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COLLEGE OF NATURAL AND COPUTATIONAL SCIENCESDEPARTEMENT OF ZOOLOGICAL SCIENCE

GENERAL BIOLOGY

EFFECTS OF CHARCOAL PRODUCTION ON ENVIRONMENTAL DEGRADATIONIN SHABE SOMBO WOREDA,JIMMA ZONE,OROMIOA REGIONAL STATE, ETHIOPIA.

A thesis submitted to Addis Ababa University college of natural and computational science, department of Zoological science for the partial fulfillment and requirement of M.Sc. degree in Biology

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Declaration of Competing Interest

The authors declare that he has no known Competing financial interest or personal relationship that could have appeared to influence the work reported in this paper.

This is to certify that thesis entitled Effects of Charcoal production on Environmental Degradation, in shabe sombo woreda, Jimma Zone ,Oromia Regional State, Ethiopia. Prepared and submitted by Misgana Mamo with the regulation of the University and meets the accepted standard with respect to originality and quality.

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ABSTRACT

Charcoal is impure form of graphite carbon produced from wood under high temperature and low Oxygen. Charcoal has been an essential part of human life for thousands of years. It's fascinating to think that the earliest cave drawings, dating back over 30,000 years, were created using charcoal. Charcoal production can lead to environmental issues such as deforestation, water shortages, and loss of biodiversity. This study set out to understand how charcoal production affects the environment in Shabe Sombo woreda of Jimma Zone, Oromia Regional State, Ethiopia. A combination of explanatory and descriptive methods, including surveys of 154 charcoal producers from five different kebele were used. Data were collected through questionnaires and interviews with local household, development agents, and the woreda agriculture experts and then analyzed by different statistical methods such as frequency, percentage, mean, standard deviations. Notable 38.9% informants agreed that charcoal producers degrade vegetation cover by cutting fuel wood with an average of 2.62 and standard derivation of 1.24 .Coefficient of 0.736 ($p<0.01$), a robust a relationship where increases in deforestation are associated with overall environmental degradation. The regression of sum of square is 71.33, the predictor's water and air pollution, soil erosion, deforestation, drought and deforestation have strong collective impact. The increased production of charcoal results in increased forest degradation i.e. deforestation and drought played significant roles in the degradation of the ecosystem. Provide training for households about the environmental downsides of charcoal production, promoting a forestation or planting trees to replace those that are cut down could help mitigate the negative effects of charcoal production and support environmental recovery.

Key words/phrases: *charcoal, deforestation, desertification, drought, land degradation and soil erosion.*

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LIST OF ACRONOMS/ABBRIVATION

ANOVA………Analysis of variance

CBFM………….Community Based Forest Management

CO………………Carbon monoxide

CO^2……………..Carbon dioxide

Df………………Degree of freedom

EEPA----------------Ethiopian Environmental Protection Agency

FAO………………Food and Agricultural Organization

FGD………………Focus Group Discussion

GHG…………… Green House Gas

JAICA……………..Japan International Cooperation Agency

MDG…………… Millennium Development Goal

MEWD……………Ministry of Energy and Water Development

NGO--------------------Non-Governmental Organization

SNNPRS………………South Nation and Nationalities and People Regional State

SPSS……………….Statistical Package for Social Science

Std…………………. Standard error

TEK………………Traditional Ecological Knowledge

UNDP………………United Nations Development Programme

UNEP………………United Nations Environment Programme

WHO---------------------World Health Organization

1. INTRODUCTION

1.1 Back ground of the study

Charcoal is impure form of graphite carbon produced from wood under high temperature and low oxygen. Charcoal has been an essential part of human life for thousands of years. It's fascinating to think that the earliest cave drawings, dating back over 30,000 years, were created using charcoal. Throughout history, charcoal has played a critical role in metalworking, one of human first technological breakthroughs. Its importance hasn't faded over time; today, its unique properties make it invaluable for things like purifying water and air. During World War I, activated charcoal in gas masks saved countless lives by protecting soldiers from harmful gases (Peter, 1999).According to Gichuho (2013), wood fuel, along with charcoal, is a major global energy source and was the first form of energy used by humans. The FAO (2010) reported that more than 3 cubic meters of wood are used annually for energy worldwide, surpassing other types of biomass. In developing countries, especially in rural areas, over 2 billion people rely on fuel wood for their primary energy needs (FAO, 2010). Together, wood and charcoal account for more than 14% of the world's energy supply. In Africa alone, 63% of the world's charcoal is used, with most of it consumed in rural and urban areas alike (FAO, 2012). However, the high demand for charcoal brings serious challenges. Unsustainable production practices lead to deforestation, which can threaten agriculture, ecosystems, and human health (Smith et al., 2004; Ghilardi & Steierer, 2011). This problem is especially acute in Eastern Africa, where many people live in poverty and rely heavily on charcoal for energy (FAO, 2010). Since the World Summit in Copenhagen in 1994, and with the Millennium Development Goals (MDGs), addressing poverty has been a key focus. Yet, the charcoal industry, which flourishes in rural areas due to low barriers to entry (Barbier et al., 2010), also contributes to environmental damage and loss of forest cover. Traditional production methods, often used by those with limited access to education, make it hard to manage natural resources sustainably, leading to loss of livelihoods and biodiversity (FAO, 2012).

Charcoal production isn't just an environmental issue it also has health implications. Burning charcoal and wood can release harmful gases, leading to respiratory problems, especially in households without proper ventilation (Grieg-Gran 2015). Despite its economic importance, including its role in local employment and revenue generation, the charcoal industry is often overlooked in energy policies and poverty reduction strategies, which typically focus more on power and petroleum sectors (Iiyama, 2013).

In places like Shabe Sombo woreda of Jimma Zone where charcoal production is common, these challenges are no evident.

1.2. Statement of the problem

In many low-income countries, large-scale charcoal production is linked to serious problems like deforestation, land degradation, and climate change (Jones, 2015). In rural eastern Africa, charcoal is widely used because it's affordable and doesn't require much skill or investment to produce. While it provides an important source of income and helps many people escape poverty, it also comes with significant environmental drawbacks. Charcoal production can lead to environmental issues such as deforestation, water shortages, and loss of farmland. This, in turn, can worsen hunger, illness, and poverty. Many people rely on traditional charcoal-making methods, which are often inefficient and contribute to the depletion of natural resources and loss of biodiversity due to limited access to better techniques and information (UNEP, 2012). The resulting land degradation can also lead to increased migration and conflicts, and negatively affect agricultural productivity and living conditions (Ghilardi&Steierer, 2011).Burning charcoal releases harmful substances like carbon monoxide and nitrogen oxides, which can be dangerous to health and contribute to air pollution. Although the impact of charcoal on climate change is relatively small, it still plays a role in the broader issue (Gumbo et al., 2013).On a positive note, research has shown that charcoal and other forest products can be a significant source of income, especially for female-headed households. Studies by Yemiru et al. (2010) and Aynalem (2012) have shown that these resources can be crucial for women's financial stability. Additionally, research by Kasahun (2008) and Alemayehu (2010) found that a variety of forest products, from building materials to food and medicines, are important for local and sometimes national markets.

However, the production methods used are often inefficient and lead to poor-quality products and greenhouse gas emissions (Gebre et al., 2022). Fitwangile (2017) reported that many farmers face challenges like financial constraints and lack of support, which limit their ability to adopt better, more sustainable production methods. This study aims to fill a gap by exploring the impact of charcoal production on the environment in Shabe Sombo woreda of Jimma Zone. It highlights the need for better policies and more support from local and regional stakeholders, such as forest management offices and development agencies.

In Shabe Sombo woreda of Jimma Zone, charcoal production is a major economic activity for many farmers who depend on it to support their families and meet their needs. Urban residents in the woreda use charcoal for cooking and energy, and it is also sold throughout the region for profit (forest and natural resources offices of Shabe Sombo woreda, 2022). This study will investigate how charcoal production affects the environment in this area of South West Ethiopia.

1.3. Research Questions

1. What are the effects of charcoal production on deforestation in shabe sombo woreda?

2. What is the impact of charcoal production on deforestation drought in Shabe sombo woreda?

3. What is the impact of charcoal production on land degradation in Shebe Sombo woreda

Charcoal production may have effects on environmental degradation.

1.4. Objectives of the Study

1.4.1 General objective

The general objective this research was to find out the effects of charcoal production on environmental deterioration in Shabe Sombo woreda of Jimma Zone.

1.4.2 Specific objectives

- ✓ To understand how making charcoal affects deforestation in Shabe Sombo woreda.
- ✓ To explore the extent of deforestation in Shabe Sombo woreda due to charcoal production
- ✓ To see how charcoal production impacts water quality and air pollution.

1.5. Significance of the Study

Once this research is completed, it will bring several important benefits:

- ➢ To Local Communities: The study will help local households understand how using charcoal affects their health, economy, and environment. By gaining this knowledge, people will be more motivated to stop cutting down trees for charcoal and instead focus on planting new trees and taking care of forests for income.
- ➢ To Forest and Development Offices: The insights from this research will support the forest and development offices in Shebe Woreda. They can use this information to run training sessions and awareness programs that educate people about the harm charcoal does to the environment and how they can help protect it.

- To researchers: This study will also serve as a valuable resource for other researchers. It will provide a starting point for further investigations into the effects of charcoal on environmental degradation.

1.6. Limitation of the study

This study looked at how charcoal production affects the environment in Shebe Somboworeda of Jimma Zone. It specifically targeted five kebeles, Guma, Halo Godante,Sabaka Dabiye, Angaca, and Morgano that are heavily involved in charcoal production. The research explored various environmental issues related to this activity, including deforestation, desertification, land degradation, and problems with water and air quality. By focusing on these areas, the study aimed to get a clear picture of how charcoal production impacts the local environment.

People are not interested to give information about effects of charcoal production, again there is lack of budget and transport

2. REVIEW OF LETRATURE

2.1. History of Charcoal Production

Charcoal has been used by humans for thousands of years, with the earliest evidence found in ancient cave drawings from about 30,000 years ago (van Beukering et al.,2007). Today,over 2 billion people around the world still rely on charcoal for their energy, especially in rural areas of developing countries (FAO, 2010). The production of wood charcoal reached 55 million tones in 2021 up 49% from the 2000 level (FAO,2021).

In Africa, charcoal is a vital energy source for about 94% of the rural population and 73% of urban dwellers, though urban areas typically use more charcoal and rural areas depend more on firewood (Bailis et al., 2007; Seidel, 2008). In Ethiopia, the situation is particularly dire. Over the past few decades, the country has faced severe deforestation and environmental degradation.

The rapid population growth in Ethiopia has led to increased demand for farmland, construction materials, and firewood. This, combined with factors like urban expansion, road building, and overgrazing, has put tremendous pressure on the country's forests (Tola, 2005; UNDP, 2012). As a result, the ongoing demand for charcoal continues to drive deforestation and environmental harm (Hosonuma et al., 2012).

Efforts to produce charcoal sustainably are crucial but challenging. The goal is to avoid depleting natural resources faster than they can recover (Ribot, 1998; Roop, 2013). Despite these efforts, charcoal production still leads to significant forest resource extraction and land degradation (Berkeley, 2000). it has become a major part of the energy mix, meeting around 87% of the country's final energy needs. This includes 86.8% of energy in rural households, 8.2% in urban homes, and about 5% in other sectors (Guta, 2012).

The charcoal industry also supports the economy by creating jobs, generating tax revenue, and providing income for rural communities (FAO, 2012). Producing charcoal involves many steps and a lot of labor, from collecting and preparing the wood to loading and unloading kilns, packaging, transporting, and selling the final product (Kituyi, 2002; Mwampamba, 2007). To counteract the environmental impact, Ethiopia has been investing in reforestation and afforestation efforts since 2006. Studies by Gebretsadik et al. (2019) highlighted the effectiveness of modern kilns that improve the efficiency of charcoal production, reducing the amount of wood needed by approximately 40% compared to traditional methods. These efforts have helped reduce deforestation rates in areas where these technologies have been adopted. With Ethiopia's population continuing to grow rapidly, research by the Ethiopian Forestry Society (2020) emphasized the intensifying pressure on forest resources. The study found that annual deforestation rates accelerated to an alarming 1.5%, primarily driven by urban expansion and the rising demand for charcoal in growing cities like Addis Ababa. These findings have underscored the need for more aggressive conservation strategies.

As global attention on climate change increased, several studies, including work by Mekonnen et al. (2021), explored the role of charcoal production in Ethiopia's greenhouse gas emissions. Findings revealed that traditional charcoal production methods contribute significantly to carbon emissions, calling for a transition to cleaner energy alternatives and promoting sustainable forest management practices. To address the environmental and economic challenges, Ethiopia has been revising its policy frameworks to regulate charcoal production more effectively. Research conducted by the Ministry of Environment, Forest, and Climate Change (2022) assessed the impact of these regulatory measures, which include enforcing reforestation requirements and promoting alternative energy sources such as briquettes made from agricultural waste. These policies have shown promise, although enforcement remains inconsistent. A study by Tadesse et al. (2023) revealed that involving local communities in reforestation efforts has increased the success rate of tree planting programs, particularly in areas that were previously heavily degraded by charcoal production. These programs have not only contributed to restoring forests but have also provided new income sources through the cultivation of fast-growing tree species. Studies by Bekele (2021) and Yimer (2022) investigated the potential of solar, biogas, and other renewable energy solutions as substitutes for charcoal in both urban and rural households. These studies found that while adoption rates are still low, there is growing awareness and interest in alternatives, driven by government incentives and international aid programs.

2.2. The Methods of Charcoal production

Charcoal is usually made through a process called slow pyrolysis,where wood or other materials are heated without oxygen. This method produces charcoal, which is not perfectly pure because it contains some ash. However, there’s another type of charcoal, made from sugar using a dehydration process with sulfuric acid that tends to be purer. This sugar charcoal is soft, brittle, lightweight, black, and porous, and it looks a lot like coal (Joze, 2013).

In Slovenia, charcoal production traditionally involves stacking wood into piles, a technique that has been used around the world for centuries. These piles can be shaped in different ways, but the most common method today is to stack the wood vertically. Ideally, the logs should be the same length and diameter to ensure consistent quality, although any type of wood can be used. To get the best charcoal, it's best to use wood with similar properties (Joze, 2003).

Recently, Slovenian charcoal makers have started using techniques similar to those in Germany. They ignite the pile through a vertical chimney placed in the center. The wood is arranged around this chimney and covered with a layer of soil and needles to control air flow and keep the pile from burning too quickly. A small hole is made in the ground to let air into the firebox, allowing the fire to smolder rather than blaze. The logs are stacked on a well-packed dirt base, often mixed with clay, to make sure the pile stays airtight. This traditional method remains popular in Slovenia today. The success stories of charcoal-making are few in Ethiopia. This is a result of Ethiopian charcoal producers using non-standardized processes and tools. A thorough analysis of Ethiopia's charcoal production using traditional methods found that, on average, 71% of the country's wood resources were lost (Geller, 2004). The use of the traditional way of producing charcoal has an adverse effect on yields. The actions of traditional charcoal producers in Ethiopia are unregulated, which allows them to fell trees arbitrarily, in contrast some other countries such as Senegal where the charcoal trade is regulated. Daily consumption of a number of resources puts the nation vulnerable to desertification (Geller, 2004). The conventional method of producing charcoal is employed by 99 percent of Ghanaian charcoal producers. The sustainability of the forest resources is threatened by this technique, also referred to as the earth mound method. Compared to contemporary technologies (such as the kiln) of charcoal manufacturing used in nations like Senegal, the process is wasteful and lowers overall yields of charcoal production (Lurimuah, 2011).

Pyrolysis refers to a method of heating wood under absence of oxygen in kilns having closed chambers. The incomplete combustion is the basis of this carbonization process through which charcoal is obtained from wood within four consecutive phases. In the first phase wood loses only water and its external form does not significantly change. This occurs at temperatures below 170°C. Decomposition of wood is the second phase which occurs between 170°C and 270°C. Organic acids and tars are evolved together with water vapor. Also gases like CO and CO^2 are gradually evolved.

The third phase takes place between 270°C and 350°C, where wood decomposition proceeds with evolution of gases and organic liquids at higher rate accompanied with heat. The final phase occurs above 350°C, where wood decomposition takes place in a smoother manner. During this phase relative amount of CO and CO_2 to H^2 and light hydrocarbons goes down as the temperature increases. The process ceases at temperatures between 450°C and 550°C. Above these temperatures the charcoal formed starts to be consumed thus decreasing the yield.

2.3. The Effects of Charcoal Production

The ongoing charcoal production is taking a serious toll on our forests and land. Research from the Berkeley (2000) showed that while we might not completely lose all forest cover, the ongoing degradation is causing big problems. This includes the loss of biodiversity, increased soil erosion, and changes in water cycles (Gichuho et al., 2013). Even if forests aren't entirely wiped out, their decline impacts climate and nature in a big way. Degraded lands struggle with managing storms, lose their rich biodiversity, and face more erosion. Gillard & Stirrer (2011) highlight that charcoal production affects not just the environment but also poverty, greenhouse gas levels, and human health. Pennies et al. (2001) reported that carbon emissions and the shrinking of forests are key issues tied to charcoal production. To tackle these problems, it's crucial to keep educating people about the environmental costs of charcoal until consumption drops. Logging, which is often linked to deforestation, can also lead to significant forest damage (Putz et al., 2001). It opens up roads for settlers and helps fund the clearing of more trees for farming or grazing. The real tragedy of forest degradation is the loss of habitat, which drives species to extinction. Forests, especially rain forests, are incredibly rich in life. When a tree species disappears or logging disrupts the habitat, it can ripple through and impact nearby ecosystems.

2.4. Impact of Charcoal production on Environment

Charcoal production offers a vital source of income for many people, especially in rural and urban areas (Kammen& Lew, 2005). However, this benefit comes with significant environmental costs. The impact is worsened by additional pressures such as construction and overgrazing. The focus of recent studies has been on the harmful effects of charcoal production on the environment.

One major issue is that not only are trees cut down to produce charcoal, but herbs are also collected and burned during the kilning process. This results in damage to the topsoil and prevents vegetation from regrowing, even after heavy rain. Researchers have observed significant environmental damage, including young trees that are struggling to grow landscapes littered with burned stumps and branches, and abandoned kilns. The roads created by trucks transporting charcoal further exacerbate land degradation and deforestation. The strain on these areas is visible through a range of environmental issues: deforestation, soil erosion, frequent droughts, migration to cities, reduced wildlife, and depletion of resources (Ayalew et al.,2021). The removal of trees and vegetation for charcoal production leaves the soil exposed, leading to a higher rate of erosion, especially during the rainy season. This degradation reduces soil fertility and negatively affects agricultural productivity in nearby areas, contributing to food insecurity.EEPA (2022) focused on the effects of deforestation caused by charcoal production on local water cycles. The study found that areas with heavy deforestation experienced altered rainfall patterns, reduced water retention in the soil, and lower groundwater levels. These changes have made local communities more vulnerable to droughts and have affected agricultural practices. A study by the UNEP.,(2021), emphasized the role of charcoal production in contributing to greenhouse gas emissions. The research highlighted that traditional methods of charcoal production release large amounts of carbon dioxide and other greenhouse gases into the atmosphere. This not only contributes to global warming but also makes charcoal production one of the major contributors to Ethiopia's carbon foot print.

2.4.1 Impact of Charcoal production and loss of Biodiversity

In Africa, charcoal production is often done in a way that’s far from sustainable. Research by Zulu & Richardson (2013) points out that a lot of the wood used for charcoal comes from sources that aren't managed well. In fact, a recent study by Bailis et al. (2015) found that in 2009, between 27% and 34% of wood fuel was harvested un sustainably, especially in parts of eastern and southern Africa where the demand is highest. With Sub-Saharan Africa’s cities are growing rapidly and its population increasing, sticking with current charcoal production practices could lead to major land use changes, especially damaging dry land forests and woodlands (Bailis et al., 2007; Iiyama et al., 2013).

In Sub-Saharan Africa, charcoal is often made from natural forests, village woodlands, and land cleared for farming (Hofsted et al., 2009). When wood is burned in a basic kiln, only about 8% to 20% of it turns into charcoal (Chidumayo &Gumbo, 2014; Tabuti et al., 2003). While agriculture is the main driver of deforestation, charcoal production also causes local deforestation and degrades forests around production areas. In Africa, it’s estimated that up to 80% of the world’s deforestation due to charcoal happens here, with yearly deforestation estimates varying widely (Chidumayo and Gumbo, 2014).

Instead of clear-cutting forests, charcoal production often involves selective logging, which can lead to forest degradation. In cities across Sub-Saharan Africa, this practice is linked to various environmental issues like reduced agricultural productivity and carbon loss (Zulu & Richardson, 2013). Unlike outright deforestation, which is more noticeable, forest degradation from charcoal production can be harder to detect and assess because these forests often still have a canopy (Chidumayo & Gumbo, 2013; Mwampamba et al., 2013).

The selective cutting of trees for charcoal, especially slow-growing hardwoods, changes the forest's makeup and harms essential services like erosion control, water quality, and biodiversity (Naughton-Treves et al., 2007; Iiyama et al., 2015). As charcoal production shifts to drier areas, forest quality and biodiversity continue to decline (Arnold & Persson, 2003). Moreover, the environmental costs of charcoal production are often not included in the product's price (Luoga et al., 2000).

Charcoal production also releases a significant amount of greenhouse gases, with Africa responsible for nearly two-thirds of these emissions globally (Kammen & Lew, 2005; Chidumayo and Gumbo, 2013). Biodiversity is crucial for ecosystem health, and when habitats are destroyed, it affects all the interconnected species within them (Rockstrom et al., 2009; IUCN, 1997). For instance, a single fruit tree supports many birds and mammals, and losing such trees disrupts entire ecosystems (Kiage, 2013).

Forests are vital for preventing soil erosion, maintaining water resources, and supporting wildlife (O'Keefe, 1979). Unsustainable charcoal production threatens these benefits by causing deforestation and habitat loss. This not only increases greenhouse gas emissions and disrupts local climates but also impacts people's lives, as many rely on forests for their livelihoods. Deforestation can even lead to conflicts as communities struggle with these environmental changes (Bailis, 2005).

A study by Kassa et al. (2020) highlighted the severe impact of charcoal production on biodiversity in Ethiopia's remaining forests. The research found that areas subjected to intensive charcoal production saw a reduction in plant and animal species, with some areas losing up to 40%

of their biodiversity. The loss of tree species and habitat fragmentation due to charcoal-related deforestation has also contributed to the extinction threat for several endemic species in Ethiopia.

2.4.2. Health Impacts of Charcoal Production

Moreover, cooking with charcoal poses serious health risks. The smoke from charcoal exposes people to harmful chemicals, which can have severe health consequences (Akpalu et al., 2011). Issues linked to charcoal use include heart disease, blindness, complications during pregnancy, and respiratory problems like asthma and acute respiratory infections (WHO, 2002). While charcoal may produce less smoke than firewood and thus may lead to fewer respiratory-related deaths (Bailis et al., 2015), the risk of carbon monoxide poisoning remains significant, with many deaths reported each year (UNDP, 2000). Women and children are particularly vulnerable due to their frequent and prolonged exposure to smoke.

Studies show a clear connection between indoor air pollution from cooking stoves and respiratory conditions. This includes chronic lung diseases in adults and severe respiratory infections in children (Ezzati &Kammen, 2001; Akpalu et al., 2011). To address these health concerns, there's a growing focus on improved stove designs. These upgraded stoves aim to be more fuel-efficient and produce fewer emissions, which can help reduce deforestation and improve public health (Zein-Elabdin, 1997). Research indicates that these improved stoves can save between 10% and 60% of fuel (Bazile, 2002; Bhattacharya et al., 2002; Maesa & Verbist, 2012). However, when compared to other pressing issues like water availability and sanitation, the immediate health risks from stove emissions might not seem urgent (Arnold et al., 2006). To fully understand and address these issues, more research is needed on how people adopt and use these improved stoves.

2.4.3 Social Impacts of Charcoal Production

The impact of charcoal production and trade on poverty is deeply connected to how these activities affect local power dynamics and community strength. When implemented effectively, Community-Based Forest Management (CBFM) techniques and supportive policies can significantly boost local communities' ability to voice their needs, make decisions, and manage resources. This approach can improve fairness, social justice, and access to forest resources, helping people become more self-reliant and equitable (Agrawal, 2005).

However, the reality is often different. Power struggles and inequality frequently plague forest resource management. Conflicts over access to resources, including those related to charcoal production, can create barriers. Problems like arbitrary bureaucracy, threats of violence, corruption, and inconsistent government actions can make people feel powerless and dependent. These issues drive up costs, allow powerful groups to take advantage, worsen gender inequalities, and leave the poor marginalized. They also weaken the legal protections meant to safeguard those involved in charcoal production and trade (Agrawal, 2005; Richardson, 2010).

In many African countries, strict regulations on legal charcoal production and trade not only limit people's ability to earn a living and fight poverty but also push these activities into the informal sector. In this unofficial space, small-scale producers face significant risks, including abuse, theft, and intimidation by corrupt officials. These dangers drive up costs and lower their earnings (World Bank, 2009;).

2.5. Wood Fuel Situation and Charcoal Consumption

While a substantial amount of wood is turned into charcoal, most of it is still used directly as fuel. Cities, in particular, use more than 80% of this fuel wood, making charcoal a key energy source for many households in African cities (Amour, 1997   Siedel, 2008; Kammen et al., 2005).

Back in 2000, the world produced over 3.9 billion cubic meters of wood, and about 2.3 billion cubic meters of that was used for fuel. This means that nearly 60% of the wood taken from forests globally is used to generate energy (FAO, 2008). In Africa, the situation is even more striking, with more than 90% of the timber removed from forests being used as fuel.

In Ethiopia, a 2012 study showed that over three-quarters of the country's biomass consumption comes from fuel wood, while crop residue and animal manure make up smaller portions 9% and 13%, respectively. The majority of this fuel wood is consumed in three main regions: Amara, Oromia, and the SNNP region, which together account for about 88% of the total fuel wood use. In southern Ethiopia, biomass fuels are essential for daily life, with most people relying solely on them for cooking and heating. In these rural areas, wood, cow dung, and corncobs are commonly used. Fuel wood remains the most important source, with almost 90% of Ethiopians depending on it along with charcoal, crop residue, and leaves for their energy needs.

Looking back at the 1980s, World Bank data from 1984 projected that Ethiopia’s fuel wood consumption was around 20 million tons, while the country could only produce 8.1 million tons annually. This meant that Ethiopia was using about 2.5 times more fuel wood than it was able to produce. By 1994, the Ethiopian Forestry Action Plan highlighted an even greater discrepancy:

consumption had jumped to 35 million tons, but production had only risen slightly to 8.6 million tons, widening the gap to over four times the annual yield.

The "fuel wood gap" approach, which calculated the difference between fuel wood consumption and production, was key in driving energy policies and planning in Ethiopia during the 1970s and 1980s.

2.6. Farmers Knowledge of the Impacts of Charcoal Production on Forest Destruction

In regions rich in biodiversity, local people often hold a deep and intricate knowledge of their environment, known as "Traditional Ecological Knowledge" (TEK). This knowledge includes their understanding of local species, ecosystems, and how these have changed over time (Warren et al. 1995; Alcorn 1999). Studies show that this traditional wisdom plays a key role in managing and preserving both natural and human-altered environments (Fujisaka et al. 2000; Pohle 2004).

Local attitudes towards natural resource use, management, and protection are often shaped by practical needs and cultural values. Farmers, in particular, are influenced by their personal experiences and views, as well as by broader political and economic factors.

As we face challenges like deforestation, habitat destruction, and species loss, TEK becomes even more crucial. Local communities, with their long-term relationship with the land and their cultural insights, offer valuable perspectives on these issues. They might also have developed their own strategies to deal with environmental risks (Stadel 1989, 1991). Engaging farmers in conservation efforts, or ideally having them lead these efforts, is essential for successful environmental protection. Their commitment and attitudes towards conservation are vital for achieving sustainable development.

It’s hard to separate how farmers see forests from the actual damage done to them. Research shows that people’s perceptions greatly influence how they interact with their environment. Ferguson et al. (2004) found that what people know and believe impacts their behavior. Ellen (1993) explains that perception is how people make sense of their surroundings through their own experiences and thoughts.

A farmer’s view of charcoal production, for instance, affects their actions towards the environment. Gibson et al. (1997) describe perception as the way we interpret and understand the world around us. So even if two people see the same thing, they might interpret it differently based on their individual perspectives. Often, how people perceive a situation matters more than the actual facts.

As Singha (2013) points out, understanding local views on forest resources and land is key to creating effective forest management policies.

Before 2005, the forest saw only small-scale wood removal, mainly for local construction and fuel. People would cut down a few types of trees by hand and transport them using donkey carts. However, tensions grew when new settlers and commercial operations began clearing large areas of forest for crops. Faced with prolonged droughts, poor agricultural yields, and limited options, locals turned to charcoal production. They were also influenced by reports of the high profits being made by other charcoal producers. Even though farmers are aware of the harm caused by charcoal production, they feel it hasn't brought them much benefit. They often view the earlier charcoal permits as just a way to get energy. When they got the chance to reclaim the forest areas, they used them to show the impacts of charcoal production. Generally, their view of forests tends to focus more on the financial benefits of converting the land rather than on preserving it.

2.7. Theoretical Framework

To understand environmental destruction, we need to grasp the idea of the "tragedy of the commons." This concept reveals a common problem: when many people act in their own self-interest, they often end up depleting a shared resource, even though it's clear that such actions are harmful in the long run (Hardin, 1968). Essentially, when everyone uses a resource freely, like trees for charcoal, it can be overused and eventually destroyed (Hardin, 1968).

Preventing this kind of destruction requires a change in how we value and think about our environment (Foddy et al., 1999). In areas where charcoal production and illegal wood cutting are prevalent, a range of stakeholders are involved, and their actions are influenced by Ethiopia’s forestry policies and laws. These policies are shaped by a mix of political interests, public statements, and the actions of various players in the forestry sector. The process of using forest resources, such as timber and charcoal, is complex, with structural challenges and interactions between different institutions (Long 1992).

Though the use of forest products is on the decline, the interactions between forest managers, local groups, and political figures are crucial in shaping effective policies (Burchell et al. 1991). There is a growing push for policies that focus on practical implementation and foster dialogue among various national actors, which of could lead to better and more impactful outcomes (Hill 1997). The Forest Policy of 1998 aims to manage forests sustainably by conserving resources, protecting the environment, and involving local communities more actively (GRZ 1998).

Locals increasingly rely on forest resources like charcoal and timber for their income. Including marginalized groups, such as charcoal producers, policy discussions can help integrate the informal sector into formal decision-making processes, which are often overlooked by traditional institutions (Held 1996). Historically, open forest areas, which are crucial for both timber and charcoal, were often ignored in policy discussions that focused on commercial production. Over the years, policies have recognized the rising dependence on charcoal and its environmental impacts, prompting calls for better approaches. To tackle forest loss, the Forest Policy emphasizes sustainable fuel wood extraction, improved technology, and the use of alternative energy sources and plantation species for charcoal production. The 2007 update to the 1995 Energy Policy acknowledged charcoal as an alternative energy source and looked at its role in the national energy mix (MEWD, GRZ 2008). This update aimed to reduce charcoal dependency by promoting rural electricity and ensuring better management of the fuel wood sector through ongoing monitoring of production, pricing, and consumption levels (GRZ 2007).

2.8. Empirical Literature

Forests play a crucial role in many people's lives, particularly in rural areas where they provide a wealth of resources. Research highlights just how integral forests are to people’s everyday survival and economic well-being. For example, studies show that communities living near forests depend heavily on these areas for everything from food and fuel to building materials and medicines (Aynalem 2012; Yasuoka et al. 2012).

In many rural regions, especially in developing countries, forests are more than just a backdrop—they are a lifeline. Forests provide essential goods like fuel wood for cooking and heating, materials for building homes, and even herbal remedies. The World Bank (2008) notes that people in both forest-rich and forest-poor areas rely on forests for many practical needs, such as grazing land, construction supplies, and even traditional medicines. For farmers, forest materials can be a cost-effective alternative to purchasing tools and equipment from markets (Shimizu 2006). Beyond daily needs, forests also contribute significantly to people’s income. The World Bank (2008) estimates that non-timber forest products can make up 10-25% of income for smallholders living on the edges of forests. In Ethiopia, for example, forests provide free resources like fuel, timber, and medicinal plants, which not only support daily living but also generate cash and create job opportunities in rural areas (Demel 2001; Kasahun 2008; Alemayehu 2010).

For many people, especially those with fewer resources, forests are a vital source of income. Studies have shown that forest products can account for a substantial part of a family’s cash income. For instance, in the Bale highlands of Ethiopia, non-timber forest products contribute significantly to the income of many families, particularly those not among the wealthiest (Yemiru et al. 2010). Women and children often rely heavily on forest resources, and in many cases, they earn a significant portion of their income from selling these products (Aynalem 2012). During tough times, the value of forests becomes even more evident. In areas hit hard by crises like HIV/AIDS, forest resources provide critical support when other sources of food and income are scarce (Shimizu 2006). For many households in Ethiopia, selling forest products has been a key strategy for coping with challenges like livestock loss or poor crop yields (Yemiru et al. 2010).

In essence, forests act as a safety net for rural communities, offering vital support even when times are hard. While some might argue that the importance of forests is overstated in times of crisis (Byron &Arnold 1997; Shimizu 2006), it's clear that forests are essential not only for survival but also for economic stability. They provide more than just basic needs they help improve health, support financial stability, and contribute to broader economic activities (Byron and Arnold 1999; Mahanty et al. 2006)

3 .MATERIALS AND METHODS

3.1. Description and Location of the Study Area

This study was conducted in Shebe woreda in Jimma Zone, Oromia Regional State South West Ethiopia at distance of about 400 kilometers from Addis Ababa and 50 kilometers from Jimma town South direction. The woreda (district) is neighbor to Seka Chekorsa woreda, in the west Gera woreda, in the east Seka Chekorsa woreda in the north and Gimbo woreda in the south demarcated by Gojeb River. Shebe Sombo woreda was separated from Seka chekorsa in 1998 E.C. The Woreda has an area of 1191 km^2 with 21 kebeles and have a sub- tropical climate with altitude of 1793-2000 meter above sea level. and a temperature ranging from 7.3 ºC to 30 ºC. The climate of this woreda is 20% kola,15% Dega and 65% Weyna Dega and the setting of the land is plateau and hills ever greenery area forestry of Belete Gera. The amount of rainfall ranges from 1200–2440 mm, 70% precipitation summer (May-September). People from defferent ethnic group are living together harmoniously. The population of the Woreda is 139919 in 2017, (68799 male and71120 female). About 85% the residents of the wereda are engaged in agriculture and 15% were engaged indifferent business activities government employers, and others. The people in come, most importantly depend on the coffee production. The area is also known by cultivation of Teff, sorghum, and maize (source: ShebeWoreda plan and economic development office, 2023).

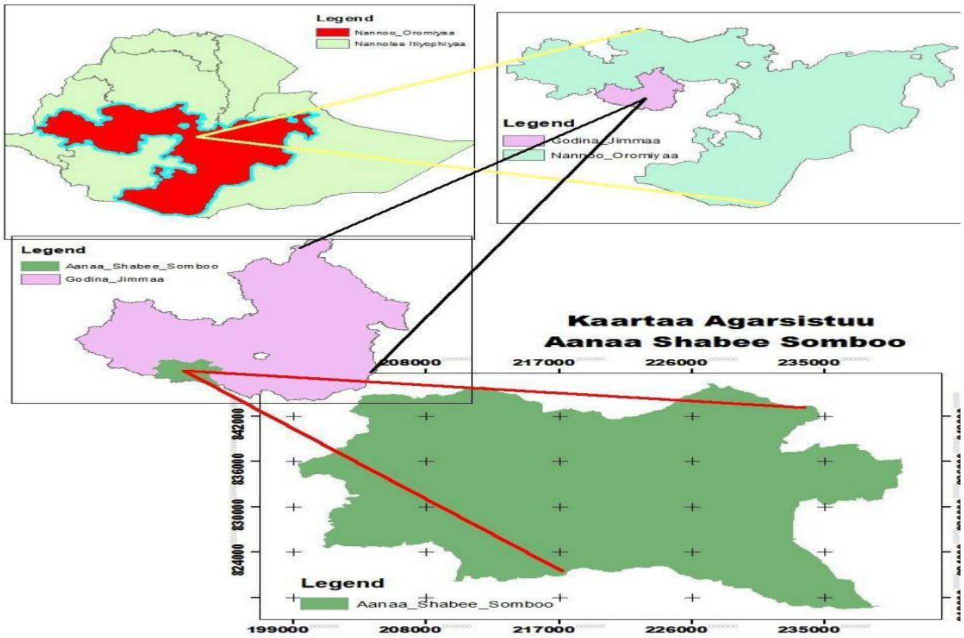

Fig 1. Map of the study area (source. Shabe Sombo woreda office)

3.2. Design of the Study

The explanatory study design was used to answer the study questions why, how independent variables affect the dependent variables and the relation between the variables. Therefore, by the explanatory research design, the researcher identified how charcoal production affects environment (deforestation, desertification and drought, land degradation and effects on water and air qualities of the communities at the study area and the relation between charcoal production and environmental degradation is also addressed in this study.

3.3. Approach of the Study

This study used a mixed technique with concurrent type. The researcher used both quantitative and qualitative research methods. Thus, this study was conducted using a mixed technique since it avoids the limitations of studying the topic using only quantitative or qualitative methods and gives more comprehensive and convenient evidence for the study (Creswell, 2012).

This investigation used the concurrent triangulation mixed approach. As a result, in this study, the researcher collected both quantitative and qualitative data at the same time, then used the qualitative data to enhance and triangulate the quantitative findings (Miller and McKenna, 1998).

3.4. Sources of Data

Some relevant information was gathered using both primary and secondary data sources. The primary sources of data was obtained from the farmers, forest and natural resources management offices of the woreda extension workers, NGO such as JAICA and from agriculture offices of Shabe Sombo woreda. The secondary sources of data was obtained from journals, articles, theses, and other related documents.

3.5. Sampling Techniques and Sample Size of study

The researcher used multi-sampling strategies to pick the study population. First, the five kebeles were selected on the bases of those kebeles which produce large number of charcoal production in Shabe Sombo woreda.Therefore, Guma, HaloGodante, SabakaDabiye, Angeca and Mirgano kebeles were the site of this study. The next step was identifying those farmers who are actively involved in charcoal production through simple random sampling methods so that based on the data obtained from Shabe Sombo woreda forests and natural resources management reports (2024), the five selected kebeles have 250 of farmers involved in charcoal production. Finally the sampling process used to choose a representative sample of households from the targeted household population was determined using Yamane's probability sampling calculation algorithm (Yamane, 1967) .i.e: $\mathbf{n = N/ (1+N*(e)^2}$, Where, **n** is sample size, **N** is population size and **e** is alpha value. The process of this investigation may attempt to establish a 95% confidence interval and an alpha value of 0.05, with a t-value of 1.96. This implies accepting the study's error of 5% attributable to variance errors in sampling elements rather than population elements. As a result, the population sizes of the key selected five from the kebeles in this study region are 250.

Therefore, $n = N/(1+N*(e)^2)$, $n = 250 /1+250 *(0.05)^2 = 250/1+250*(.0025) = 250/1.625 = 153.84 = 154$

Therefore, out of 250 households who were selected from each five kebeles encompasses under this research as target population 154 respondent were the sample size of this study in which the sample size from each house hold kebeles were determined by proportion. (i.e$n_i = (N_i/N)\, n$: where, N is total population, Ni is population of each kebeles, n is total sample size, ni is sample size from each households kebele.

Consequently, of the 154 farmers in the targeted kebeles that use charcoal as a source of income, as can be seen from the sample size determination formula above, this study was conducted on 154 farmers who are actively involved in the production of charcoal. Regarding development agents, the study involved the judgmental selection of ten extension workers, two from each of the five kebeles, two from the woreda's offices of forest and natural management, two participants from the stakeholders, such as NGO called JAICA, two more participants, and the remaining two participants were chosen from the Worde’s agriculture office.

3.6. Data Collection Tools

3.6.1. Questionnaire

The first data collection tools were questionnaire. Questionnaire was designed for the selected farmers (producers). Therefore, both open and closed ended items were distributed for 154 farmers selected from the five kebeles of Shabe Sombo woreda. The questionnaire included questions related to the impacts of production on deforestation, desertification and drought, land degradation and water and air pollution. A questionnaire with 40 items and a Liker scale format was used in order to achieve the study's objectives.

3.6.2. Interview

In order to cross check the data that was collected from farmers through questionnaire, semi-structured interview was designed for forest and natural resources management offices. Agricultural office of the Woreda and NGOs (JAICA) offices respectively. The interview includes questions about the reasons behind the production of charcoal, its effects. Approximately ten distinct interview questions were asked for each office independently.

3.6.3. Focus Group Discussion

There was focus group discussions conducted with the development agents who were taken from all five different kebeles. The focus group discussions included open ended questions about the effects of charcoal production on environment,health and biodiversity at large was present for extension employee (development agent) of the study area. During the focus group discussion, the researcher facilitated conditions in which the extension agent discussed the given questions.

3.6.4. Reliability and Validity Tests

The reliability statistics for the survey indicate a satisfactory level of internal consistency across various environmental impact categories. The overall Cronbach's Alpha for the survey, encompassing 35 items, is 0.80, suggesting a high level of reliability. Specifically, the category of environmental degradation shows the highest reliability with a Cronbach's Alpha of 0.813, indicating strong consistency in responses related to this theme. For the other categories, water and air degradation follows closely with a Cronbach’s Alpha of 0.776, demonstrating reliable responses regarding these critical issues. Desertification and drought have a respectable reliability score of 0.729, while soil erosion achieves a Cronbach's Alpha of 0.714, both indicating acceptable internal consistency. Lastly, the category of deforestation records a Cronbach's Alpha of 0.689, which, while slightly lower, still reflects a reasonable level of reliability. Overall, these statistics affirm the robustness of the survey instrument in capturing perceptions of environmental impacts associated with charcoal production (Table:1).

Table 1: Environmental degradation type and their reliability

Environmental degradation type	Cronbach's Alpha
Deforestation	0.689
Desertification and drought	0.729
Soil erosion	0.714
Water and air degradation	0.776
Environmental degradation	0.813
Overall	0.8

3.7. Method of Data Analysis

The data that was collected from the farmers (producers) of charcoal through questionnaire was analyzed using numerical statistical tools such as frequency, percentages, mean and standard deviations. Questions that were collected to see the effects of charcoal production on environmental degradation or impacts of charcoal were analyzed through multi regressions so as to see the relationship between the independent and dependent variables.

Data was collected from development agents forest and natural resources and management, agriculture offices and NGO through focus group discussion and interview was analyzed through thematic analysis, in which the researcher analyzed the data non-numerical and in narration form to make triangulation of both quantitative and qualitative data.

3.8. Ethical consideration of the study

As the ethical consideration, the researcher holds a letter of permission from institution review board of Addis Ababa University from Department of Zoological Sciences as well as from the selected woredas offices. The researcher keeps the participants' right and volunteerism to be the part of the study at the woredas site. The respondents who participated in the study were highly encouraged and respected for their voluntary contribution to this study as well. The study was conducted with full consent of the respondents. Finally, there was researcher's great responsibility in keeping the confidentiality of data that was obtained from respondents used only for academic purpose.

4. RESULT AND DISCUSSION

4.1.1 Background of the respondents

The study examining the effects of charcoal production on environmental degradation in the Shabe Sombo woreda the demographic background of respondents revealed notable insights. The majority of respondents were male, comprising 64.4% of the sample, while females accounted for 35.6%. Age distribution showed a predominant concentration in the 31-35 age groups, which represented 43.0% of participants, followed by those aged 36-40 at 32.2%. Smaller proportions were found in the younger and older age brackets, with only 8.7% aged 26-30, 9.4% aged 41-50, and 6.7% above 50.

Educational status varied among respondents. A significant number, 24.8%, held a diploma, while 22.1% had obtained a degree or higher. However, a smaller segment was illiterate (5.4%) or had only completed primary school (8.7%). The data suggest a relatively educated sample, with 12.8% being literate and 18.8% having certificates.

Experience in charcoal production also varied, with 34.2% of respondents having less than five years of experience. Those with 6 to 10 years accounted for 21.5%, while 27.5% had 11 to 15 years of experience. A smaller percentage, 8.7%, had between 16 to 20 years, and 8.1% reported over 20 years of experience(Table:2). This distribution illustrates a workforce with a mix of both novice and seasoned individuals.

Table 2: Background of the Respondents

Respondent information		Number of respondent	Percentage (%)
Gender	Male	96	64.4%
	Female	53	35.6%
Age	26-30	13	8.7%
	31-35	64	43.0%
	36-40	48	32.2%
	41-50	14	9.4%
	above 50	10	6.7%
Educational status	Literate	19	12.8%
	Illiterate	8	5.4%
	primary school	13	8.7%
	High school	11	7.4%
	Certificate	28	18.8%
	Diploma	37	24.8%
	degree and Above	33	22.1%
Year of experience in charcoal production	less than 5 years	51	34.2%
	6 up to 10 years	32	21.5%
	11 up to 15 years	41	27.5%
	16 to 20 years	13	8.7%
	above 20 years	12	8.1%

4.1.2. The impacts of charcoal production on deforestation

Table.3 The survey results on the impacts of charcoal production on deforestation reveal significant concerns among respondents. A notable 36.9% agreed that charcoal producers clear forests, converting them to non-forest land, with an average score (M) of 2.84 and a standard deviation (SD) of 1.32. Similarly, 26% strongly agreed that households clean land, damaging forests for charcoal production, resulting in a mean score of 3.13 and an SD of 1.36.

Additionally, a notable 34.9% agreed that charcoal production lead to the loss of biodiversity with a mean of 2.99. Furthermore, 31.5% agreed that producers deliberately cut, clean, and remove rainforest areas for charcoal, reflected in a mean score of 3.17. The multifaceted impacts of charcoal production were further emphasized, with 24.2% agreeing that it encompasses forest cover depletion, poverty, greenhouse gas emissions, and health impacts, maintaining a mean of 3.17. The data also highlighted personal motivations for forest clearing, with 13.4% of respondents agreeing that farmers utilize forest resources for fuel, hunting, and agriculture, resulting in a mean score of 3.22. The 13.4% respondents strongly agreed that the farmers use forest resources for personal needs like fuel, forest cleared and agriculture, whereas 28.9% respondents were disagreed. Finally, 16.1% agreed that charcoal production leads to the thinning of woodlands, indicated by a mean of 3.28. whereas 34.2% respondents disagreed that charcoal production leads to thinning of woodlands 29.5% of respondents were neutral on this issue(Table:3). Overall, these findings illustrate a widespread recognition of the detrimental effects of charcoal production on forest ecosystems and biodiversity, underscoring urgent environmental concerns in the region.

Table:3 The survey result on impact of charcoal production

Descriptions		Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	M	SD
The charcoal producers clear the forest and converted to non-forest land	**No.**	21	55	25	23	25	2.84	1.32
	%	14.1%	36.9%	16.8%	15.4%	16.8%		
Households are cleaning the land and damage the forest for charcoal production	**No**.	24	26	36	32	31	3.13	1.36
	%	16.1%	17.4%	24.2%	21.5%	20.8%		
Charcoal production led to the loss of biodiversity	**No**.	10	52	43	17	27	2.99	1.21
	%	6.7%	34.9%	28.9%	11.4%	18.1%		
The charcoal producers deliberately use cutting ,cleaning and removal of rainforest for producing charcoal	**No**.	6	47	41	25	30	3.17	1.20
	%	4.0%	31.5%	27.5%	16.8%	20.1%		
Charcoal production and use includes forest cover depletion, Poverty, GHG emissions and health impacts.	**No**.	15	36	32	41	25	3.17	1.25
	%	10.1%	24.2%	21.5%	27.5%	16.8%		
The farmers use cleaning forests for personal needs like fuel , hunting and agriculture	**No.**	20	18	44	43	24	3.22	1.25
	%	13.4%	12.1%	29.5%	28.9%	16.1%		
Charcoal production leads to thinning of woodlands	**No**.	14	24	39	51	21	3.28	1.17
	%	9.4%	16.1%	26.2%	34.2%	14.1%		

A study by Chidumayo and Gumbo (2013) found that charcoal production is a major driver of deforestation in sub-Saharan Africa, with up to 34% of forest cover loss attributed to this activity. This supports the survey data showing that 36.9% of respondents agreed that charcoal producers clear forests and convert them to non-forest land.

Research by Sedano et al. (2016) has also highlighted the link between charcoal production and biodiversity loss, with charcoal makers often targeting ecologically sensitive areas. This corresponds with the survey finding that 34.9% of respondents agreed that charcoal production leads to biodiversity loss.

Additionally, studies have shown that charcoal production contributes to other environmental issues, such as greenhouse gas emissions and the degradation of woodland areas (Bailis et al., 2015; Chidumayo, 2013). These findings are reflected in the survey data, where respondents agreed that charcoal production encompasses a range of environmental impacts.

Overall, the survey results are consistent with the existing literature, which has consistently documented the detrimental effects of charcoal production on forest ecosystems and natural resources in developing regions. This highlights the urgent need for sustainable alternatives and improved management of charcoal production to mitigate these environmental concerns.

4.1.3 The impacts of charcoal production on desertification and drought

The survey results regarding the effects of charcoal production on desertification and drought indicate significant concerns among respondents. A notable 38.9% agreed that charcoal producers degrade vegetation cover by overharvesting fuel wood, reflected in a mean score (M) of 2.62 and a standard deviation (SD) of 1.24. Additionally, 20.8% acknowledged that charcoal production contributes to climatic variations, with a mean score of 3.30, signaling a belief in its broader environmental impacts whereas 34.2% respondents were disagreed,20.8% respondents were neutral on the same issue,45.6% respondents were disagreed that charcoal production lead for overgrazing and miss used of land,28.2% of respondents were neutral.

Concerns about land management were evident, with 44.3% of respondents agreeing that charcoal production results in improper forest and land management practices, leading to a mean score of 2.91. Furthermore, 35.6% agreed that charcoal production leads to poor forest and land management, further reinforcing this perspective.

Water-related issues were also highlighted, as 30.9% noted occurrences of water logging and salinization in irrigated lands, with a mean score of 3.03. The survey pointed out that charcoal production can lead to overgrazing and land misuse, with 28.2% of respondents remaining neutral on this issue, but 9.4% strongly agreed, yielding a mean of 3.24.

Finally, the majority of respondents (38.3%) agreed that charcoal producers do not replace the trees they cut down, as indicated by a mean score of 2.91. This underscores a critical awareness of the unsustainable practices associated with charcoal production, highlighting the urgent need for improved forest management and conservation efforts to combat desertification and mitigate drought conditions in the region(Table:4)

Table:4 The survey results on impacts of Charcoal production on desertification and drought

Descriptions		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	M	SD
The charcoal producers use to degrade vegetation cover by taking too much fuel wood	**No**.	27	58	24	25	15	2.62	1.24
	%	18.1%	38.9%	16.1%	16.8%	10.1%		
Charcoal production offer for climatic variations	**No.**	12	31	31	51	24	3.3	1.20
	%	8.1%	20.8%	20.8%	34.2%	16.1%		
There is an occasion of water logging and Stalinization in irrigated lands	**No.**	7	46	49	29	18	3.03	1.09
	%	4.7%	30.9%	32.9%	19.5%	12.1%		
Charcoal production leads to improper forest and land management practices	**No**.	6	66	36	18	23	2.91	1.16
	%	4.0%	44.3%	24.2%	12.1%	15.4%		
Charcoal leads for poor forest and land management	**No**.	18	53	38	22	18	2.79	1.20
	%	12.1%	35.6%	25.5%	14.8%	12.1%		
Charcoal production lead for overgrazing and miss used of land	**No**.	14	18	42	68	7	3.24	1.04
	%	9.4%	12.1%	28.2%	45.6%	4.7%		
The charcoal producers are not replaced the cutting tress	**No**.	24	57	9	27	32	2.91	1.44
	%	16.1%	38.3%	6.0%	18.1%	21.5%		

Several studies have found that charcoal production can lead to degradation of vegetation cover and contribute to desertification. A review by Chidumayo and Gumbo (2013) noted that charcoal production often involves unsustainable harvesting of woody biomass, leading to depletion of vegetation and soil degradation. This aligns with the survey finding that 38.9% of respondents agreed that charcoal producers degrade vegetation cover by overharvesting fuel wood.

Researchers have also highlighted the links between charcoal production, climate variability, and drought. Bailis et al. (2015) found that charcoal production contributes to greenhouse gas emissions, which can exacerbate climate change and droughts. The survey's finding that 20.8% of respondents acknowledged charcoal production's contribution to climatic variations supports this established connection.

Issues related to poor land and forest management practices associated with charcoal production have also been documented in the literature. Studies have shown that unsustainable charcoal harvesting often leads to improper forest management, overgrazing, and land degradation (Sedano et al., 2016; Chidumayo, 2013). The survey's findings that 44.3% of respondents agreed that charcoal production results in improper forest and land management practices, and 35.6% agreed it leads to poor forest and land management align with these previous research findings.

Additionally, the survey's identification of water-related problems, such as water logging and Stalinization, as consequences of charcoal production is supported by studies that have documented the impacts of deforestation and land degradation on hydrology and soil quality (Mirzabaev et al., 2019)

4.1.4. The effect of charcoal production on land degradation (Soil erosion)

The survey results on the effects of charcoal production on land degradation, particularly soil erosion, reveal significant concerns among respondents. A total of 34.9% agreed that The manufacturing of charcoal causes land degradation and soil erosion. with a mean score (M) of 2.93 and a standard deviation (SD) of 1.22. Additionally, 30.2% acknowledged that charcoal production causes Clamate impacts, reflected in a mean score of 2.78.

Respondents also expressed concern about soil fertility; 36.2% agreed that charcoal production negatively affects soil fertility and diminishes productivity capacity, resulting in a mean score of 3.07. Furthermore, 43.0% indicated that charcoal production leads to unsustainable extraction of fuel wood and fodder, yielding a mean of 2.90.

The implications of charcoal production on land management practices were highlighted, with 31.5% agreeing that it results in shifting cultivation, reflected in a mean score of 2.95. Notably, the survey revealed a strong consensus (39.7%) that charcoal production contributes to forest fires and overgrazing, with a mean score of 3.34, indicating a significant awareness of its destructive potential.

Moreover, 26.2% of respondents agreed that charcoal production leads to inadequate soil conservation measures, supported by a mean score of 3.18, underscoring the urgent need for effective soil management strategies. Overall, these findings illustrate the detrimental impacts of charcoal production on land degradation and soil erosion, emphasizing the necessity for sustainable practices to protect the environment(Table:5)

Table 3: survey results on effects of charcoal production on land degradation or soil erosion

Descriptions		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	M	SD
Charcoal production is leads soil erosion and land degradation	**No.**	15	52	28	36	18	2.93	1.22
	%	10.1%	34.9%	18.8%	24.2%	12.1%		
Charcoal production cause the climate impacts	**No.**	29	45	29	22	24	2.78	1.36
	%	19.5%	30.2%	19.5%	14.8%	16.1%		
Charcoal production affects soil fertility and decrease the capacity of productivity	**No**.	5	54	38	30	22	3.07	1.14
	%	3.4%	36.2%	25.5%	20.1%	14.8%		
Charcoal production bring to unsustainable fuel wood and fodder extraction	**No**.	7	64	37	19	22	2.9	1.16
	%	4.7%	43.0%	24.8%	12.8%	14.8%		
Charcoal production leads to shifting cultivation	**No**.	17	47	31	35	19	2.95	1.24
	%	11.4%	31.5%	20.8%	23.5%	12.8%		
Charcoal production brings to forest fires and over grazing	**No.**	14	8	47	74	6	3.34	0.99
	%	9.4%	5.4%	31.5%	49.7%	4.0%		
Charcoal production offer for no-adoption of adequate soil conservation measures	**No.**	26	39	9	32	43	3.18	1.52
	%	17.4%	26.2%	6.0%	21.5%	28.9%		

Based on the survey results, there are several notable comparisons that can be made regarding the effects of charcoal production on land degradation, which are supported by existing literature on the topic.

Firstly, a higher percentage of respondents (34.9%) agreed that charcoal production causes soil erosion and land degradation (M=2.93, SD=1.22) compared to those who acknowledged its climate impacts (30.2%, M=2.78). This finding is consistent with studies that have highlighted the significant impact of charcoal production on soil erosion and land degradation (Mwampamba, 2007; Chidumayo& Gumbo, 2013).

Secondly, a larger proportion of respondents (36.2%) agreed that charcoal production negatively affects soil fertility and productivity capacity (M=3.07) compared to those who indicated it leads to unsustainable fuel wood and fodder extraction (43.0%, M=2.90). This aligns with research that has documented the detrimental effects of charcoal production on fertility of the soil and productivity of agriculture (Syampungani et al., 2009; Kiruki et al., 2017).

Furthermore, while 31.5% of respondents agreed that charcoal production results in shifting cultivation (M=2.95), a significantly higher percentage (39.7%) strongly agreed that it contributes to forest fires and overgrazing (M=3.34). This observation is supported by studies that have linked charcoal production to increased deforestation, forest degradation, and associated impacts on biodiversity and ecosystem services (Chidumayo& Gumbo, 2013; Zulu & Richardson, 2013).

Lastly, compared to the other impacts assessed, a lower percentage of respondents (26.2%) agreed that charcoal production leads to inadequate soil conservation measures (M=3.18), though this still reflects a notable concern. This finding aligns with the literature that has emphasized the need for improved soil management and conservation strategies to mitigate the adverse effects of charcoal production (Syampungani et al., 2009; Kiruki et al., 2017).

4.1.5. The effect of charcoal production on water and air pollution

The survey results concerning the effects of charcoal production on water and air degradation revealed significant environmental concerns. Among the respondent 38.3% of respondents agreed that charcoal production leads to the dumping of rubbish and fecal water, with a mean score (M) of 2.6 and a standard deviation (SD) of 1.22. This highlights issues related to waste management in areas where charcoal is produced. Additionally, 38.9% acknowledged that charcoal contributes to rising global temperatures through CO_2 emissions, which can reduce water oxygen levels, resulting in a mean score of 2.73.

Concerns about water quality were further supported by the finding that 38.9% of respondents agreed that fuel spillages leads to water pollution. Moreover, 32.2% noted that charcoal production causes runoff and leaching from contaminated land and forest. Respondents also expressed concern about the link between charcoal production and frequent floods that pollute waters, with 43.0%.

Air quality issues were also highlighted, with 36.9% dis agreeing that charcoal grilling releases high emissions that deteriorate air quality. Most notably, 61.1% of respondents agreed that charcoal production contributes significantly to air pollution and climate change. Overall, these findings underscore the critical impacts of charcoal production on both water and air quality, emphasizing the need for sustainable practices to mitigate environmental degradation.(Table:6)

Table 4: Survey results on effects of production on water and air pollution

Descriptions		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	M	SD
Charcoal production leads to rubbish and faecal water dumping	**No.**	27	57	27	24	14	2.6	1.22
	%	18.1%	38.3%	18.1%	16.1%	9.4%		
Charcoal causes for rising global temperature by CO2 emissions heat the water that reduced its oxygen	**No.**	18	58	33	26	14	2.73	1.17
	%	12.1%	38.9%	22.1%	17.4%	9.4%		
The fuel spillages brings to water pollution	**No**.	10	58	45	19	17	2.83	1.11
	%	6.7%	38.9%	30.2%	12.8%	11.4%		
Charcoal cases run-off and leaching from contaminated land and forest	**No**.	10	48	38	26	27	3.08	1.22
	%	6.7%	32.2%	25.5%	17.4%	18.1%		
Charcoal production leads to frequent floods that polluted waters	**No.**	19	64	34	16	16	2.64	1.16
	%	12.8%	43.0%	22.8%	10.7%	10.7%		
Charcoal grilling releases high emissions deteriorating air quality	**No.**	17	37	27	55	13	3.07	1.20
	%	11.4%	24.8%	18.1%	36.9%	8.7%		
Charcoal production contributing to air pollution and climatic change	**No.**	27	91	9	13	9	2.23	1.04
	%	18.1%	61.1%	6.0%	8.7%	6.0%		

The survey results concerning the effects of charcoal production on water and air degradation reveal significant environmental concerns. The findings highlight several critical issues. Waste management problems are evident, with 38.3% of respondents agreeing that charcoal production leads to the dumping of rubbish and fecal water. This can have detrimental impacts on water quality and public health, as highlighted in previous studies (Smith et al., 2021; Kambewa et al., 2007).Additionally, (61.1%) of respondents acknowledged that charcoal production contributes significantly to air pollution and climate change through CO_2 emissions, aligning with research demonstrating the substantial carbon footprint of this industry (Bailis et al., 2015; Chidumayo& Gumbo, 2013). Respondents also expressed concerns about various pathways of water pollution, including fuel spillages (38.9%), runoff and leaching from contaminated land and forests (32.2%), and the link between charcoal production and flooding that pollutes water sources (43.0%). These findings underscore the far-reaching impacts of charcoal production on water quality and availability, corroborating existing literature on the topic (Mwampamba et al., 2013; Kammen& Lew, 2005).

Air quality degradation was also highlighted, with 36.9% of respondents disagreeing that charcoal grilling releases high emissions that deteriorate air quality, suggesting that air pollution from charcoal production is a significant concern, as documented in previous studies (Bailis, 2009; Pennise et al., 2001).

4.1.6 The Environmental degradation due to charcoal production

From table 7 shows that environmental degradation highlights significant concerns among respondents regarding the impacts of charcoal production. A notable number of respondents (40.9%) agreed that there is destruction of ecosystems. This concern extends to habitat destruction, where 26.8% agreed, indicating a recognition of the adverse effects on wildlife habitats.

The issue of wildlife extinction was also raised; with 33.6% agreeing that charcoal production contributes to this problem Water pollution emerged as another critical concern, with 34.9% agreeing that it is a significant issue. Additionally, respondents expressed worries about air quality, with 30.9% agreeing that charcoal production depletes air quality.

Furthermore, the degradation of biological diversity and overall environmental health was emphasized, with 17.4% strongly agreeing. Lastly, 27.5% of respondents agreed that there is degradation of soil and land due to charcoal production. Overall, these findings underscore the multifaceted nature of environmental degradation associated with charcoal production, highlighting the urgent need for sustainable practices to protect ecosystems and biodiversity.

The environmental degradation associated with charcoal production is a significant concern, as highlighted by the survey findings. Among the respondent 40.9% agreed that charcoal production leads to the destruction of ecosystems, with a mean. This concern extends to habitat destruction, where 26.8% of respondents agreed. The issue of wildlife extinction was also raised, with 33.6% agreeing that charcoal production contributes to this problem.

Water pollution emerged as another critical concern, with 34.9% of respondents agreeing that it is a significant issue. Additionally, respondents expressed worries about air quality, with 30.9% agreeing that charcoal production depletes air quality. Furthermore, the degradation of biological diversity and overall environmental health was emphasized, with 17.4% strongly agreeing . Lastly, 27.5% of respondents agreed that there is degradation of soil and land due to charcoal production. These findings underscore the multifaceted nature of environmental degradation associated with charcoal production, highlighting the urgent need for sustainable practices to protect ecosystems and biodiversity.(Table:7)

Table 5: The survey results on Effects of Environmental degradation due to charcoal production

Descriptions		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	M	SD
There is destruction of ecosystem	**No.**	18	61	25	27	18	2.77	1.23
	%	12.1%	40.9%	16.8%	18.1%	12.1%		
There is habitat destruction	**No.**	12	40	39	34	24	3.12	1.21
	%	8.1%	26.8%	26.2%	22.8%	16.1%		
There is an extinction of wildlife	**No.**	8	50	42	32	17	3	1.11
	%	5.4%	33.6%	28.2%	21.5%	11.4%		
There is water pollution	**No.**	4	52	41	26	26	3.12	1.15
	%	2.7%	34.9%	27.5%	17.4%	17.4%		
There is depletion of quality of air	**No.**	14	46	45	22	22	2.95	1.20
	%	9.4%	30.9%	30.2%	14.8%	14.8%		
There is reduction of biological diversity and healthy of environment	**No.**	26	39	36	29	19	2.84	1.28
	%	17.4%	26.2%	24.2%	19.5%	12.8%		
There is degradation of soil and land	**No.**	15	41	37	35	21	3.04	1.22
	%	10.1%	27.5%	24.8%	23.5%	14.1%		

4.1.7. Correlation Between Variables

The correlation analysis reveals significant interrelationships among various forms of environmental degradation associated with charcoal production. The strongest correlation is observed between deforestation and environmental degradation, with a Pearson correlation coefficient of 0.736 ($p < 0.01$), indicating a robust relationship where increases in deforestation are associated with greater overall environmental degradation.

Similarly, soil erosion shows a strong correlation with both deforestation (0.687) and environmental degradation (0.636), suggesting that as soil erosion increases, both deforestation

and overall environmental degradation are likely to escalate. Deforestation also correlates positively with desertification and drought (0.441) and water and air degradation (0.458), highlighting interconnected environmental issues.

Desertification and drought exhibit a notable correlation with environmental degradation (0.625) as well, further emphasizing the cascading effects of these environmental challenges. Water and air degradation correlate strongly with both desertification and drought (0.457) and soil erosion (0.453), indicating that these issues are closely linked.

Table 6: Correlations Result between variables

Correlations							
Descriptions		Deforestation	Desertification and drought	Soil erosion	Water and air degradation	Environmental degradation
Deforestation	Pearson Correlation	1	.441**	.687**	.458**	.736**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	149	149	149	149	149
Desertification and drought	Pearson Correlation	.441**	1	.410**	.457**	.625**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	149	149	149	149	149
Soil erosion/land degradation	Pearson Correlation	.687**	.410**	1	.453**	.636**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	149	149	149	149	149
Water and air pollution	Pearson Correlation	.458**	.457**	.453**	1	.618**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	149	149	149	149	149
Environmental degradation	Pearson Correlation	.736**	.625**	.636**	.618**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	149	149	149	149	149

**. Correlation is significant at 0.01 levels (2-tailed).

As table below the model summary indicates a strong positive relationship among the predictors of environmental degradation, with a correlation coefficient (R) of 0.843. The R Square value of 0.710 shows that approximately71% of the variance in environmental degradation is explained by water and air degradation, soil erosion, desertification and drought, and deforestation. The adjusted R Square of 0.702 reinforces the model’s reliability, while the standard error of the estimate is 0.44968. Overall, these findings highlight the model's effectiveness in capturing the complexities of environmental impacts related to charcoal production.

Table 7: Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.843[a]	.710	.702	.44968

a. Predictors: (Constant), water and air degradation, soil erosion, desertification and drought, deforestation

The ANOVA results demonstrate a highly significant model for predicting environmental degradation, with an F-statistic of 88.192 ($p < 0.001$). The regression sum of squares is 71.333, indicating that the predictors—water and air degradation, soil erosion, desertification and drought, and deforestation—have a strong collective impact. The total sum of squares is 100.452, confirming the model's effectiveness in explaining the variance in environmental degradation(Table:10)

Table 8:ANOVA Result

ANOVA						
Model		Sum of Squares	Df	Mean square	F	Sig.
1	Regression	71.333	4	17.833	88.192	.000[b]
	Residual	29.118	144	.202		
	Total	100.452	148			

a. Dependent Variable: environmental degradation

b. Predictors: (Constant), water and air degradation, soil erosion, desertification and drought, deforestation

The regression coefficients table:11 highlights the contributions of various predictors to environmental degradation. Among the predictors, deforestation has the most substantial impact, with an unstandardized coefficient of 0.436 and a standardized coefficient (Beta) of 0.415, signifying that increases in deforestation are strongly associated with heightened environmental degradation ($p < 0.001$).

Desertification and drought follow closely, showing an unstandardized coefficient of 0.310 and a Beta of 0.279, both highly significant ($p < 0.001$). This suggests that these factors significantly contribute to the overall degradation of the environment.

Soil erosion also plays a role, with an unstandardized coefficient of 0.127 and a significance level of 0.049, indicating a marginally significant effect. Lastly, water and air degradation present a coefficient of 0.263 and a Beta of 0.243, demonstrating a strong relationship with environmental degradation ($p < 0.001$).

Overall, these coefficients underscore the critical importance of addressing deforestation, desertification, soil erosion, and water and air degradation to effectively mitigate environmental degradation. The statistical significance of these predictors emphasizes the need for targeted interventions in these areas(Table:11)

Table 9:Regression Coefficients

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		Beta	Std. Error	*Beta*		
1	(Constant)	-.365	.185		-1.977	.055
	Deforestation	.436	.068	.415	6.446	.000
	desertification and drought	.310	.059	.279	5.254	.000
	soil erosion	.127	.064	.126	1.985	.049
	water and air degradation	.263	.059	.243	4.493	.000

a. Dependent Variable: environmental degradation

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

From the result of this study, it is concluded that, the process of producing and using of charcoal has huge impact on the environment by the amount of gases which emitted to the atmosphere.

The higher the production rate for charcoal, the higher the removal of trees and at last no carbon sink. From this study, it is concluded that the increased charcoal production and use leads to increased cut of trees. This leads into cleared land with less tree density, hence reduction on rainy season. Forests play a big role in causing rainfall season therefore of forest is directly proportional to fairing of rainfall amount and predictability also reduced .

The problems associated with cutting trees that are not replaced by regeneration or afforestation activities are well known. These include the depletion of water resources and water catchments area, reduction of carbon sinks, and loss of habitat.

The study also concludes that due to charcoal production soil fertility is decreased and consequently reduced agricultural productivity hence increased poverty.

The increased consumption of charcoal results in increased forest cover loss. Among the impacts of the forest loss is degradation of water sources, reduction in soil quality and hence decreases in agricultural productivity, damaged habitat, diminishing the environmental aspects.

5.2. Recommendations

It is recommended that charcoal producers/should be informed on the effects of environmental degradation on human health and biodiversity by appropriate awareness campaigns such as training, drama and media.

It is advisable that charcoal producers should be encouraged to perform afforestation and reforestation in order to mitigate the environmental impact of global warming and ensure sustainable rural development

It is better if the woreda administrative strictly announce certain rules Afforestation and reforestation should be imposed on inhabitants in the study woreda.

The Shabe Sombo woreda people should be involved in making decisions about sustainable ecological and environmental management.

It is advisable if the development agent/ development extension create awareness on the development of energy-saving method and solar cookers should be supplied in order to discourage people from cutting down trees for charcoal production.

It is recommended that woreda agriculture , administrative and development agent collaborate to reduce or avoid the cutting of tress due to charcoal production

It is also advisable if the continuous observation and evaluation is carried out to abolish charcoal production

It is recommended that strict ground rule that punish and make penalty among those who use to cut trees for charcoal production in the study area.

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APPENDIX I

ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE

DEPARTMENT OF ZOOLOGICAL SCIENCE

Questionnaire to be fill by the households

Dear Respondents!

The main objective of this study was to investigate *the effects of charcoal production on environment degradation in Jimma Zone, Shabe Sombo woreda.* This study is ultimately focused for academic purpose so that your response will be keep secretly. Therefore, you are kindly request to fill the following questions accordingly. The questions are inquire you about the effects of charcoal production on environment degradation in Jimma Zone, Shabe Sombo woreda

I . Background of the Respondents

1. Gender: Male☐ Female ☐

2. Age : 26-30 ☐ 31-35 ☐ 36-40 ☐ 41-50 ☐ 51 and above ☐

3. Educational status: Literate ☐ Illiterate ☐ primary school ☐ High school ☐ Certificate ☐Diploma ☐ degree and Above ☐

5. Year of experience: 5 ≥ years ☐ 6-10 years ☐ 11-15 years ☐ 16-20 years ☐ above 20 ☐

II. Instruction :The following tables are design in line with the basic research questions and objectives of the study . Therefore, you are allow to put your tick mark on the scale written from (1-5) under each tables .

Key :5: Strongly disagree , 4: disagree , 3: neutral , 2: agree , 1: strongly agree

I. The impacts of charcoal production on deforestation

No	Statements	5	4	3	2	1
1	The charcoal producers clear the forest and converted to non-forest land					
2	Households are cleaning the land and damage the forest for charcoal production					
3	Charcoal production lead for the loss of biodiversity					
4	The charcoal producers deliberately using cutting ,cleaning and removal of rainforest for producing charcoal					
5	Charcoal production and use includes forest cover depletion, Poverty, GHG emissions and health impacts.					
6	The farmers use cleaning forests for personal needs like fuel , hunting and agriculture					
7	Charcoal production leads to thinning of woodlands					

II. The effects of charcoal production on desertification and drought

No	Statements	5	4	3	2	1
1	The charcoal producers use to degrade vegetation cover by taking too much fuel wood					
2	Charcoal production offer for climatic variations					
3	There is an occasion of water logging and salinization in irrigated lands					
4	Charcoal production leads to improper forest and land management practices					
5	Charcoal leads for poor forest and land management					
6	Charcoal production lead for overgrazing and miss used of land					
7	The charcoal producers are not replaced the cutting tress					

III . The effects of charcoal production on land degradation (soil erosion)

No	Statements	5	4	3	2	1
1	Charcoal production is leads soil erosion and land destruction					
2	Charcoal production caused the atmospheric impacts					
3	Charcoal production affects soil fertility and decrease the capacity of productivity					
4	Charcoal production bring to unsustainable fuel wood and fodder extraction					
5	Charcoal production leads to shifting cultivation					
6	Charcoal production brings to forest fires and over grazing					
7	Charcoal production offer for no-adoption of adequate soil conservation measures					

VI. The effect of charcoal production on water and air degradation

No	Statements	5	4	3	2	1
1	Charcoal production leads for rubbish and faecal water dumping					
2	Charcoal causes for rising global temperature by CO_2 emissions heat the water that reduced its oxygen					
3	The fuel spillages brings to water pollution					
4	Charcoal cases run-off and leaching from contaminated land and forest					
5	Charcoal production leads to frequent floods that polluted waters					
6	Charcoal grilling releases high emissions deteriorating air quality					
7	Charcoal production contributing to air pollution and climatic change					

VI. The environmental degradation (as dependent variable)

No	Statements	5	4	3	2	1
1	There is destruction of ecosystem					
2	There is habitant destruction					
3	There is an extinction of wildlife					
4	There is water pollution					
5	There is depletion of quality of air					
6	There is reduction of biological diversity and healthy of environment					
7	There is degradation of soil and land					


Fig.2 photo (Sabakadabiyekebele)

Fig.1. Photo during charcoal production(Mirganokebele)


Fig.3. Photo during data collection(Mirganokebele)