to different land types; of the total area, 11,623.75ha are cultivated land (19.65%) and 47,520.05ha is uncultivated land (80.35%) (BOARD, 2012).This area has sparsely vegetated higher plants, and most of it is covered by shrubs. It includes *Olea europea subsp cuspidata, Juniperus procera, Eucalyptus globules, Acacia abyssinica, Euphorbia abyssinica, Aloe megalacantha, Opuntia ficus indica, Rhamnus prinoides, Rumex nervosus, Rhus retinorrhoea, phytolacca dodecandra, Maytenus arbutifolia, Bacium grandifolium, and Dodonia angustifolia* (BOARD, 2012).

3.1.4. Farming system and agricultural production

In the study area, wheat, barley, teff, beans, peas, and lentils are the major crops cultivated. The farming system of the area is classified as mixed farming (crop production and livestock rearing). Crop production plays a major role in the area as a source of food crops grown there. Livestock production also contributes a large proportion of income to people's livelihood strategies. Livestock, such as cattle 72743, sheep 57475, goats 39387, donkeys 8615, and poultry 131399, are the major types reared in the study area (BOARD, 2012).

The populations of Gulomekeda District have an estimated population of 102793, of whom 52325 are men and 50468 are women, based on figures published by the Central Statistical Agency (CSA, 2012). Gulomekeda District also has 23744 households, of which 11822 are men and 11922 are women, with an estimated area of 59143.8 ha. Hagere-Selam kebele is one of Gulomekeda District, with a total population of 7451; 3844 are male and 3607 are female, for a total of 1620 households, 836 male and 784 female households (BOARD, 2012).

3.2. Methods

3.2.1. Vegetation Sampling and Data Collection Method

To investigate the environmental impact of cactus pear on the structure and diversity of vegetation, plots of 100 m2 (10m x 10m) were established for vegetation sampling. A total of 30 sample quadrats were taken from a cactus-dense area. Similarly, a total of 30 sample quadrats were taken from a cactus-free area. Within each sampling plot, all species that fall within the sample plot were recorded using the vernacular name "Tigrigna. For woody species (trees and shrubs) having a diameter at breast height (DBH), their DBH was measured at 1.3m above ground, and their height was visually estimated. Trees and shrubs with DBH ≥2.5cm, height greater than 2 m, are recorded as adults, and those with DBH < 2.5cm, height less than 2 m, are recorded as sapling.

3.2.2. Household sampling method

The study area had four villages, and three villages were still purposefully selected using cactus availability and transport accessibility. From the sampling frame of the three villages, the study selected 93 sample households using proportional and simple random sampling methods. The sample size was calculated using the following formula for sample size determination (Kothari, 2004) and the following sampling technique for dispersed populations:

$$n = \frac{Nz^2PQ}{e^2(N-1) + z^2PQ}$$

$$n = \frac{1261 * (1.96)^2 0.07 * 0.93}{0.05^2 * (1261-1) + (1.96)^2 0.07 * 0.93}$$

n=93

Where; n= sample size the researcher uses

N= Total population size (1261)

z=value of standard at a given confidence level (1.96)

p= sample proportion of success (.07)

e= acceptable error/ precision level (.05)

q= confidence level (.93)

Table. 3.1 Sample size taken proportional allocation from each villages

Serial No.	Villages	Households size in each villages	Sample taken or proportional allocation (ni $= \frac{n}{N} * Ni$)
1	V-01	453	33.41=33
2	V-02	417	30.75=31
3	V-03	391	28.84=29
Total		1261	93

3.2.3. Socio-economic data collection method

The study used diverse data collection methods to collect reliable data. A focus group discussion was conducted with representatives from elders, women, youth groups, sector office experts, and associations. Individual farmers were randomly selected for an interview, which was conducted both in the homestead and on the farmland to develop the farmers trust in the interviewer. Each farmer was well-informed about the purpose of the survey and why he or she was chosen for the interview. The questionnaire contained open-ended and closed-ended questions. Open-ended questions served the purpose of disclosing the system of knowledge and structuring of ideas central to respondents' own views of the research problem. While in closed or forced questions, yes or no answers were giving information. The questionnaire included questions on household profiles such as age, educational level, marital status, and the number of individuals in the household.

The physical production of goods and services was valued using the actual market prices of the resources (Shylajan and Mythili, 2007). Information was collected on each source of income of the households, and each respondent was required to give an estimation of how much was produced, consumed, and sold from each source of income in 2020/2021. This depends on the household's estimation of the amounts harvested, consumed, and sold, rather than being actually measured by researchers. In this study, income included both cash and subsistence income for households.

3.2.4. Vegetation data analysis

Descriptive statistical methods were used for data analysis. For species diversity analysis, Shannon and Wiener's (1949) Diversity Index was used. Vegetation data for the woody species was calculated and summarized on an Excel spread sheet using the following formulas:

$$\text{Relative dominance (RD)} = \frac{\text{Dominance of a species}}{\text{Total dominance of all species}} * 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} * 100$$

The sums of the relative measures are relative dominance, and relative frequency for species, Importance Value Index, (IVI) (Kent and Coker, 1992).

Importance Value Index (IVI) = RD+RF

For different plant habits (shrubs and trees), species richness was expressed as number of species per unit area.

Shannon Diversity Index (H') $$H' = -\sum_{n=1}^{s} Pi \; lnPi$$

Where: H' = Diversity of species

S= the number of species

Pi= the proportion of individuals abundance of the i^{th} species

ln= log base

For examining the effect of cactus on species richness and diversity, data from cactus dense and cactus free area were compared.

3.2.5. Household survey data analysis

The collected data were checked, coded, and encoded into a computer, which was then analyzed to extract meaningful information. Descriptive statistics such as mean, percentage, and frequency, as well as inferential statistics such as correlation, pair-sample t-test, and multiple linear regression, were used to present the household survey results. Various data analysis techniques were employed since both qualitative and quantitative data were collected; the qualitative data that were obtained through group discussion were narrated and summarized. The quantitative data obtained through a formal survey was analyzed using the Statistical Package for Social Sciences (SPSS) version 20. The results were presented using tables, charts, and frequency distributions.

CHAPTER-FOUR

4. RESULTS AND DISCUSSION

4.1 Demographic characteristics

In the demographic characteristics section, the questionnaires explored the following information: gender of the respondents, age of the respondents, educational level of the respondents, occupation of the respondents, and cactus of ownership.

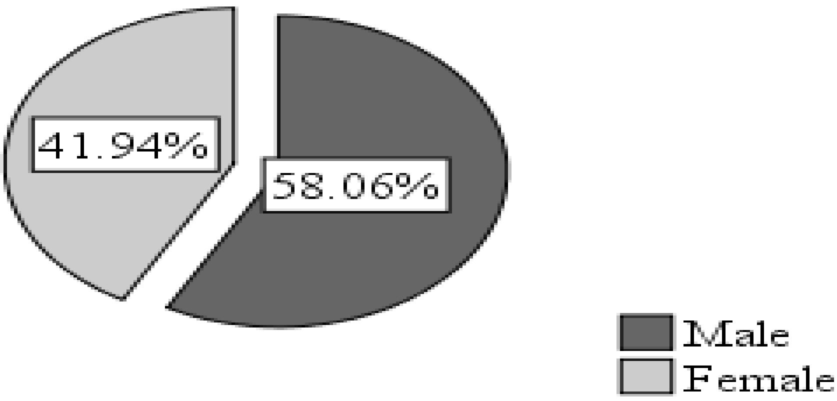

Figure 4. 1 Gender of respondents

As indicated by the data interpreted and written in the above figure, the number of male respondents was 58.06%, while the number of female respondents was 41.94%.

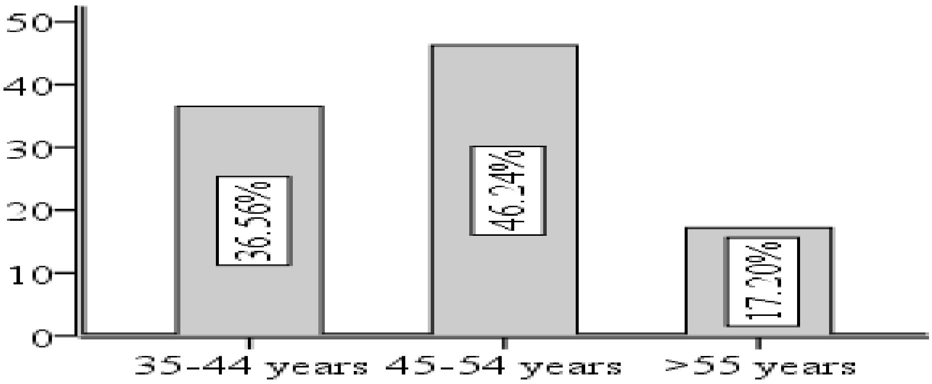

Figure 4.2 Age of respondents

The results depicted on the above bar graph indicate that the three sets of age groups were taken as part of the study. 46.24% of the respondents were between 45 and 54 years old. Of the total respondents, 36.56% were 35–44 years old. And also, actively they have been participated in the socioeconomic importance of cactus since they are more productive and powerful peoples. The rest 17.20% of the respondents were over 55 years old. From the above-depicted data, the researcher concluded that all the respondents have a lot of valuable information about the benefit of cactus production.

Table 4.1 Educational status of Respondents

Variables	Frequency	Percent
Illiterate	75	80.65
Literate	18	19.35
Total	93	100.0

The data listed in Table 4.1 above illustrates the educational status of respondents who participated in the study. Hence, 80.65% of the respondents were illiterate, while the number of literate respondents was 19.35%. According to the table that shows educational level, all of the respondents had a certificate. However, through formal and informal learning, 18 respondents have the skill to read and write in their local language, Tigrigna. Thus, they filled out the questionnaire themselves. The rest of the 75 respondents have no reading or writing skills. However, both literate and illiterate people follow changes on their land eagerly, and they provide constructive ideas and recommendations.

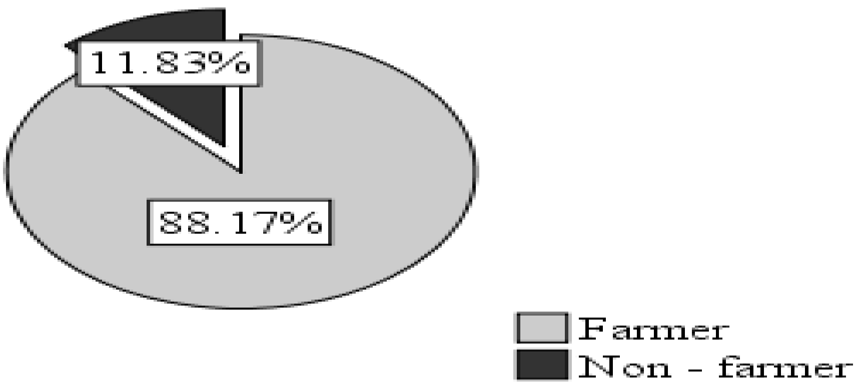

Figure 4.3 Occupation of Respondents

The above table illustrates that 88.17% of the respondents are agrarians because they are farmers. On the other hand, 11.83% of the respondents were non-agrarians because they were not farmers. As a result, the researcher can conclude that more than half of the respondents’farmers depend on agricultural activities such as cactus production.

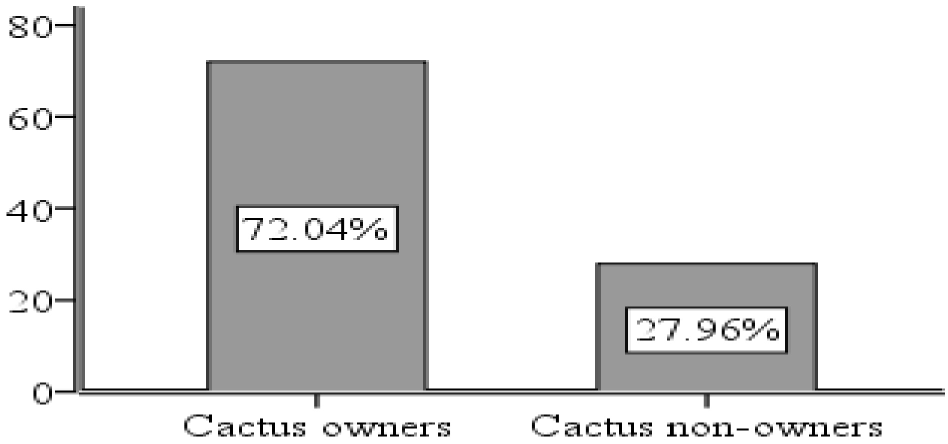

Figure 4.4 Cactus ownership of respondents

Based on the data interpreted and written in the above Figure 4.4, 72.04% of the respondents were involved in cactus production, while remaining 27.96% had no cactus because of landinsecurity and a lack of awareness. Therefore, the researcher concluded that cactus production respondents had a greater number than no cactus respondents at that time or at the time of data collection.

Table 4. 2 Family size and land holding size perhectare

Correlations					
				Family size	Land holding size
Family size	Pearson Correlation			1	0.314
	Sig. (2-tailed)				0.002
	N			93	93
	Bootstrap[c]	Bias		0	-.002
		Std. Error		0	.086
		95% Confidence Interval	Lower	1	.134
			Upper	1	.476
Landholding size	Pearson Correlation			.314**	1
	Sig. (2-tailed)			.002	
	N			93	93
	Bootstrap[c]	Bias		-.002	0
		Std. Error		.086	0
		95% Confidence Interval	Lower	.134	1
			Upper	.476	1

In Table 4.2, we can see that the Pearson correlation coefficient, *r*, is 0.314 and that this is statistically significant ($P < 0.05$). A Pearson product-moment correlation was run to determine the relationship between family size and land holding size per hectare. There was a positive correlation between family size and land holding size per hectare, which was statistically significant (r = 0.314, n = 93, p< .002).

Table 4.3 Cactus land size per hectors and Average income per birr

Correlations					
				Cactus land size	Average income
Cactus land size	Pearson Correlation			1	.838
	Sig. (2-tailed)				.000
	N			93	93
	Bootstrap[b]	Bias		0	.000
		Std. Error		0	.034
		95% Confidence Interval	Lower	1	.764
			Upper	1	.899
Average income	Pearson Correlation			.838[**]	1
	Sig. (2-tailed)			.000	
	N			93	93
	Bootstrap[b]	Bias		.000	0
		Std. Error		.034	0
		95% Confidence Interval	Lower	.764	1
			Upper	.899	1

In Table 4.3, we can see that the Pearson correlation coefficient, r, is 0.838 and that this is statistically significant (P < 0.05). A Pearson product-moment correlation was run to determine the relationship between the cactus land size per hectare and the average income per birr. There was a positive correlation between cactus land size per hectare and average income per birr, which was statistically significant (r = 0.838, n = 93, p< .000).

4.2. Effect of cactus on species diversity

4.2.1. Species composition

A total of 2315 number of individuals were documented from the study area, out of which 756 were in cactus-occupied sites and 1559 in cactus-free sites (Table 4.4-4.5). The result showed that a cactus-free site had more species composition than a cactus-occupied site, showing that the species composition of the plant community is significantly influenced by the spread of *O. ficus-indica* species. In other studies, the same result showed that the species composition of the plant communities was significantly homogenized by the presence of *O. ficus-indica*, while species richness and Shannon diversity were not significantly affected by the presence of *O. ficus-indica* (Tesfay, and Kreyling, J, 2021).

Table 4.4 Cactus-occupied site plots and Cactus-free site plots

Plots	Paired Samples Test				
	Mean	SD	T	Df	P-Value
Cactus occupied site	25.2000	1.33907	191.671	29	.000
Cactus free site	51.9667	1.51960			

As defined by the pair of variables, there are 30 plots to illustrate that the average number of cactus-occupied site plots was 25.20 and the standard deviation of cactus-occupied site plots was 1.34. While the mean of Cactus-free site plots was 51.97 and the standard deviation of Cactus-free site plots was 1.52, Since it was statistically significantly associated between Cactus occupied site plots and Cactus-free site plots((t = 191.67) degree of freedom was 29, p< 0.05), 0.000 less than 0.05. Besides this, it was also pointed out that 100% of the key informants answered that there was an increase or big difference between cactus-occupied site plots and cactus-free site plots. The findings show that the extent of cactus-free site plots is greater than when compared to cactus-occupied site plots. Appendix III in Table 1 shows the Paired Samples Statistics report.

Table 4.5 Densityof species in Cactus occupied site and Cactus free site

Density of species	Paired Samples Test				
	Mean	SD	T	Df	P-Value
Cactus occupied site	108.00	108.99	-2.582	6	.042
Cactus free site	248.57	249.564			

As defined by the pair of variables, there are seven total species found common to both areas (*Becium grandiflorum, Rumex nervosus, Vachelia lahai, Maytenus senegalensis, Maytenus arbutifilia, Dodonaea angustifolia, and Vachelia etbaica).* The cactus-occupied site per species was 108.00, and the standard deviation of the cactus occupied site per species was 108.99. While the mean of cactus-free sites per species was 248.56 and the standard deviation of cactus free sites per species was 249.564. Since it was statistically significantly associated between cactus occupied site per species and cactus free site per species ((t = -2.582) degree of freedom was 6, p< 0.05), 0.042 less than 0.05. Besides this, the researcher can cross-check with the table listed below. The scientific names of the species taken from Ben Salem and Habtu (1996) are *Becium grandiflorum, Rumex nervosus, Vachelia lahai, Maytenus* *arbutifolia, Maytenus senegalensis, Dodonaea angustifolia, Vachelia etbaica, Calpurnia aurea, Withania somnifera, Phytolacca dodecandra, and Aloe megalacantha*. The findings show that the density of species in cactus-free site were greater than when we compare them to the density of species in cactus-occupied site. As shown in Table 4.6.The appendix III in Table 2 shows the Paired Samples Statistics report.

Table 4.6. Species name of Cactus occupied site and Cactus free site

Species Name	Cactus occupied site	Cactus free site
Becium grandiflorum	327	774
Rumex nervosus	164	351
Vachelia lahai	106	163
Maytenus senegalensis	71	98
Maytenus arbutifilia	41	78
Dodonaea angustifolia	28	61
Vachelia etbaica	19	34

The study further showed that the cactus-free site had a higher density of woody species (trees and shrubs) than the cactus-occupied site (Figure 4.5). According to Tesfay, and Kreyling (2021), due to the continuous pressure of the invasion by cactus pear *(O. ficus-indica)* on the species composition and dry climates, further homogenization in the native species diversity is to be expected in the future for the highlands of Eritrea.

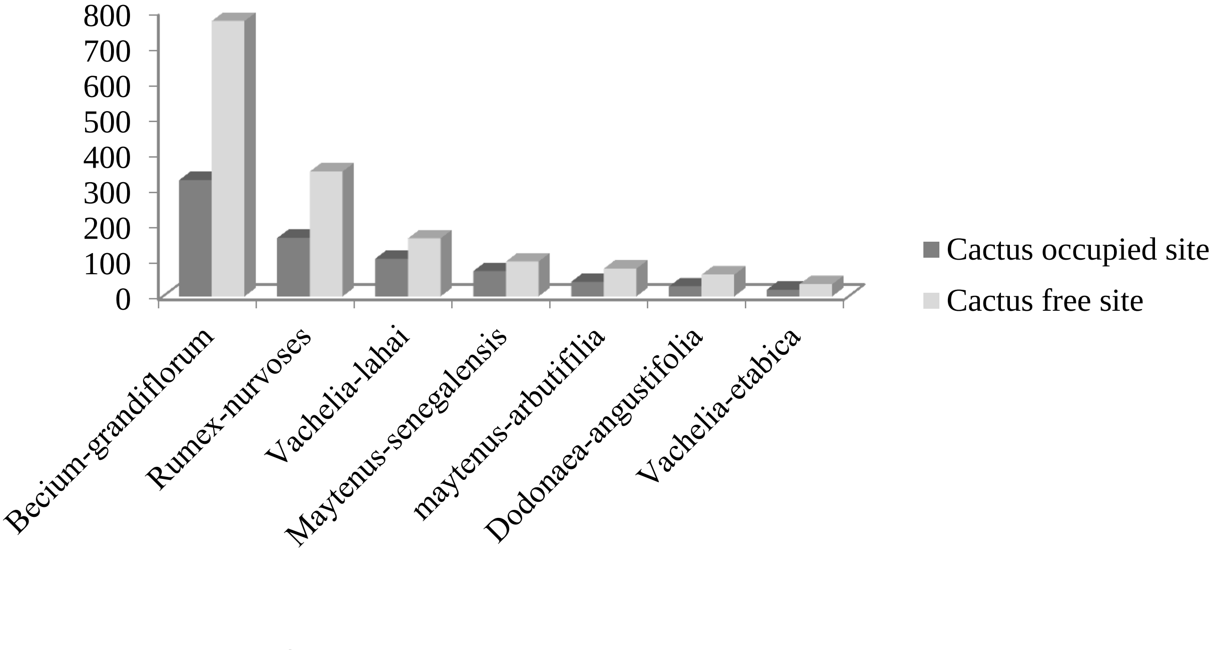

Figure 4.5. The density of woody species (trees/shrubs) in cactus-occupied sites and cactus- free sites

From the analysis of vegetation composition, a high species composition status was recorded in the cactus-free area over that of the cactus-dense area (Figure 4.6). The data from the environment showed that in the cactus-free area, there were 197 trees and 1362 shrubs, and in the cactus-dense area, there were 125 trees and 631 shrubs. The difference in vegetation composition in the study areas might have resulted from the effect of cactus on species diversity. In other studies, the average cumulative cover of woody vegetation declined with increasing cactus cover (Habtu, 2010).

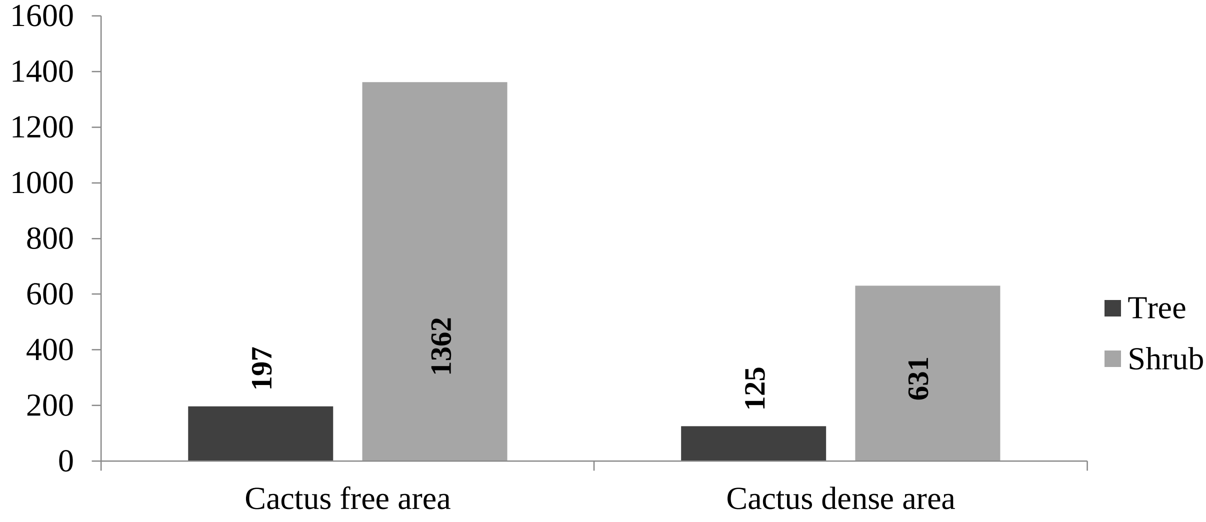

Figure 4.6 Density of speciesin terms of habit shrubs and trees in cactus-free and cactus-dense area

Table 4.7 Density ha-1 for sapling and adult in the cactus-free area and cactus-dense area

Sites	Adult	Sapling	Total
cactus free area	392	1167	1559
Cactus dense area	348	408	756

From the total density of woody plants in the cactus-free area, the proportion of adults and sapling accounted for 25.14% and 74.86%, respectively. In the cactus-dense area, adults and sapling were 46.03% and 53.97%, respectively. The density of sapling species was higher in cactus-free areas as compared to cactus-dense areas, which indicated higher species regeneration in cactus-free areas than in cactus-dense areas. On the contrary, regeneration and recruitment of sapling woody species were found to be higher in the high cactus cover area than in the cactus-free area (Habtu *et al*., 2010).

4.2.2.Population structure of woody species

A descriptive population structure analysis of woody plants based on the number of individuals by DBH size class was illustrated using the representative species common to both cactus-free sites and cactus-occupied sites. Accordingly, the diameter distribution of the species indicated that the number of individuals in the lower diameter class was low in the cactus-occupied site and comparatively higher in the cactus-free site (Table 4.8). The highest numbers of individuals were found in the diameter class of 1.8–4.5 cm, declining with increasing diameter. The number of individuals of representative species at the cactus-free site is higher than at the cactus-occupied site, and the population structure in both sites is also different. In the lower diameter class of 1.8–4.5 cm, with low numbers of individuals in the cactus-occupied site, there was no regeneration; as diameter increased because the food and water shared by cactus, there was an increase in individuals. The sapling populations of the individuals were higher in the lower diameter class of cactus-free areas, and the distribution generally followed an inverted "J"-shaped diameter frequency distribution, including good status of regeneration (Swain, 1998, cited in Meron, 2010). There was an increase in cactus-occupied sites; the lower regeneration in cactus-occupied sites indicated the negative effect of cactus on species diversity by composition for space and sunlight. According to Ueckert (2004), cited in Habtu *et al. (*2010) dense stands of cactus commonly eliminate herbaceous plant production on 25% or more of the surface area of some pastures. Generally, cactus eliminates woody species. In addition, the value of relative dominance *Becium grandiflorum (42.86%) follows by Rumex nervosus, Vacheli alahai, Maytenus senegalensis, Maytenus arbutifilia, Dodonaea angustifolia, and Vachelia etbaica* in cactus occupied site and *Becium grandiflorum(49.65%) follows by Rumex nervosus,Vachelia lahai, Maytenus senegalensis, Maytenus arbutifilia, Dodonaea angustifolia, and Vachelia etbaica* in cactus free site (Table 4.8).

Table 4.8 Population structure of species in cactus occupied site and cactus free site

Cactus occupied site							
Scientific name	Abundance	Relative frequency	Relative dominance	IVI	H’	ENS	Species Richness
Becium grandiflorum	327	0.157	0.433	0.589	1.564	4.779	7
Rumex nervosus	164	0.086	0.217	0.302			
Vachelia lahai	106	0.602	0.140	0.742			
Maytenus senegalensis	71	0.029	0.094	0.122			

Maytenus arbutifilia	41	0.029	0.054	0.084			
Dodonaea angustifolia	28	0.015	0.037	0.053			
Vachelia etbaica	19	0.082	0.025	0.108			
Cactus free site							
Becium grandiflorum	774	0.085	0.496	0.582	1.453	4.278	7
Rumex nervosus	351	0.059	0.225	0.284			
Vachelia lahai	163	0.690	0.105	0.795			
Maytenus senegalensis	98	0.032	0.063	0.095			
Maytenus arbutifilia	78	0.022	0.050	0.0721			
Dodonaea angustifolia	61	0.013	0.039	0.052			
Vachelia etbaica	34	0.098	0.022	0.120			

4.3. Importance of cactus production

Cactus production provides economic and non-economic benefits for the local communities. The respondents were requested to identify the benefits of cactus, and they listed that the species was used for human consumption, as a source of income, livestock feeding, fuel wood, and live fencing. The respondents and the participants in the focus group discussion were requested to rank the benefits of cactus according to their importance. To put it differently, they were asked to prioritize the importance with which they planted the cactus. With a slight difference, the questionnaire survey and focus group discussion gave the same ranking. They ranked consumption for humans, source income, animal feed, fence, and fuel wood, respectively, in Table 4.9. According to Habtu *et al*. (2010), the primary use of cacti was for human consumption. As a result, they were also used for fuel wood, animal feed, live fence, and as a source of money.

Table 4.9The major purpose of planting cactus

Variables	Frequency	Percent
Human consumption	22	32.83
Animal feed	14	20.89
Income source	24	35.82
Fence home stead	5	7.46
Fuel wood	2	3.00
Total	67	100.0

As indicated in the table above, about 35.82% of the respondents said that the purpose of using cactus was as a source of income; 32.83% gave the highest weight to its use for fruit consumption; 20.89% of the owner respondents appreciated cactus as animal feed; 7.46% of owners appreciated cactus as a live fence; and the least 3.00% of owners appreciated cactus as fuel wood. Therefore, the researcher can conclude that the majority of the purposes of planting cactus are for human consumption, animal feed, and income sources. Besides this, 100% of the FGD agreed on the socio-economic importance of planting cactus because of its significant effect on the socio-economic status of the households in the study area. Accordingly, the bulk of an *Opuntia's* biomass consists of cladodes, which can be stored as silage for subsequent feeding or given to animals as fresh fodder (Nefzaoui *et al*., 2010). Moreover, it makes use of food, feed for cattle, money, shelter, fuel, fences, cochineal production, and bee foraging (Gebremeskel *et al*., 2013).

4.3.1. Human consumption

Of the total respondents, about 32.83% were primarily used for human consumption. Only the fruit of the cactus was used for human consumption. However, in other studies, other parts of the cactus, such as cactus cladodes, were used for human consumption, like vegetables, fresh and processed food, salad, juice, and bread. For example, Meaza *et al.* (2010) reported that in their study in the Eastern Zone of Tigray, cactus cladodes were used as food in the form of salad and roasted food. Jams have been prepared from the fruits of the cactus. There are also several cactus by-products that can be obtained from cactus, and these include edible oil from cactus seeds, sauce, and marmalade; candy from cladodes and fruits; shampoo, soaps, and thickeners from mucilage (Tesfay, 2010b).

Furthermore, the respondents were able to give quantitative values related to income for each use (Table 4.9). According to the informants, the first, second, and third incomes of cactus were from human consumption, fruit selling, and animal feed (40.27%, 29.93%, and 25.08%, respectively), and the least incomes generated were fence and fuel wood (3.19% and 1.51%, respectively) (Table 4.10). The income collected from the sale of cactus was helping the cactus owners to cover the cost of household items such as grain food, clothing, school fees for their children, and health care. According to Brutsch (1997) and Mitiku *et al*. (2002), cactus pear is utilized in Tigray for a variety of uses, including food, fuel wood, forage, monetary revenue, live fences, industrial raw materials, and soil conservation. And as of right now, cactus pear is thought to be widely distributed throughout the region, covering more than 379,338 hectares of land, or 7.4% of the entire Tigray region's land area (SAERT 1994; Nefzaoui *et al*., 2010). It also plays a significant role in the local economy. According to Tesfay *et al*. (2011), uncultivated cacti occupied over 32,000 hectares of land in the Tigray region alone.

Table 4.10 Total income of cactus production in the study area

Variables	Frequency	Percent
Fruit for human consumption	2851.3	40.27%
Fruit for selling	2119	29.93%
Animal feed	1776	25.08%
Fence	226	3.19%
Fuel wood	107	1.51%
Total	7080.06	100%

4.3.2. Animal feed

Various studies show that cactus is used for animal feed. Nefzaoui and Ben Salem (2010) explained that cactus is used all year round or as emergency feedstock in case of drought. About 26% of the respondents collect and feed middle-aged cladodes rather than young and old-aged ones, and feeding cactus was used for increasing milk production and fattening. According to the Pérez-González (2001) report, anopium-based supplement increases not only milk production but also the quality of butter in terms of consistency and storage life, as well as adding an attractive "golden" color to the finished product. Cactus is used during drought periods as a feeding gap for shortages of feed. By Tadese (2010), in the Eastern and Southern Zones of Tigray, farmers have traditionally been supplying cladodes to their daily diet by cutting, burning, and slicing them freely and mixing them with straw. Animals can consume large amounts of cladodes. For instance, cattle may consume 50 to 70 kg fresh cladodes per day, and sheep 6 to 8 kg per day. Cladode consumption can have a laxative effect, leading to a more rapid passage of the food through the animal's digestive tract. This leads to poorer digestion, especially when the cladodes constitute more than 60% of the dry matter intake; supplementing with fibrous feed (e.g., straw or hay) can alleviate such laxative effects (Nefzaoui and Ben Salem, 2002).

The cactus-owner households in the study area used cactus for animal feeding during the drought period and the rainy season as well. The most commonly described means of filling feed gaps was the use of cactus cladodes as livestock feed. There are two feed gaps: one in the winter (2-4 months) and a longer one in the summer (5–6 months). These gaps are very difficult to manage by livestock owners and require large volumes of imported concentrate feeds to supplement animal requirements, according to Pérez-González (2001). Both spine and spineless cactus were supplied to their animals, always mixed with straw; the spine cladodes were roasted, and the spineless were sliced without being roasted. Overfeeding spiny and spineless cladodes and feeding hot roasted cladodes has animal health problems, including bloating and pregnancy cow fatalities. The most common traditional treatment and prevention methods used by farmers to minimize the problems of bloating and pregnancy cow fatalities were to limit the number of cladodes and cool the roasted cladodes offered to animals.

4.3.3. Income sources

The main means of subsistence in the research region were the cultivation of crops, cacti, livestock, trade, and other techniques including porterage. Selling cactus productions brought in money to cactus owner families, which accounted for 36.18% of total income. For both cactus owner and non-owner households, crop production was the secondary source of income, making up 56.65% on average. The third-best source of revenue for cactus owner households in the area was selling animals and their byproducts, accounting for 21.59% of total income; trading and other activities came in at 7.74% and 2.05%, respectively. For cactus non-owner households, trade was the main source of income for their livelihood activities, accounting for 36.58%. Selling animals and by-products of animals were the third and fourth sources of income for cactus non-owner households, as shown in Table 4.11.

4.3.4. Live fence

The respondents said that live fencing ranked as the fourth most important level for cacti. Households used cactus living fences as a more sustainable alternative to woods and as a home garden. Out of all cactus owners, 3.19% value the production of live fences. Respondents who owned cacti favored live fencing for home gardens (67%), and farmland (4%). Cacti are frequently utilized as protective barriers for agricultural fields and homesteads; in these areas, they are referred to as cactus fences (Dena, 2009). Both varieties of cacti were planted; the spineless cacti were planted inside the spine cactus to serve as a cactus fence for the farmhouse, while the spine cactus served as a fence for the young and old cladodes.

4.3.5. Fuel wood purpose

Fuel wood was the fifth source of household income in the study area. According to the respondents the cactus owners were used to fuel wood the roots of cactus by cracking and sun- dried. But it was not as important as the other purposes; only 1.51% of households used fuel wood cactus in a small amount. Farmers used the old and dried cactus plant cladodes as fuel wood, particularly where there was no other vegetation available (Tesfay, 2010b).

Finally, the respondents and the participants in the focus group discussion were asked their perceptions of cacti. They explained that cactus production is important not only for humans but also for animals. They also said cactus plantations played a key role in soil conservation. On the damaged lands by runoff, cactus helps to hold them in place, ensuring the stability of the lands. Cactus has long roots that range from 10–15 m; it can be used in spurting terraces to control sand movement, maintain the soil, and improve vegetable cover. Nefzaoui and Ben Salem (2001) and Nefzaoui and El Mourid (2009) explained that cactus pear has been recognized as a species suitable for soil erosion control, land reclamation, and combating desertification. Furthermore, cactus plants in the study area provided fence services for houses and farmland. However, not all the farm households had cactus because of the limited private farmland. Planting farmlands had the problem of competition for space and sunlight, invaded cropland, created wildlife, and cast shadows. For such reasons, communal hillsides and barren private farmland were good and preferable for cactus production. Finally, they identified two varieties of cactus, such as red and white, depending on the nomenclature of color and taste.

Table 4.11. Average income farm households earned from different sources

Income sources	Cactus owners		Cactus non-owners	
	Frequency	Percent	Frequency	Percent
Crop-products	6348.81	32.44	3785.65	24.21
Cactus products	7080.06	36.18	0	0
Animal-products	4224.61	21.59	3557.31	22.75
Trade	1514.7	7.74	5721.15	36.58
Others	400.37	2.05	2574.62	16.46
Total income	19568.55	100	15638.73	100

As indicated in the Table above, cactus was an important source of income for households. The average income the cactus owner households obtained from the cactus product was more than seven thousand birr, which was ranked as the first income source for the households. According to the 2012 E.C. data, the income from cactus accounted for about 36.18% of the total income of the farm households. The income from fruit sales varies depending on the market price and season; in the local market, the price of cactus fruit ranges on average at 10.5 birr per kg. The estimated fruit sale account was birr 1186.5 in bad years and birr 4483.5 in good years, as shown in Table 4.11. As compared with other studies, the estimated price of selling fruit cactus was about 618 birr in a bad year and 752 birr in a good year (Habtu *et al*., 2010). The estimated price of cactus fruit sales was less than the estimated price of cactus fruit for human consumption; this showed that the fruit was used for human consumption when the stored crops existed. 10.86% of the total respondents participated in cactus fruit selling.

Table 4.12. Multiple linear regression model

Average income **(dependent variable)**								
Independent Variables	R	R^2	Adjusted R Square	Std. Error of the Estimate	Change Statistics			
					F Change	df1	df2	Sig. F Change
Family size	.643	.413	.393	112.665833	20.882	3	89	0.006
Landholding size				1151.977		3	89	0.000
Cactus land size				623.615		3	89	0.016

As the above Table 4.12 indicates, the multiple correlation coefficient of the three models (*R*, i.e., the correlation between the predictor and the outcome variables) is 0.643, respectively. The first model of regression was 0.413, which can be thought of as the amount of variance in the outcome variable that is accounted for by the predictor variable, or 41.30% of the variance of family size, land holding size, and cactus land size contributed to the average income per birr, respectively. Therefore, it was found that there was a significant effect of the independent variables of cactus owners on the dependent variable of cactus owners' average income per birr (df 1(3) and df 2(89), r =0.643, F-value = 20.882, and P< 0.05). Besides this, family size, land holding size, and cactus land size contributed to the average income per birr for cactus owners in the study area. For further information, the statistical data in the above table is available in Appendix III, Table 3.

Table 4.13. Consumption level good season per kg and consumption level bad season per kg

				Consumption level good season per kg	Consumption level bad season per kg
Consumption level good season per kg	Pearson Correlation			1	-.921[*]
	Sig. (2-tailed)				.026
	N			5	5
	Bootstrap[d]	Bias		0[e]	.007[e]
		Std. Error		0[e]	.249[e]
		95% Confidence Interval	Lower	1[e]	-1.000[e]
			Upper	1[e]	-.782[e]
Consumption level bad season per kg	Pearson Correlation			-.921[*]	1
	Sig. (2-tailed)			.026	
	N			5	5

	Bootstrap[d]	Bias		.007[e]	0[e]
		Std. Error		.249[e]	0[e]
		95% Confidence Interval	Lower	-1.000[e]	1[e]
			Upper	-.782[e]	1[e]

In Table 4.13, see that this is statistically significant among consumption levels of good season per kg and bad season per kg. There was a strong, negative correlation between consumption level in the good season per kg and consumption level in the bad season per kg, which was statistically significant (r = -0.921 and p < 0.05). In addition, FGD strongly agrees with the analysis of the studies, which show that the farm households' average fruit consumption is about 906.76 k.g. during a good year and 229.04 k.g. during a bad year. The estimated value of the fruit price ranged from birr 9520.98 in good years to birr 2404.92 in bad years. Cactus is more productive in a good season when the rains fall well and has low production when the rains fall erratic. Diseases and pests also decreased production. Non-owner households also buy cactus from owner households for human consumption. The usual method of transferring cactus is that an agreement is entered into between the owner of the cactus plantation and the buyer to use the cactus grown on a specified area of the cactus plantation. Under this agreement, only cactus fruit can be used and taken. The buyer has a right to keep taking cactus fruit from the plantation for a period of three months until the fruit is harvested, and the contractual agreement is terminated at the time the fruit is harvested.

Table 4.14.Consumption level good season per kg and consumption level good season per birr

				Consumption level good season per kg	Consumption level good season per birr
Consumption level good season per kg	Pearson Correlation			1	.993**
	Sig. (2-tailed)				.001
	N			5	5
	Bootstrap[d]	Bias		0[e]	-.003[e]
		Std. Error		0[e]	.025[e]
		95% Confidence Interval	Lower	1[e]	.900[e]
			Upper	1[e]	1.000[e]
Consumption level good season per birr	Pearson Correlation			.993**	1
	Sig. (2-tailed)			.001	
	N			5	5
	Bootstrap[d]	Bias		-.003[e]	0[e]
		Std. Error		.025[e]	0[e]
		95% Confidence Interval	Lower	.900[e]	1[e]
			Upper	1.000[e]	1[e]

In Table 4.14, we can see that the Pearson correlation coefficient, r, is 0.993 and that this is statistically significant ($P < 0.05$). A Pearson product-moment correlation was run to determine the relationship between the consumption level per kg and the consumption level per birr. There was a strong positive correlation between the consumption level of good season per kg and consumption level of good season per birr, which was statistically significant ($r = 0.993$ and $P < 0.001$).

4.4. Constraints of cactus production

The cactus owner respondents identified various problems in relation to cactus production, harvesting, and marketing. They mentioned four basic problems: birds, insects, and diseases; price fluctuation; high transport costs; and the absence of a specific market for cactus sales. They ranked the problems according to the severity and urgency of solving them (Table 4.15). According to the result, price fluctuation was the first problem and accounted for 35.82% of the respondents; birds, insects, and diseases were the second problem for 26.87% of the respondents. High transport costs and the absence of a specific market were the third and fourth constraints for the cactus owner households, representing 20.89% and 16.42% of the respondents, respectively.

Table 4.15 Primary problems the cactus owner households encountered

Variables	Frequency	Percent
Price fluctuation	24	35.82
Birds, insects and diseases	18	26.87
High transport cost	14	20.89
No specific market	11	16.42
Total	67	100.00

Cactus pear is one of the most perishable fruit types. Unless the fruit is taken to the market or consumed without delay, it can easily be spoiled within a few days of picking. Collected cactus fruit is packed in metal crates, wooden boxes, or hand-woven grass baskets. The packing of cactus fruit in woven baskets is done mainly when the fruit is to be transported fully or partly by a human head. Metal crates are used when transportation of the fruit is to be made on the donkey back, while wooden boxes are used to transport either on the donkey back or by vehicle. The metal crates are made from a used metal barrel. Transporting cactus to the market was mainly done using donkeys by carrying them on a human's back or head. As a result of the perishable nature of the fruit and the absence of transport services on time, the cost of transport services became an expensive and primary problem for about 20.89% of the cactus respondents.

The loss of cactus fruit while standing on the plant and resulting from various factors like birds was another problem for the cactus owner households. The price of cactus fruit was also not constant. It was sometimes good, while other times it was very discouraged. The price varies regularly with the ripeness of the fruits. The high fluctuation might be linked to a narrow market and a shortage of timely transport services. Accordingly, it is difficult to fully capitalize on the market for this plant in Tigray due to a lack of enhanced varieties, production methods, and processing technologies (Mondragon, 2005). The methods used in agronomy (harvesting, moving, and storing) are highly conventional (Fessehaye, 2010). Additionally, there are various approaches to managing cactus pear, including manual, chemical, biological, cultural, and physical strategies (Delgado -Sánchez, 2013).

CHAPTER-FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The study explored the effects of cactus production on species diversity and household income. The findings of the study show that cactus production is important for the reason that it survives drought. Cactus had an effect on vegetation; as compared to cactus-occupied and cactus-free sites, it has a minor impact on species diversity and richness.The regeneration of woody plants was higher in the cactus-free site than the cactus-occupied site, and the species composition was also higher in the cactus-free site than the cactus-occupied site. The result showed thatspecies richness and Shannon diversity were not significantly affected by the presence of *O. ficus-indica*. Even though cactus has an impact on species composition, it also has a positive effect on household income.

The study revealed that there was a positive correlation between family size and land holding size per hector, which was statistically significant (r = 0.314, n = 93, p<0.002).The study concludes that there was statistically significantly difference between cactus occupied site per species and cactus free site per species.

Cactus production provides economic and non-economic benefits for the local communities. According to the respondents, the purpose of cactus production was the major source of human feed, additional income, livestock feed, fence, and fuel wood in the kebelle (villages), whereas in the group discussion, human consumption, animal feed, income source, fence, and fuel wood were discussed, respectively. Cactus production accounted for about 36% of the total income of the cactus-owner households. Only the fruit of the cactus was used for human consumption in the study area, but cactus cladodes were also used for human consumption. Cactus production is important not only for humans but also for animals. The study revealed that there was a significant effect of the independent variables of cactus owners on the dependent variable of cactus owners' average income per birr (df 1(3) and df 2(89), r =0.643, F-value = 20.882, and P< 0.05).

There were various problems in relation to cactus production, harvesting, and marketing. The respondents mentioned four basic problems: price fluctuation, diseases and birds, high transport costs to take the fruit products into big markets, and the absence of a specific market for cactus. Diseases and birds were two of the major problems; diseases infected heavily cladodes and reduced the number of fruits per cladode, and households suffered from animal feed and a lack of fences rather than human consumption. Improvements in the marketing and transportation facilities would enable the farmers to sell their products at reasonable prices with an improvement in their bargaining power, as well as reduce losses that could occur during the transportation and marketing of the fruit.

5.2. Recommendation

Based on the findings of the study, the following are recommended:

- local communities to be awared on thier environmental and socioeconomic value for sustainable utilization and improvement of dry land livelihoods.
- Expanding the utilization of the plant as a green vegetable for human consumption
- By utilizing the plant for animal feed using efficient technologies.
- Access to markets has to be improved so that farmers can get the best benefit from the cultivation of their crops.
- Only the fruit of the cactus was used for human consumption in the study area; thus, training on the processing food varieties of the cactus is essential.
- Diseases and insects were the problems for cactus production; awareness creation and government support are crucial to controlling them.
- In the region, land that is not suitable for cultivation, including hillside land, has been distributed to landless youths to provide a means of income generation.
- There is a need for support from research and extension in order to increase the productivity and management of cactus in the Kebelle.
- The establishment of cactus pear fields should be promoted at the household level and on rangeland as fodder banks to provide feed in the dry season and during droughts in Tigray, particularly in the study area.
- This study only focused on the important of cactus on species diversity and the economic contribution of cactus to household income, but issues like varieties of cactus and the importance of cactus on soil conservation needed further studies.

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APPENDICES

Appendix1: Questionnaire to be filled by peasants of kebelle Hagere-Selam

The main purpose of this questionnaire is to collect valid and reliable data on the environmental and socioeconomic important of cactus at the selected villages of kebelle hagereselam eastern zone of Tigray region. Thus, your genuine response will help the researcher to provide reliable and valuable suggestions and recommendations. Your response will be used only for academic purpose. I would like to express my appreciation in advance for your time and consideration.

General Directions

1. No need of writing your name

2. Mark tick in the box of your alternative answer(s)

3. Please give answers to each close-ended item as appropriately as possible

4. Please give your short and precise responses to the open-ended questions

Section-1: Household survey

Geographic Information

Woreda; ---

Tabia (kebele); ---

Kushet (village); --

Household name (code); ---

Interview date; ---

Interviewer; ---

Demographic data

No	Household members	Age	Sex	Educational level	Marital status	Primary occupation
1						
2						
3						
4						
5						
6						
7						

Code:

1. (1= 18-30years, 2= 31-45years, 3= 46-60years, 4= above 61 years)

2. (1=illiterate, 2= 1-4 grade, 3= 5-8 grade, 4= 9-12 grade, 5= above diploma)

3. (1= unmarried, 2=married, 3=divorced, 4=widowed)

4. (1=agriculture, 2=merchant, 3=civil servant), 4= If others specify------------------------

4.1. Source of income for the household (HH)

4.1.1. What is the major source of your annual income? ---

4.1.2. How many hectares do you have? ---

No	Income source	Estimated consumed value Birr in good year	Market value (Birr in good year)	Total value Birr in good year	Estimated consumed value Birr in bad year	Market value Birr in bad year	Total value Birr in bad year
1	Animals and animal products						
2	Crop production both rain fed and irrigation						
3	Cactus fruit and cladodes						
4	Trade						
5	Others						

Section-2: Questionnaires on perception of cactus production

2.1. Do you have a cactus? Yes-------- No--------- if your answer is yes, why? ---
----

2.2. How many hectare of cactus do you have? ---

2.3. What is the purpose of cactus utilization? A. human consumption B. animal feed C. Fruit selling D. fences E. fuel wood F. other specify-------------------------------------

2.4. Do you use it in your farm land? Yes---------- No--------- if your answer is no, why? ------
----

2.5. Who manage it your cactus? A. man b. woman c. children

2.6. Does distance affect cactus production? Yes------ No------ if the answer is yes, how? ----- ---

2.7. Is family size affects cactus production? Yes----- No------ if the answer is yes, how? ------ ---

2.8. How many months of cactus production period? ---------------------------

2.9. What is the technology use for harvesting cactus fruit? A. by hand b. by metal c. by can d. others specify -------------------------------------

2.10. What are the opportunities for cactus expansion? A. cactus availability b. labor access c. access of hill side area d. suitable in poor soil e. others specify -----------------------------

2.11. On which land type it prefers? A. home garden b. farm boundary c. pasture lands d. others ----------------------------

2.12. What are the factors that affect cactus production? A. insect b. diseases c. birds

D. others specify ------------------

2.13. How do you protect your cactus from diseases, insects and birds? -------------------------- --------------------------------------

2.14. Do you have any opportunity to plant it? ---

2.15. Have you got any training in cactus production? --

2.16. Why you don't have cactus so far? ---

Section-3: Questionnaire on Biodiversity

3.1 Is cactus affect species diversity? Yes ----- No ---- if your answer is yes, how? ------------

3.2 Which species diversity easily affects by cactus? --

3.3 Which species diversity easily survives with cactus? --

3.4 Is cactus advantageous or disadvantageous? ---

Section-4: Questionnaire on income of cactus

4.1. How many kg of cactus fruit sell? In good year kg------------------------birr-----------------

In bad year kg------------------birr----------------------------

4.2. How many cactus fruit sell per birr? ----------------------------

4.3. How many kg of cactus fruit used for consumption? In good year kg---------birr---------

In bad year kg -----------------------birr ------------------------

4.4. Do you use leave of cactus for animal feed? Yes ---------No ----------

If your answer is yes, what are the uses? ---

4.5. Estimate cactus leave used for animal feed in good year birr----------------in bad year birr-

4.6. Estimate cactus leave used for fuel wood in birr ---------------per year?

4.7. Estimate cactus leave used for fences in birr-----------per year?

4.8. Do you have market problem of cactus? Yes --------- No -------- if your answer is yes, what are the problems? --

4.9. Do you collect the fruit at the right time? ---

4.10. How many days do you conserve after collected the fruit? ---------------------

4.11. What uses for cactus transportation? A. human b. animal c. other specify ----------------

4.12. On what have you spent most of your income earned from cactus harvesting?

A. education of your children b. clothing c. health care d. food e. other specify ------------------

4.13. Are cactus increases the livelihood economy? Yes ------------ No ---------- if the answer is yes, how? ---

4.14. What you will happen if your cactus is lost? ---

Appendix-II ብሓሮስ ቶስ ቀበሌ ሃገረ ሰላም ዝምላእ መጠይቕ

ቀንዲ ዕላማ ናይ እዙይ መጠይቕ ብቑዕን እሙንን መረዳእታ ንምእካብ በለስ ኣብ ከባብን ኣብ ማሕበራዊ ናብራን ዘለዎ ረብሓ ብፍላይ ከዓ ኣብ ክልል ትግራይ ምብራቓዊ ዞባ ወረዳ ጉሎመከዳ ቀበሌ ሃገረ ሰላም እንታይ ከምዝመስል እንትኸውን ስለ እቲ ሓቀኛ መልስኹም ነቲ መፅናዓይ ብቑዕን እሙንን ሓሳብ ከምኡ እውን ሪኢቶ ክረክብ ይኽእል። እቲ መልስኩም ድማ ዕላምኡ ንመፅናዕታዊ ወይ ከዓ ንትምህርታዊ ጥቕሚ ጥራሕ ይውዕል። ንምትሕብባርኩምን ግዜኹምን ካብ ልበይ ከገልፀልኩም ይፈቱ።

ኣጠቓላሊ ኣንፈት

1. ሹም ምፅሓፍ ኣየድልን
2. ኣብ ውስጢ እቲ ሳጥን ናይ ራይት ምልክት የቐምጡ
3. ክንዲ ዝተከኣለ ነቲ ክፍቲ ቦታ ሓጢርን ግልጥን መልሲ የቐምጡ
4. ክንዲ ዝተከኣለ ነንሕድሕድ ሕቶ እውን ብመልክዕ ምርጫ መልሲ የቐምጡ

1. ዳሀሳስ ስድራ-ቤት

ሓበሬታ (መረዳእታ) አቀማምጣን ኢቃዉማን ናይ‘ቲ መፅናዕታዊ ቦታ

ወረዳ፡--------------------------

ጣብያ፡-------------------------

ቁሸት፡-------------------------

ሽም ስድራቤት (መለለዩ ቁፅሪ)፡-------------------------------

ዕለት ቃለ መሕትት፡-----------------------------

ቃለ መሕትተኛ፡--------------------------------

ህዝባዊ- ሓበሬታ(መረዳእታ)

ሪጋ	ኣባላት ስድራ ቤት	ዕድመ	ፆታ	ደረጃ ትምህርቲ	ኩነታት መውስቦ	ቀንዲ (ዋና) ዕዮ
1						
2						
3						
4						
5						
6						

ኮድ(መፍለዪ ቁፅሪ)፡

1.ሀ= 18-30 ዓመት, ለ= 31-45 ዓመት, ሐ= 46-60 ዓመት, መ=ልዕሊ 61 ዓመት

2.ሀ=ዘይተምሃረ, ለ=1-4 ክፍሊ, ሐ=5-8 ክፍሊ, መ=9-12 ክፍሊ, ሠ=ልዕሊ ዲፕሎማ

3.ሀ=ዘይተመርዓወ, ለ=ዝተመርዓወ, ሐ=ዝተፋትሑ, መ=ማኣምን(ሰብኣያ ብሞት ዝተፈለያ)

4.ሀ=ሓረስታይ, ለ=ነጋዳይ, ሐ=ሰራሕተኛ መንግስቲ,መ= ካልእ እንተሃልዩ------------------------

4.1.ምንጪ እቶት ስድራ ቤት

4.1.1. ቀንዲ ዓመታዊ እተቶም እንታይ እዩ? --

4.1.2.ክንደይ ዝኣክል ሄክታር መሬት ኣለኩም? --

ሪጋ	ምንጭ እቶት	ኣብ ሰናይ እዋን ዝምገብዎ ብመንፅር ግምት	ኣብ ሰናይ እዋን ብመንፅር ዕዳጋ	ጠቕላላ ዋጋ	ኣብ ሕማቕ እዋን ዝምገብዎ ብመንፅር ግም ት	ኣብ ሕማቕ እዋን ብመንፅር ዕዳጋ	ጠቕላላ ዋጋ
1	እንስሳትን ናይ እንስሳት ተዋፅኦን						
2	ዝራእቲ (በዝናበን መስኖን)						
3	ፍረ በለስን ገልዒ በለስን						
4	ንግዲ						
5	ካልእ እንተሃልዩ						

2.<u>መጠይቕ ኣብ ርድኢት ምህርቲ በለስ</u>

2.1.በለስ ኣለኩም ዶ? እወ--------------ኣይፋልን---------------- መልስኹም እወ እንተኾይኑ ንምንታይ? ------------
----

2.2. ክንደይ ዝኣክል ሄክታር ብበለስ ዝተሸፈነ ኣለኩም? ---

2.3.በለስ ንምንታይ ዓላማ ኢኹም ትጥቀምሉ?

ሀ.ንወዲሰብ ምግብነት ለ.ንእንስሳት ምግብነት ሐ.ንዕዳጋ መሸጣ መ.ንሓጠር ሠ. ንነዳዲ ረ. ካልእ እንተሃልዩ

2.4.በለስ ኣብ ተሓራሲ መሬት ትተኽሉዶ? እወ---------------ኣይፋልን---------------

መልስኹም ኣይፋልን እንተኾይኑ ንምንታይ?--

2.5. በለስ ኣብ ስድራ ቤት ብመን እዩ ዝውነን? ሀ. ብስብኣይ ለ.ብሰበይቲ ሐ. ብቖልዑት

2.6.ርሕቐት ኣብ ምሕርቲ በለስ ፅዕንቶ ኣለዎ'ዶ? እወ----------- ኣይፋልን------------

መልስኹም እወ እንተኾይኑ ከመይ? ---

2.7.ምጣነ ስድራ ቤት ኣብ ምህርቲ በለስ ፅዕንቶ ኣለዎ'ዶ? እወ--------------- ኣይፋልን----------------

መልስኹም እወ እንተኾይኑ ከመይ? --

2.8.እዋን ምህርቲ በለስ ክንደይ ኣዋርሕ ይኸውን? -----------------------------

2.9.ፍረ በለስ ንምውራድ (ንምቕንጣብ) እንታይ ዓይነት ምህዞ ትጥቀሙ?

ሀ. ኢድ ለ.ናይ ሽቦ ብረት ሐ. ታነካ መ.ካልእ እንተሃልዩ ይጥቀሱ? ------------------------------

2.10. ተኽሊ በለስ ንምስፍሕፋሕ እንታይ ዓይነት ዕድላት ኣለዉ?

ሀ.ኣቕርቦት ተኽሊ በለስ ለ.ግድምታት ሐ.ኣብ ደረቕ መሬት ምችው ስለ ዝኾነ መ.ሓይሊ ሰብ ሠ.ካልኦት እንተሃልዮም ይጠቀሙ? ---

2.11. ተኽሊ በለስ ዝያዳ ኣበየናይ መሬት ንኽትከል ይምረፅ?

ሀ.ኣብ ከባቢ ገዛውቲ ለ.ኣብ ወሰን ሕርሻ ሐ. መሬት ሞጋሰ(መግሀጫ) መ.ካልእ እንተሃልዩ? ------------------------

2.12.ኣብ ምህርቲ በለስ ዕንቅፋት ዝኾንኹም እንታይ እዮም?

ሀ.ነፍሳት ለ.ሕማም ሐ.ኣዕዋፍ መ. ካልእ እንተህልዩ ይጥቅሱ? --

2.13. ካብ ሕማማት፣ነፍሳትንኣዕዋፍን ብኸመይ ኢኹም ትከኸላልዎ? ---

2.14.በለስ ንምትካል ዘለዓዓለኩም ምኽንያት ወይከዓ ዘለዉ ዕድላት እንታይ እዮም? -------------------------------------
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2.15. ኣብ ምስሳን ምህርቲ በለስ ዝኾነ ዓይነት ስልጠና(ሓገዝ) ረኺብኩም ዶ? ---

2.16. ገለ ስድራ ቤት ንምንታይ እዩ ተኽሊ በለስ ዘይብሎም? --

3.መጠይቕ ኣብ በዝሓ ህይወት(ስሳነ ህይወት)

3.1. ተኽሊ በለስ ኣብ በዝሓ ህይወት ፅዕንቶ ኣለዎ ዶ? እወ----------ኣይፋልን------------

መልስኹም እወ እንተኾይኑ ከመይ? --

መልስኹመ ኣይፋልን እንተኾይኑ ከመይ? --

3.2. ኣየናይ ዓሌት ተኽሊ ብቐሊሉ በተክሊ በለስ ይህሰ? --

3.3. ኣየናይ ዓሌት ተኽሊ ኸ ብቐሊሉ ብተኽሊ በለስ ዘይህሰ ወይከዓ ተኽኣኢሉ ክነብር ዝኽእል? --

3.4. ተኽሊ በለስ ጠቓማይ ድዩ ወይስ ጎዳኣይ ብከመይ? --

4. መጠይቕ ኣብ እቶት በለስ

4.1. ናብ ኪሎ ግራም እንትቕየር ክንደይ ዝኣክል ፍረ በለስ ትሸጡ?

ኣብ ፅቡቕ እዋን---------------------------ኣብ ሕማቕ እዋን---------------------------------

4.2. ንሐንቲ ፍረ በለስ ክንደይ ብር ትሸጥዎ? --

4.3. ኣብዚ ዓመት ንምግብነት ዝተጠቐምክምዎ ፍረ በለስ ብገንዘብ እንትግመት ክንደይ ይኸውን?

ኣብ ፅቡቕ እዋን --------------------------ብር ኣብ ሕማቕ እዋን -------------------------------ብር

4.4. ገልዒ በለስ ንእንስሳት ምግብነት ትጥቀምዎ'ዶ? እወ----------- ኣይፋልን----------------

መልስኹም እወ አንተኾይኑ ንምንታይ? ---

4.5. ብግምት ንእንስሳት ዝውዕል በለስ ብገንዘብ እንትትመን ኣብ ፅቡቕ እዋን -----------------------ብር

ኣብ ሕማቕ እዋን --------------------------ብር

4.6. ኣብዚ ዓመት ብግምት ንነዳዲ ዝውዕል በለስ ብገንዘብ እንትልካዕ ክንደይ ይከውን? ---------------------------------

4.7. ኣብዚ ዓመት ብግምት ንሓፁር ዝውዕል በለስ ብገንዘብ እንትልካዕ ክንደይ ይኸውን? -------------------------------

4.8. እቲ በለስ ኣብ ትክክለኛ እዋን ትእክብዎ'ዶ? ---------------------------------------

4.9.ፍረ በለስ ምስኣከብክምዎ ክንደይ መዓልቲ ትዓቑርዎ(ይፀንሕ)? -------------------------------------

4.10. ንመሸጢ በለስ ዝኸውን ናይ ዕዳጋ ፀገም ኣለኩም ዶ? እወ---------------- ኣይፋልን----------------------

መልስኹም እወ እንተኾይኑ እቲ ፀገም እንታይ እዩ? --

4.11. በለስ ንምጉዕዓዝ እንታይ ትጥቀሙ?

ሀ. ወዲ ሰብ ለ. እንስሳ ሐ.ካልእ እንተሃልዩ ይጥቀሱ? -------------------------------------

4.12. ካብ ምሀርቲ በለስ ዝረኸብክምዎ እቶት ኣብ እንታይ ቁም ነገር ተውዕልዎ?

ሀ.ንመምሃሪ ቆልዑ ለ.ንክዳን ሐ.ንሕክምና መ. ንምግቢ ሥ.ካልእ እንተሃልዩ ይጥቀሱ? --------------------------

4.13. ተክሊ በለስ እቶት መነባብሮኹም ይውስኽ ዶ? እወ--------------- ኣይፋልን-----------------

መልስኹም እወ እንተኾይኑ ብኸመይ? ---

4.14. ተኽሊ በለስ እንድሕር ደኣ ጠፊኡ እንታይ ከጋጥመኩም ይኽእል? ---

Appendix III

Table 1 Paired Samples Statistics

			Statistic	Bootstrap[a]			
				Bias	Std. Error	95% Confidence Interval	
						Lower	Upper
Pair 1	Cactus occupied site	Mean	51.9667	.0053	.2695	51.4000	52.5000
		N	30				
		Std. Deviation	1.51960	-.04496	.21963	1.05324	1.88875
		Std. Error Mean	.27744				
	Cactus free site	Mean	25.2000	.0030	.2351	24.7333	25.6992
		N	30				
		Std. Deviation	1.33907	-.04542	.21078	.85075	1.69136
		Std. Error Mean	.24448				

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Paired Samples Test

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Cactus occupied site - Cactus free site	**26.76667**	**.76489**	**.13965**	**26.48105**	**27.05228**	**191.671**	**29**	**.000**

Table 2 Cactus occupied site and Cactus free site

Paired Samples Statistics

			Statistic	Bootstrap[a]			
				Bias	Std. Error	95% Confidence Interval	
						Lower	Upper
Pair 1	Cactus occupied site	Mean	108.00	.97	39.23	43.44	194.67
		N	7				
		Std. Deviation	108.995	-15.746	35.239	29.137	145.361
		Std. Error Mean	41.196				
	Cactus free site	Mean	248.57	1.22	89.51	110.45	447.83
		N	7				
		Std. Deviation	249.564	-41.210	94.358	33.276	339.557
		Std. Error Mean	94.326				

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Cactus occupied site - Cactus free site	-140.571	144.035	54.440	-273.781	-7.362	-2.582	6	.042

Table 3

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	ıge Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.643[a]	.413	.393	1665.50354	.413	20.882	3	89	.000

a. Predictors: (Constant), Cactus land size , Family size, Land holding size
b. Predictors: (Constant), Cactus land size , Land holding size, Family size

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	173771842.463	3	57923947.488	20.882	.000[b]
	Residual	246877281.817	89	2773902.043		
	Total	420649124.280	92			

a. Dependent Variable: Average income

b. Predictors: (Constant), Cactus land size , Family size, Land holding size

c. Predictors: (Constant), Cactus land size , Land holding size, Family size

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	13343.241	910.446		14.656	.000	11534.204	15152.278
	Family size	-318.580484	112.665833	-0.170355	-2.827658	0.005791	-542.445094	-94.715875
	Land holding size	6662.948	1151.977	.531	5.784	.000	4373.994	8951.902
	Cactus land size	1531.325	623.615	.215	2.456	.016	292.215	2770.434

Figure. Preakly cactus pear on the marketing

Figure. Cacti roastedand feed processing

Figure. Cattle feeding on pads of cactus

Figure.Cactus used as live fence on the home stead

Figure.Cactus occupied areas

Figure. Edible cactus pear in the field

Figure. Cactus pear in the market

Figure.Cactus pear harvested

Figure.*Opuntia ficus-indica* in the field