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PREFACE

Haramaya University has the triple mandates of teaching, research, and community engagement. The university was established in 1954 and pioneered agricultural education and research in the country. During the last six decades, the university contributed significantly to technology generation and deployment and strived to conserve the biodiversity of the country. In this connection, it was felt necessary to organize a platform for scientists and prcatitioners to exchange and collate knowledge and experiences gained in the hitherto made efforts to address problems associated with conservation of biodiversity as a strategy for climate change mitigation and adaptation. The workshop was aimed also to contribute to maintain the quality of the earth's ecosystems and achievie sustainable development.

This publication emanated from the International Conference on Biodiversity Conservation and Ecosystems Services for Climate Change Mitigation and Sustainable Development held from 20 - 22 December 2012 at Haramaya University in Ethiopia. The conference was organized by the university in collaboration with the United Nations Development Programme (UNDP). We believe that this publication will be an impetus to the wider public for engaging in the conservation of biodiversity and mitigation of climate change. Haramaya University appreciates the efforts of all people who contributed to the realisation of the conference and the publication of these proceedings.

1. INTRODUCTION

Biodiversity provides free of charge services that are vital to billions of peoples in the world and critical for the wellbeing of every segment of society. Biodiversity is intimately linked to the earth's climate and inevitably to climate change as it is the foundation of the natural processes of climate regulation. Biodiversity and sustainable development are also inextricably interconnected. Changes in the ecosystem influence both climate and people's ability to cope with its change and adverse impacts. In return, climate change and people's responses to it affect biodiversity. Understanding these interrelationships clearly shows that conserving and managing biodiversity enhances the resilience of the natural ecosystem and helps people to deal with the shifting global climate. This increasing dependence of human society on biodiversity and ecosystem services has gained prominence at a time when the future of biodiversity itself is at stake. Therefore, conservation of biodiversity is fundamental to mitigate and adapt to climate change, thereby achieving sustainable development.

The objective of the conference was to review the hitherto gained achievements in biodiversity conservation and ecosystem services for climate change mitigation and sustainable development and to identify the ways forward for conservation, management, and financing of biodiversity and ecosystem services.

The conference was meant also to provide an opportunity for sharing and exchanging information and experiences, including the capacity to meet the challenges of climate change mitigation and adaptation. The conference was also designed to furnish stakeholders with a platform for reviewing the social, economic, and political aspects of biodiversity conservation and ecosystem services and to achieve sustainable development in the changing environment.

The conference brought together more than 170 participants from a number of countries in diverse disciplines. The prominent participants included scientists from different countries, representatives from the UNDP, delegates from various ministries and organizations in Ethiopia, including, Ethiopian Environmental Protection Authority, Ethiopian Institute of Biodiversity, Ethiopian Institute of Agricultural Research, Universities, Non-Governmental Organizations, Private Sectors, Regional States, Regional Research Institutes, the House of Peoples' Representatives, and the House of Federation.

WELCOMING SPEECH

Mr. Sintayehu Workeneh, chairperson of the organizing committee

Ladies and gentlemen,

On behalf of the organizing committee, I would like to welcome you all to this International Conference on Biodiversity Conservation and Ecosystem Services for Climate Change Mitigation and Sustainable Development jointly organized by Haramaya University (HU) and UNDP-Ethiopia to be held here on the main campus of Haramaya University from December 20 - 22, 2012. I particularly appreciate participants who joined us from other countries as well as from Ethiopia who travelled all the way to Haramaya University to contribute to the conference.

Biodiversity provides free of charge services that are vital to billions of people in the world and critical for the wellbeing of every society. Maintaining biodiversity is a key goal of global biodiversity policy, which aims at promoting ecosystem health and resilience in the face of increasing deforestation, habitat fragmentation, and climate change. Therefore, this international conference will address a number of these and related issues by bringing together stakeholders from across the globe and providing a platform to share current experiences and information in the field of biodiversity conservation and climate change mitigation.

Organizing this event would not have been possible without the generous financial support of the UNDP-Ethiopia Programme (the sponsor of the conference), the excellent facilitation by the Office of Research Affais of Haramaya University, and the dedicated efforts of many other people. I would like to thank them all for their contributions and efforts. I am grateful to all of the volunteers, keynote speakers,

panelists, facilitators, and research paper authors for their contributions. I hope that the three-day conference will be a significant accomplishment that will provide an action packed agenda, which will include thought-provoking keynote speeches, challenging panel discussions, presentations, group discussions, informal networking outside the conference room for future partnerships in the area of biodiversity conservation and mitigation of climate change.

Thank you!

OPENING SPEECH

Dr. Nigussie Dechassa, Vice-President for Research Affairs

Ladies and gentlemen,

First, I would like to extend a very warm welcome to all of you to this International Conference on Biodiversity Conservation and Ecosystem Services for Climate Change Mitigation and Sustainable Development.

This conference has been organized by Haramaya University and with the sponsorship of UNDP-Ethiopia programme. I would like to thank UNDP-Ethiopia programme for the generous financial support they provided to realize this workshop. Thank you UNDP-Ethiopia again. Please, join me in applauding UNDP Ethiopia for this vital support.

Ethiopia is a nation endowed with a wealth of biodiversity. The country has gifted the world with a number of vital crops among which coffee, durum wheat, and teff are prominent. However, genetic erosion, land degradation, and periodic droughts have been taking their tolls on the biodiversity of the nation as well as the services people gain from it. Therfore, conserving the biodiversity of Ethiopia is a vital part of conserving the biodiversity of the entire world.

Such a conference could have been conducted at no better time than now when threats of climate change and its negative impact on biodiversity and the services

people derive from it have become a matter of common urgency for the entire nations of the world. Therefore, it is important that, we, scientists, experts, policy-makers, practitioners, and stakeholders from all walks of life come together as family members and deliberate on and seek solutions to issues at stake in terms of biodiversity conservation and climate change mitigation.

The conduct of this international workshop is also of relevance to our nation at the time when it has embarked up on growth and transformation plan out of which agricultural growth programme (AGP) stands out as the pillar of the development endeavour. It goes without saying that our country could meet its aspiration of socio-economic development provided that it tackles the problems of loss of biodiversity owing to unwise use of resources as well as due to the negative impact of the global climate change.

Haramaya University takes great pride in hosting this international conference and we are very glad to have you (eminent scientists, policy makers, and practitioners) to participate in this conference.

Finally, I wish you a lively and stimulating conference.

Thank you.

Dr. Nigussie Dechassa, Vice President for Research Affairs. Haramaya University

KEYNOTE SPEECH

His Excellency Dr. Tewolde Berhan Gebre Egziabher, General Director of Environmental Protection Authority of Ethiopia

Dr. Nigussie Dechassa, Vice President for Research Affairs,
Participants of this International Conference,
Ladies and Gentlemen,

It is my honour to have been asked to deliver a keynote speech at this timely conference. It is also a great pleasure for me to deliver it physically at Haramaya University. This is so because I stayed here, albeit only for a few days, in the 1980s when it was only an agricultural college and I have been visiting it off and on since then. I now can see that it has grown into a vibrant major university. Congratulations to you all who have been involved in its gratifying transformation.

I am here today to speak to you on "Biodiversity Conservation and Ecosystem Services for Climate change Mitigation and Sustainable Development." The world has now shrunk owing to globalization into a unit more accessible than Ethiopia was when I was young. In 1955, it took me six days to travel from Adwa to Addis Ababa. Now, it would take me about half that time to go around the world.

Nevertheless, the world is still very diverse in many contexts. For example, in the least developed countries, including Ethiopia, the majority of us live on less than 1 U.S. dollar per day. In contrast, in the richest of countries, those who have to live on 100 U.S. dollar per day are indeed not considered rich.

That is why we expect much from our universities to hasten Ethiopia's economic development so as to enable us also to be rich.

But, what do we mean by economic development? Different people might answer this question differently. However, I expect that, in the final analysis, they will all say that it means the maximization into the indefinite future of our use of the natural resources that our planet Earth keeps providing us. In other words, we want a sustainable maximization of enjoying the ecosystem services that our biosphere can provide. I must emphasize that this maximization of the availability of ecosystem services in the form of goods and services that we can enjoy must be for each one of us. The greedy among us will always want more of those goods and services for themselves irrespective of those of us who may not have enough even to live on. They will want to heap many, many more goods than they could ever use and imagine the services they could enjoy without ever being able to enjoy them because they are limited individuals like any one of us. Nevertheless, they will prevent us, the less fortunate individuals, from using the extra goods that they could never use, and the extra services that they could never possibly enjoy. Therefore, it is not only the total wealth in a country that prevents poverty; it is also the distribution of that wealth.

Imagine an ideal society where the wealth is plenty, and the distribution is fair. Would such a society not be marvellous? Yes, it would be.

Ladies and Gentlemen,

Would it be sufficient to build such a society? It would if one additional conditionality were also fulfilled.

That additional conditionality is that Mother Earth must be able to keep on providing us and our children and their children into the indefinite future these sane maximized and thus plentiful evenly shared out goods and services. Is that possible?

In my view, it is possible. But only if our process of withdrawal of the natural resources does not reduce the ability of Mother Earth to keep on giving us those resources continuously into the indefinite future. Also in my view, an ever continuing supply is not possible with all natural resources. For example, you know that we are mining gold in Shakiso. Someday, that gold will run out. We are likely to find gold also in another area. If we start mining it, that gold will also run out. What should we then do? We can keep on mining gold until it runs out and not suffer negative consequences if, at the same time, we undertake to learn how to satisfy our needs for goods and services with the natural resources that do not run out. Are there such natural resources? Yes, there are. In fact, all the essential natural resources are. An example is trees and other types of biodiversity. But, deforestation eliminates trees,

you may say. I would then say to you that planting seedlings and caring for them until they become new trees repeatedly into the indefinite future makes them inexhaustible. In other words, when properly managed, trees and other types of biodiversity become renewable, and basing our wealth on them becomes inexhaustible. A development based on renewable natural resources is thus referred to as sustainable.

Therefore, for our economic development to become sustainable, it must be based on renewable natural resources.

I am not saying to you that we should not have mines to benefit from the exhaustible natural resources that we have. All I am saying is that we should use that exhaustible wealth not only to obtain goods and services, but also to shift our wealth into coming from renewable resources.

More importantly, we must protect, and when needed also develop, Mother Earth's capacity to continue giving us those renewable natural resources into the indefinite future.

How do we do that?

Before answering this question, I need to point out to you the main renewable natural resources that we get from Mother Earth. They vary to varying degrees from country to country.

In Ethiopia, besides trees and the various related forms of vegetation cover, crops and domestic and wild animals, I want to mention soil, rain, rivers, lakes, ground water, wind, sunshine, and heat deep down in the Earth that boils ground water to give us geothermal power.

We do not have to care for the sun or the wind; they will continue to be our ever present natural resources whatever we do. Even the Earth underneath will continue to be hot and will thus continue to give us geothermal power if we would only harness it to produce electricity. But the soil can erode away denying us fields to grow crops and hillsides to grow trees. The rainwater would then also simply flow away and the subsequent rainless months become waterless. You know all this, and thus I need not say more.

But even when water is available, it can be polluted and thus become harmful. We must, therefore, protect our soil and flowing as well as standing and ground water from pollution.

As Ethiopians, united, and knowing both what we want and what we must do, we can care for Mother Ethiopia so that we, our children and their children into the indefinite future can enjoy lives of wealth through sustainable development.

There is only one thing that we, Ethiopians on our own, cannot do in Ethiopia. We cannot, on our own, prevent long-lasting air pollution in Ethiopia.

As you know, wind blows across the world not caring for political boundaries. Therefore, this globalizing world must unite to prevent our Mother Earth's atmosphere from long-lasting pollutants. Ethiopia alone cannot keep its air entirely clean.

But, we live on land; what harm can atmospheric pollution cause? You may ask.

Some atmospheric pollutants, e.g. vaporized pesticides, can come from other countries with blowing wind and become toxic to us or to our natural resources.

More importantly, carbon dioxide, when present in excess amounts in the atmosphere, traps heat. There are also many other gases, mostly containing carbon, e.g. methane, that have the same effect. We call them collectively greenhouse gases. These greenhouse gases thus warm up the whole Earth, including Ethiopia. We, in Ethiopia, cannot, on own, reduce these greenhouse gasses sufficiently.

When the Earth thus heats up, climate changes, including in Ethiopia.

The industrial revolution started by burning fossil fuels, including coal and petroleum, and released net additional carbon dioxide and other greenhouse gases into the atmosphere. Consequently, the Earth has been warming up and climate has been changing, more so in our not yet industrialized countries. This is so because our countries are almost all near the naturally hotter equator and the industrialized countries are all near the naturally cold polar areas. To make matters worse, our countries are poor and they are rich.

Ladies and Gentlemen,

The fact that Mother Earth's climate is changing because of the global warming caused by the greenhouse gases in the atmosphere became clear in the 2nd half of the 20th century. This moved the world to negotiate the United Nations Framework Convention on Climate Change. This Convention divides the countries of the world into those in its Annex I and those not in that Annex I. Those in Annex I are the countries that have been emitting greenhouse gases into the atmosphere for a long time by burning fossil fuels to industrialize. These are the rich developed countries of Europe and North America, with Japan, Australia and New Zealand being added from the Far East. They caused the atmospheric pollution while getting rich. For this reason, the poor Non-Annex I countries were to be provided with financial resources,

technology and capacity development opportunities by the Annex I countries to enable the whole world to unite together in reducing atmospheric pollution. The support by the rich countries is also meant to help the poor developing countries to formulate and implement their respective programmes of adaptation to that part of climate change that has now become inevitable. Understandably, it was seen that the Annex I countries have to reduce atmospheric pollution as a requirement of international law. The developing countries were also to reduce atmospheric pollution but only to the extent that they were helped by the rich developed countries enumerated in Annex I.

The Kyoto Protocol was negotiated to become the international law to force Annex I countries to reduce specified amounts of atmospheric pollution. The Kyoto Protocol came into force in 2007 for five years, i.e. until 2012. Unfortunately, the biggest atmospheric polluter of the time, the United States of America, refused to ratify the Kyoto Protocol. Therefore, the Kyoto Protocol's real positive impact became limited right from the start.

Negotiations for the second emission reduction commitment period created more followers of the United States of America. Japan, Russia and New Zealand refused to undertake a second emission reduction commitment period under the Kyoto Protocol. Canada formally withdrew from the Kyoto Protocol. New big atmospheric polluters including China, India, and others emerged. The United States of America insisted that, if the new big polluters do not also reduce their greenhouse gas emissions, it would continue to refuse accepting any legally binding emission reduction commitment. Only Western Europe and Australia have agreed to undertake a second emission reduction commitment period under the Kyoto Protocol. Western Europe's greenhouse gas emission amount to less than 15% of the global amount. Australia's is even much less. Therefore, their emission reduction alone cannot have much impact on climate change.

The world was in this disarray when the 17th Conference of the Parties to the United Nations Framework Convention on Climate Change took place in Durban, South Africa, at the end of November and the beginning of December 2011. Bitterness and recrimination were evident in the negotiations in Durban. However, finally sense prevailed and an agreement was reached to negotiate a new, all inclusive, international law. This law is expected to bring about the needed reduction in greenhouse gas emission to slow down climate change. Negotiations to produce the new law have started.

The 18th Conference of the Parties took place in Doha, Qatar, from the 26th of November to the 8th of December this year, 2012. The second commitment period of the Kyoto Protocol was accepted to be eight years, i.e. 2013-2020. Then, hopefully, all countries will be parties to the new international law. The countries that refused to

undertake emission reduction commitments under the Kyoto Protocol gave their word in Doha that they would reduce their emissions albeit not under the Kyoto Protocol. The majority of developing countries are also taking mitigation actions voluntarily. As you will have heard, the Rio+20 World Summit on Sustainable Development took place last June 2012. In a preparatory meeting for that Summit, African countries agreed to adopt green economy for their development.

If we delay action, how big will the climate change that is taking place become? I am sure that it will become the biggest that has ever happened in the last 45 million years. Do you know what happened 45 million years ago? The dinosaurs went extinct. What is the likelihood that now humans will soon follow the dinosaurs? Very high. Then, what should we do? Of course, we should all unite to both reduce the magnitude of change in climate, and adapt to that inevitable part of the change. We have no choice, and, at last, we seem to be agreeing.

I want to finish by telling you what Ethiopia is doing to combat climate change. Ethiopia's greenhouse gas emission was estimated to be 150 million tonnes of CO_2 e. in 2010, or 1.8 tonnes/capita per year. If we had not reoriented our development trajectory into becoming green, Ethiopia's emission would have risen to 400 million metric tonnes by 2030, or 3.0 tonnes/capita/year.

To reorient our development path, efficient woodfuel cooking stoves are spreading throughout the country. We will continue to harness our hydropower, geothermal power and wind-power potentials to generate enough electricity for our industrial development and for the development of our neighbouring countries. A railway network which will be powered by electricity entirely from renewable sources has started being constructed. Our forest cover had been steadily decreasing since the 19th century. This trend has started being reversed. We are increasing the vegetation cover of our land very fast. The increasing vegetation cover will absorb greenhouse gases from the atmosphere. We have formulated our development plan to that end. We are already implementing this green economy plan as a component part of our Growth and Transformation Plan.

We also have developed through consultation down to the village local community level our Programme of Adaptation to Climate Change. This Adaptation Programme is now being used to ensure that our green economy will gather momentum without being hindered by intensifying climate change. In other words, we are finalizing our climate resilient green economy strategy.

Our development partners have been very supportive in the formulation and implementation of this ambitious climate resilient green economy strategy.

Therefore, I am confident that Ethiopia's vision of becoming a carbon neutral middle income country by 2025 will happen. What do I mean by carbon neutral? I mean that

the net sum of emissions of greenhouse gases in Ethiopia will be zero or even negative, especially thanks to the removal of greenhouse gases from the atmosphere by our fast-growing vegetation cover. In the meantime, our economy will continue to grow so that we will all become of average wealth in the world in less than 15 years.

I am feeling optimistic not only because of what we are doing in Ethiopia, but because the world seems to be realizing that all humanity has to unite to reverse climate change, to save not only ourselves but also as much biodiversity as possible and thus to heal Mother Earth so that humanity and all living things will enjoy the ecosystem service that they need into the indefinite future.

Thank you all for hearing me through. Good luck in this conference!

Dr. Tewolde Berhan Gebre Egziabher

Theme 1

Climate Change, Biodiversity, and Ecosystems

GLOBAL CLIMATE CHANGE: CAUSES, IMPACTS AND SOLUTIONS

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ABSTRACT

Climate change has become a reality, and is one of the greatest challenges the world is facing today. Climate change is mainly caused by anthropogenic activities, which release greenhouse gases into the atmosphere, particularly burning of fossil fuels, agriculture, and deforestation. The environment and humanity have been threatened by the escalating impacts of climate change. Thus, urgent actions are needed to combat this scenario. A comprehensive strategy for addressing climate change must include both mitigation and adaptation. Climate change is a truly global problem and thus requires a global solution. The aim of this paper is to highlight the causes and impacts of climate change and its mitigation and adaptation options.

Keywords: Adaptation, biodiversity, deforestation, greenhouse gases, mitigation

1. INTRODUCTION

Climate change is expressed as deviations from a regional climatology determined by analysis of long-term measurements, usually over a period of at least 30 years (IPCC, 1998; Wigley, 1999). Scientists believe that the global average surface temperature has risen over the past century in both space (globally across the land surface air, up to about 1.5 m above the ground, and sea surface temperature to around 1 m depth) and time (an annual mean over a defined time period) (Stern, 2006). Since 1900, the global average surface temperature has risen by about 0.76°C (UNESCO/UNEP, 2011). There have been changes in global average near-surface temperature from 1850-2005 (Figure 2). On the other hand, the Inter-governmental Panel on Climate Change (IPCC) asserts that continued emissions of greenhouse gases at or above the current rates would cause an increase in the global average surface temperature by 1.8^{o}C to 4.0^{o}C by 2100 (IPCC, 2007a). The rapid increase in global temperature is expected to lead to regional and global changes in climate that could have significant impacts on humans and natural systems.

1.1. Causes of Climate Change

Climate change is caused by several natural factors such as changes in the Earth's orbit around the sun, volcanic eruptions, or even periods of heightened or diminished solar activity (i.e. solar variation). It is also caused by anthropogenic activities, particularly burning of fossil fuels, agriculture and land use change (particularly deforestation). The emission of greenhouse gases is the main driver of climate change (IPCC, 2007a).

The concentrations of greenhouse gases in the atmosphere have been increasing substantially over the past 100 years due to anthropogenic activities. However, the burning of fossil fuels has been the main cause of increased levels of greenhouse gases in the atmosphere. High concentrations of greenhouse gases in the lower atmosphere trap more heat and this is increasing the overall surface temperature of the earth. This phenomenon is known as global climate change, or more popularly global warming.

1.2. Major Greenhouse Gases

The major greenhouse gases responsible for climate change are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). The former three are natural greenhouse gases while the latter are man-made greenhouse gases. The six Kyoto greenhouse gases are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (Kyoto Protocol, 1997).

Carbon dioxide is the primary cause of climate change. Although molecules of methane, nitrous oxide and CFCs trap much more heat per molecule than carbon dioxide, the larger input of carbon dioxide makes it the single most important greenhouse gas produced by human activities. Carbon dioxide contributes to about 55% of the climate change. The contributions of the other greenhouse gases are 25% for CFCs, 15% for methane and 5% for nitrous oxide (IPCC, 2007a).

1.3. Greenhouse Gas Emissions

The major sources of greenhouse gases are power, industry, transport, agriculture, and deforestation.

Carbon dioxide: Huge quantities of carbon dioxide have been pumped into the Earth's atmosphere due to burning of fossil fuels, fuel wood and forests. As a result, the concentrations of atmospheric carbon dioxide have measurably increased. Since pre-industrial times (around 1750), the concentrations of carbon dioxide in the atmosphere have risen from 280 ppm to nearly 380 ppm (Stern, 2006).

Methane: Methane (and carbon dioxide) is produced by the decomposition of organic matter by anaerobic bacteria in wetlands, peat deposits and thawing permafrost and in the intestine of cattle, sheep and termites. Burning of oil, natural gas and biomass are also significant sources. Its level today is said to be a double of the pre-industrial level.

Nitrous oxide: The major sources are nylon production, burning of fossil fuels and biomass, and breakdown of nitrogen fertilizers in the soil.

CFCs: These are industrial products and significant greenhouse gases. They also contribute to depletion of the ozone layer. The main sources are refrigerators, fire extinguishers, air conditioners, aerosol propellants, and plastic foams.

In total, the warming effect due to all (Kyoto) greenhouse gases emitted by human activities is now equivalent to around 430 ppm of carbon dioxide (referred to as CO_2 equivalent or CO_2e) and rising at around 2.3 ppm per year (Stern, 2006). If annual emissions were to remain at today's levels, greenhouse gas levels would reach close to 550 ppm CO_2e by 2050 (Stern, 2006). Without action to combat climate change, atmospheric concentrations of greenhouse gases will continue rising.

2. IMPACTS OF CLIMATE CHANGE

Climate change has environmental, social, economic and political impacts. Of course, climate change exacerbates poverty. The impacts of climate change are global in scope and unprecedented in scale. There are observed and expected impacts of climate change.

2.1. Environmental Impacts

2.1.1. Melting of ice and glaciers

Glaciers are in retreat in most parts of the world, and those on high peaks in the tropics like Mt. Kilimanjaro are receding at a rate that they will likely cease to exist in 15 years (UNEP, 2007). The melt rate of Greenland glaciers is increasing and the seismic activity they generate is accelerating; Arctic sea ice is retreating at an unprecedented rate (Lovejoy, 2010). Over the 20th century, Kilimanjaro's glaciers have been melting rapidly, and if current climatological conditions persist, the remaining glaciers are likely to disappear between 2015 and 2020 (Thompson *et al.*, 2002).

2.1.2. Sea level rise

Climate change will lead to sea level rise due to melting of ice and glaciers and expansion of water resulting from rising temperatures. As a result, there would be submergence and disappearance of small islands and inundation of low-lying coastal

areas. An estimated 50 cm rise in sea level by 2100 could inundate large areas of land. Melting or collapse of ice sheets would raise sea levels and eventually lead to loss of at least 4 million km^2 of land, which today is home to 5% of the world's population (Stern, 2006).

Sea level rise will increase coastal flooding, raise costs of coastal protection, lead to loss of wetlands and coastal erosion, and increase saltwater intrusion into surface and groundwater (Stern, 2006). Rising sea levels will lead to a large increase in the number of people flooded each year. There will be serious risks and increasing pressures for coastal protection in South East Asia (Bangladesh and Vietnam), small islands in the Caribbean and the Pacific, and large coastal cities such as Tokyo, Shanghai, Hong Kong, Mumbai, Calcutta, Karachi, Buenos Aires, St. Petersburg, New York, Miami, Florida and London.

2.1.3. Changes in precipitation patterns

Climate change will cause changes in the global distribution of precipitation, i.e. decrease in precipitation in low latitudes (tropical regions) and increase in middle and higher latitudes (temperate and polar regions). Increased rainfall in temperate regions may cause more frequent flooding.

2.1.4. Extreme weather events

When global temperatures increase, there are huge changes to the Earth's weather systems. Climate change will increase the frequency and intensity of extreme weather events such as droughts, floods, heat waves, storms/hurricanes, etc.

2.2. Impacts on Species and Ecosystems

Climate change will bring shifts in the distribution of species and ecosystems. In general terms, most of the species show a reduction of their distribution or certain species will even disappear, but some species show an increase in distribution.

Climate change will cause extinction of species and reduction in biodiversity. According to one estimate, global average surface temperature increase of 2°C could commit about 15-40% of species to extinction (Stern, 2006).

2.2.1. Desertification

The United Nations Convention to Combat Desertification (UNCCD) defines desertification as "degradation of lands in arid, semi-arid and dry sub-humid zones following various factors among which climatic variations and human activities". A major impact of desertification is reduced biodiversity and diminished productive capacity. Climate change will increase desertification in tropical regions. Currently,

two-thirds of Africa is desert or dryland, a situation that is going to be aggravated by climate change (FAO, 2003). In Nigeria, 3,500 km^2 of land transform into desert each year, making desertification the country's primary problem (UNESCO/UNEP, 2011).

2.2.2. Wildfires

Climate change will increase the frequency and intensity of wildfires, which destroy forests and wildlife. For instance, there is a statistically significant increase in wildfires in the American West because longer summers and earlier melt of the snow pack have led to dryer environments and higher fire vulnerability (Flannigan *et al.*, 2000). Parts of southern Australia had extraordinarily high temperatures and devastating fires in the summer of 2008-2009 (Lovejoy, 2010).

2.2.3. Pollution

Climate change will increase pollution of the environment since high temperatures induce complex chemical reactions that lead to the production of toxic and harmful substances.

2.3. Socio-economic Impacts

2.3.1. Impacts on agriculture and food security

Reduction in crop and livestock production will increase hunger especially in poor countries and causes social and economic chaos. Declining crop yields, especially in Africa, are likely to leave hundreds of millions without the ability to produce or purchase sufficient food (Stern, 2006). Climate change will pose the most massive threat to food security the world has ever faced. The most vulnerable social groups like women and children will be severely affected.

2.3.2. Impacts on water supply

Climate change is a major factor affecting the distribution, amount and quality of water around the world. Water availability decreases in many areas (may increase in others). Climate change will cause shrinkage and drying up of streams, rivers and lakes in tropical areas and reduce water supply for drinking, irrigation, industrial use, hydroelectric power generation, sanitation and recreation. The number of people facing water scarcity has been increasing as a result of climate change. In the face of climate change, water scarcity is one big problem for most African countries (UNESCO MAB and OAS, 2011).

2.3.3. Impacts on human health

Climate change will pose threats to human health. Climate change will increase the frequency and intensity of pests and diseases. A variety of tropical diseases (e.g. malaria, cholera, yellow fever, meningitis) are sensitive to changes in temperature, rainfall and humidity (Alebachew Adem and Woldeamlak Bewket, 2011). For instance, the mosquito belt has considerably expanded to higher elevations due to the temperature incline.

2.3.4. Impacts on transport

Warmer temperatures decrease heating requirements but increase cooling demand. Water transport will be affected by lowered water levels or increased flooding.

2.3.5. Impacts on gender

Climate change is not gender-neutral. Gender inequalities influence the specific ways in which climate change affects men and women. As such, women manifest differential vulnerability to the impacts of climate change. Women are the most vulnerable to the climate change impacts due to their socially constructed roles, rights and responsibilities, and they are often poor (Alebachew Adem and Atsede Guta, 2011). Women are 'over-represented' in agriculture and the informal economy, sectors that will be hardest hit by climate change (Stern, 2006). On the other hand, women's limited access to resources and decision-making processes increases their vulnerability to climate change (Alebachew Adem and Woldeamlak Bewket, 2011). This calls for redressing gender imbalances and empowering women to climate change mitigation and adaptation, among others.

2.3.6. Migration and conflict

Climate change may drive many rural people from their lands. These people are likely to either go to cities to look for jobs, often adding to urban poverty, or to other rural areas to look for other lands where they may be able to continue their agricultural livelihoods or find employment in the agricultural sector (Magrath and Sukali, 2009; Martin, 2010; Gemenne, 2011). By the middle of the century, 200 million more people may become permanently displaced due to rising sea levels, more intense droughts and heavier floods (Stern, 2006). Women and children are particularly vulnerable to displacements following natural disasters.

2.4. Impacts on Education

Climatic disasters can threaten educational infrastructure making it physically impossible for children to attend school. For example in 1998 Hurricane Mitch

destroyed 25% of Honduras' schools (ODI, 2005). Education levels may also decline through climate-induced changes in income and health conditions (Stern, 2006). Schooling will become less affordable and accessible, especially for girls, as income, assets and employment opportunities are affected by climate change. Children will need to help more with household tasks or prematurely engage in paid employment leaving less time for schooling. Deteriorating health conditions will also affect both a child's learning abilities and school attendance, and the supply of teachers. Children will be deprived of the long-term benefits of education and be more vulnerable to the impacts of climate change.

3. SOLUTIONS TO CLIMATE CHANGE

Currently, climate change is the top international agenda. It has been realized that human activities that increased atmospheric concentrations of greenhouse gases have global effects, leading to a concerted international policy response. The most notable policy responses at international level are the United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention to Combat Desertification (UNCCD) and Kyoto Protocol (KP).

3.1. Climate Change Mitigation and Adaptation

There are two basic approaches to address climate change: mitigation and adaptation. Climate change mitigation and adaptation complement each other and together can significantly reduce the risks of climate change. They are analogous to disease prevention and cure. Any comprehensive strategy for addressing climate change must include both mitigation and adaptation (IFAD, 2008). Several climate change mitigation and adaptation options have been suggested.

3.2. Climate Change Mitigation

Mitigation of climate change is an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (Chidumayo *et al.*, 2011). The first option is to reduce the consumption of fossil fuels, thereby reducing greenhouse gas emissions; the second one is to keep CO_2 out of the atmosphere by storing the gas or its carbon component somewhere else, a strategy known as carbon sequestration. As such, climate change mitigation includes creation of carbon prices and markets, interventions to support low-carbon investment and technology transfer, cooperation on technology development and deployment, and action to reverse deforestation. Mitigating climate change by reducing greenhouse gas emissions is a global issue and requires committed international action and cooperation. Enhanced action on mitigation is essential to meet the goal of holding the global average surface temperature rise below 2^oC.

Curbing deforestation is a highly cost-effective way of reducing greenhouse gas emissions and has the potential to offer significant reductions fairly quickly (Stern, 2006). It also helps preserve biodiversity and protect soil and water quality. Encouraging new forests (afforestation, reforestation, agroforestry), and enhancing the potential of soils to store carbon, offer further opportunities to reverse emissions from land use change.

3.3. Clean Development Mechanism (CDM)

The CDM allows industrialized countries to offset their emissions by investing in emission reduction projects in developing countries. This flexible approach is regarded as a 'win-win' strategy by policy-makers as developing countries benefit whilst developed countries are able to meet their commitments under the Kyoto Protocol. This also has attracted a lot of interest from conservationists because of the potential for obtaining CDM payments to cover the cost of forest conservation on the grounds that carbon lost through deforestation will contribute to GHG emissions. From a conservation perspective, this is a 'win-win' in that forest biodiversity will be protected whilst preventing CO_2 emissions. In addition to energy reduction projects, carbon could be sequestered in plantations or biofuel crops could be planted to replace oil-based transport fuels in developed countries.

However, the distribution of CDM projects has been strongly skewed by sector and geographical regions. Two-thirds of all CDM projects in 2008 are in the renewable energy sector, generating two-fifths of all Certified Emission Reductions (CERs) (Chidumayo *et al.*, 2011). The CDM market has been dominated by four countries: China, India, Brazil and Mexico, holding 75% of CDM projects. Over 95% of CDM projects and CERs are in the Asia-Pacific and Latin American regions, with Africa hosting only about 2.2% of CDM projects and 3.3% of projected CERs by 2012. Thus, African share of the CDM market is low.

3.4. Reducing Emissions from Deforestation and Forest Degradation (REDD)

REDD has been developed to reducing deforestation and forest degradation in developing countries. Now REDD has evolved to reducing emissions from deforestation and forest degradation plus related pro-forest activities (REDD+). Thus, REDD+ includes reducing deforestation and forest degradation, promoting the conservation and sustainable management of forests and enhancing forest carbon stocks. This can end thousands of years of deforestation, which is critical because about 20% of global greenhouse gas emissions come from tropical deforestation. Interventions that hold significant potential in terms of REDD+ include enhancement of bioenergy efficiency, large-scale forest plantations (afforestation, reforestation, agroforestry), better wood and non-wood forest products harvesting and processing techniques, improvements in crop and livestock production, diversification of rural

livelihood options, and better planning and management of other land uses like infrastructure (roads, railways, power lines, dams). REDD+ is now high on the global climate change agenda, but it is not clear how internationally negotiated modalities and eventual national implementation will affect the people whose livelihoods depend totally or partially on forests (FAO, 2012).

3.5. Agriculture, Forestry and Other Land Uses (AFOLU)

In addition to REDD+, there is a drive towards AFOLU as a comprehensive mitigation package in the land sector. Such a move will widen the scope significantly for participating by small-scale growers and farmers since the most effective measures to implement REDD+ require interventions in the agricultural and other land use sectors. Reducing greenhouse gas emissions from AFOLU offers a great opportunity for the developing world like Africa to contribute to climate change mitigation and help millions of smallholder farmers adapt to climate change impacts.

3.6. Climate Change Adaptation

Effective mitigation is lagging behind whereas climate change is taking place rapidly. Political impasse on international agreements for greenhouse gas reductions means that CO_2 levels will continue to rise. Thus, the world is left with adaptation.

Some of the counter measures for strengthening climate change adaptation include providing accurate information about climate change and its impacts; carrying out vulnerability assessment; implementing land use zoning; enhancing resilience of livelihoods using existing knowledge and coping strategies; using stress-tolerant crops including varieties; employing conservation agriculture; using appropriate technologies for water harvesting and storage; ensuring access to primary healthcare services; empowering communities so that they participate in assessments and feed their knowledge into the process at crucial points; diversifying production and marketing strategies; mainstreaming climate change into environment and development issues; providing resources (human, financial, technical, technological, institutional, infrastructural); improving governance, including a transparent and accountable policy and decision-making process and an active civil society (Stern, 2006; Conway, 2008; Chidumayo *et al.*, 2011; Starke, 2011).

3.7. Community-based Adaptation Strategies

Community-based adaptation strategies are currently advocated as the best approach to counter the effect of climate change. This adaptation strategy enables communities to enhance their own adaptive capacity, and empowers them to increase their own resilience to the impacts of climate change. It involves strengthening the adaptive capacity of poor communities to deal with the potential impacts of climate variability

and change. Communities have developed a range of practices and options which have helped them to adapt to climate change and its impacts (IPCC, 2007a). The most notable ones include soil and water conservation practices, management of forest fires, rangeland management, crop diversification, composting, and diversification of livelihoods. Thus, the use of indigenous knowledge and local coping strategies should be promoted as a starting point for planning climate change adaptation (Chidumayo *et al.*, 2011).

3.8. Agroforestry Systems

Agroforestry systems hold considerable potential for human and domestic animal adaptation to climate change. Agroforestry systems supplement food supplies and also serve as a buffer during periods of droughts and crop failures. Moreover, agroforestry has the potential to reduce pressure on forests and provide ecosystem services such as carbon sequestration, biodiversity conservation and land restoration.

3.9. Ecological Agriculture

Ecological agriculture has high potential for both climate change mitigation and adaptation (FAO, 2011). Ecological agriculture such as avoiding the use of synthetic fertilizers results in reduced greenhouse gas emissions, particularly nitrous oxide. Ecological agriculture practices such as soil and water conservation, agroforestry, crop diversification (including farmers' varieties), crop rotation, crop residue retention; mulching and compositing enhance soil fertility and lead to the stabilization of soil organic matter and in many cases to a heightened sequestration of carbon in the soils.

3.10. Flexible Livestock Production Strategies

Mobility, grazing reserves and communal water management are important strategies used by African livestock keepers to cope with variable rainfall conditions (Chidumayo *et al.*, 2011). For instance, the Boranapeople in southern Ethiopia have elaborate institutions for ensuring that their livestock are able to maintain access and good care for water points and pastures. The Sukumapeople of western Tanzania have revived their customary *ngitili* arrangement for reserving dry season grazing areas.

3.11. Use of Non-Timber Forest Products (NTFPs)

Non-Timber Forest Products (NTFPs) are products other than timber, as well as services, derived from forests. NTFPs are harvested from forest areas and are produced in farmers' fields. The major NTFPs include food, fodder, medicines, construction materials, handicrafts, fibres, honey and beeswax, spices, oils, gums,

resins, dyes, tannins, latexes, etc. Harvesting and use of NTFPs has been a coping strategy to adverse climatic conditions, particularly during droughts and crop failures.

3.12. Climate Change Education (CCE)

With the greater awareness about the unfolding impacts of climate change on countries and communities, citizens and politicians are turning to educating the community as part of the response to climate change (UNESCO/UNEP, 2011). Educators and education planners are increasingly being called upon to include climate change in their programmes in order to help inform the next generations and to better equip them to respond to the climate-related challenges ahead. However, teaching climate change in an interdisciplinary manner poses challenges to educators. Educators are called upon to understand the complex emerging science and to communicate it to the next generations.

3.13. Information Exchange and Dissemination

Provision of accurate information on the impacts of climate change will be crucial to guide and prioritize action on climate change. The information should be made available to policy-makers and institutions concerned with climate change. For example, the Stern Review on the Economics of Climate Change for the UK Government has helped to focus on the need to take urgent measures (Stern, 2006). On the other hand, lack of local weather data makes it very difficult to predict with any degree of accuracy what will happen as a result of climate change at a country, or even sub-regional level in Africa (Conway, 2008).

4. CONCLUSIONS AND RECOMMENDATIONS

Climate change has become a reality, and is one of the greatest challenges the world is facing today, and is caused mainly by human activities. Therefore, urgent actions are needed to tackle the problem. A comprehensive strategy for addressing climate change must include both mitigation and adaptation. To combat climate change and sustain the environment and humanity, it is necessary to reduce the anthropogenic emissions of greenhouse gases, shift from fossil fuels to renewable energy and energy efficiency, and promote the conservation and sustainable management of forests and other terrestrial ecosystems. This implies that develop appropriate climate change policies, strategies and action plans should prior agenda of nations. It is also important to promote national, regional and international collaborations and networking on climate change issues.

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PARTHENIUM WEED INVASION AND BIODIVERSITY LOSS IN ETHIOPIA

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ABSTRACT

Parthenium weed (*Parthenium hysterophorus* L.) is an invasive alien species whose mode of introduction is uncertain. It was first recorded in Ethiopia in 1968. Since then it has been colonizing disturbed sites very aggressively, impacting pastures, croplands and forests by outcompeting native species and has become a major threat to the natural environment. It has been found to be widespread in north, east and south-western regions of the country. It is rapidly expanding in urban and rural areas. Initially, the weed was confined to railway tracks, roadsides, non-crop areas but it is now found to colonize pasturelands, cropped areas rapidly. The invasion by *P. hysterophorus* is causing biodiversity degradation, yield losses in field and horticultural crops, health problems to human beings and animals. Germination and growth of indigenous plants are inhibited by its allelopathic effect. It is being increasingly seen as a threat not only to biodiversity and ecosystem but it is also seriously affecting economic development and human wellbeing. Most of the studies conducted focused on changes in floristic communities in western Hararghe, Afar, Jigjiga, and north-eastern pasturelands in the country. Based on eco-climatic index, Ethiopia is highly favourable for the weed. Studies conducted have revealed substantial decline in plant species richness and abundance, reducing native plant species diversity and fodder supply to animals. In north-eastern grazinglands of Ethiopia, a regression analysis showed a highly significant but negative relationship between the aboveground species diversity and evenness with parthenium abundance. The results have also shown a build-up of soil seed bank in favour of parthenium in medium to highly infested areas. Thus, the invasive alien plant species poses significant challenges to managing and maintaining indigenous biodiversity in natural ecosystems.

Keywords: Abundance, biodiversity degradation, eco-climatic index, ecosystem, species richness

1. INTRODUCTION

The invasion of natural habitats by weeds has been associated with human movements throughout the evolutionary development. The exploitation of natural areas resulted in colonisation and establishment of introduced plants. Invasions by alien species are thought to be one of the most serious threats to both natural and managed ecosystems worldwide (Mack *et al*., 2000). Weeds are repeatedly excellent at surviving and reproducing in disturbed environments and are the first species to

colonise and dominate the ecosystem and impose severe losses to farm and forest productivity. Weeds invade crops, smother pastures and grazinglands, and in some cases even harm livestock and humans. They aggressively compete for water, nutrients, and sunlight, resulting in reduced crop yields and poor crop quality.

Parthenium weed (*Parthenium hysterophorus*) also known as carrot weed is an annual multi-branched herb of the family Asteraceae. It is native to tropical and sub-tropical Americas and is one of the world's worst invasive weeds. The weed is currently distributed in Argentina, Australia, Bangladesh, China, Cuba, Dominican Republic, Ethiopia, Haiti, Honduras, India, Jamaica, Madagascar, Mauritius, Mexico, Mozambique, Nepal, New Caledonia, Pakistan, Papua New Guinea, Puerto Rico, Seychelles, South Africa, Sri Lanka, Swaziland, Tanzania, Trinidad, Uganda, United States of America, Venezuela, Vietnam, West Indies, and Zimbabwe.

In many introduced ranges, parthenium has posed serious threats to crop production, natural biodiversity, animal and human health because of prolific growth, rapid spreading and production of toxic allelochemicals (Chippendale and Penetta, 1994; Kohli *et al*., 2006; Asresie *et al*., 2008). Although *P. hysterophorus* was first recorded in Ethiopia in 1968 (Haramaya University, Herbarium), its mode of introduction is still uncertain. Probably it remained unnoticed and the major spread of the weed took place after 1980 when infestation was observed at Dire Dawa. It is also believed that parthenium was introduced to Eastern Hararghe, Jigjiga, and Dire Dawa during the Ethio-Somalia war in 1976-77 by army vehicles (Tomado and Milberg, 2000). The second major centre of infestation was subsequently found near Dessie, Wello and north-eastern Ethiopia, which were major food distribution centres. There is strong proposition that the weed was imported from sub-tropical America during the 1988 famine (Murphy and Cheesman, 2006). Thus, it is likely that the entry occurred as a seed contaminant of food grains imported from overseas. The area coverage is enormously increasing across the agro-climatic zones of the country and has become an environmental weed. Higher infestations have been reported in eastern Ethiopia, notably in the range and cropping lands of the east and west Hararghe Zones.By 1999, parthenium weed was reported to be spreading to western Ethiopia. Even though there is no actual data on the total area of land infested by the weed, widespread occurrence of the weed has been reported in the north, east and south-western regions (Mc Connachie *et al*., 2010). Currently, parthenium is spreading at an alarming rate in eastern Ethiopia, the Central Rift Valley, and neighbouring localities of Afar Region, east Shewa, Arsi, Bale, and in southern Ethiopia. A recently developed CLIMAX model has shown that much more land within Ethiopia is suitable to support the growth of parthenium (Mc Connachie *et al*., 2010) and it is anticipated that the problems caused by the weed will increase with its expansion.

1.1. Impact of Parthenium

The weed has economic, environmental, and social impacts. It is destroying native habitats, threatening native plants and thus reducing plant biodiversity and consequently the degradation of natural vegetation. It competes with beneficial pasture grass in pasturelands; it is hazardous to livestock and human health; it reduces crop yields, increasing cost of production. It also reducesrecreational and aesthetic values.

Heavy infestations of new areas by the weed could be attributed to absence of natural enemies (particularly insect pests and diseases).Infestations by the weed could also be ascribed toits faster growth than native plants and its ability to outcompete other plant species for available nutrients, water, space, and sunlight. Growth inhibitors like lactones and phenols are released from this plant into the soil through leaching, exudation of roots, and decay of residues. These growth inhibitors suppress the growth and yield of native plants. Therefore, the weed reduces natural diversity by smothering native plants and may exhibit natural heterogeneity to homogeneity. Parthenium weed is extremely prolific and has a wide range of ecological adaptation, ability to spread quickly and grow in diverse habitats (Annapurna and Singh, 2003). Parthenium can invade new areas rapidly by means of relatively high numbers of seeds, dispersal via vehicles and rails, water, animals, farm machinery, and rapid growth.Personal observations of the authors in India and Ethiopia showed that construction sites are more vulnerable toinfestation by the weed not only through vehicles/ heavy machinery but also construction such as gravels, sand, soil, etc. A single parthenium plant produces 810 flower heads and on an average 15,000 seeds.Under favourable conditions, for example, in a highly infested field in India, a single plant produced 200, 000 seeds/m^2 (Joshi, 1991). Seeds are very light in weight and easily disseminated to other areas. It has a huge soil seed bank reserve ranging between 7000-8000 seeds m^2 (Nguyen *et al*., 2010).Its decaying roots release soluble sesquiterpene lactones, mainly partenin (Jarvis *et al*., 1985; Pandey *et al*., 1993). These chemicals inhibit the germination and growth of other plant species including pasture grasses, cereals, vegetables, etc (Navie *et al*., 1996; Evans, 1997).

1.2. Impact on Biodiversity

Infestation by parthenium degrades natural ecosystems. With the passage of time, parthenium invasion enriches the compositional diversity but may result in extinction of native species (Noss, 1990). The weed is known to exert significant impact on the natural communities causing their displacement and hence exert imbalance in the natural and agricultural ecosystem (Sakai *et al*., 2001). This imbalance causes the formation of large monoculture of invasive plants in the alien environment. Several studies revealed the adverse effects of parthenium on plant biodiversity (Cock, 2001; Kohli *et al*., 2004). Lisanework *et al*. (2010) found that within the soil seed bank, the

viable seed density for parthenium was 68.5% as against 25.7% for grass and 5.8% for other species. Similarly, in grasslands dominated by parthenium, native plant species composition and abundance was found to be low (Taye*et al*., 2010). Similarly, in Australia, parthenium caused a significant reduction in native plant diversity (Nguyen*et al*., 2010). In sorghum fields, 79.5 % of the weed diversity and 61.4% of the species evenness was attributed to parthenium invasion in Kobo, north-eastern lowlands of Amhara region (Asresie *et al*., 2008) and the plant species heterogeneity decreased with the increase in parthenium infestation and the evenness index was higher in less infested areas. There was considerable reduction in species richness as the density of parthenium increased. The authors also observedthat the area covered by parthenium was 34% of the total area covered by weeds with the importance value of 45.6%, which demonstrated the invasiveness of parthenium with the potential to replace other native species entirely.

Parthenium infestation of native pastoral lands has led to a significant decline in native flora seed banks in Ethiopia and reduction in diversity index, evenness, and species richness with the increase in the density of the weed. This demonstrates the significant threats posed by the weed on the native plant diversity (Lisanework *et al*., 2010). The exact estimates of pastoral lands invaded by parthenium are not known in Ethiopia. However, wherever the invasion of this species exists, there is a lot of pressure created on grazing lands by livestock. This would further create more pressure on native pasture species to be outcompeted by the weed. Furthermore, prolonged droughts in some parts of the country have favoured the invasion of the weed.

In Serengeti–Masai, the largest wildlife migration is under attack from parthenium, threatening the migration of millions of animals in Kenya (Chadwick, 2010). Infestation of parks and other reserve areas has been reported in India (Goyal and Brahma, 2001) and the weed has poseda serious challenge to the diversity of herbaceous plant species in the Awash National Park in Ethiopia (Fish *et al*., 2010; Ayana *et al*., 2011), which calls for immediate action.

The most frequent and sturdy flushes are observed during the rainy season, coupled with comparatively higher temperatures, producing a large number of seeds. Therefore, with the change in climate, the increasing temperature may not only facilitate the spread of parthenium to new areas but also the intensity and robustness of plants in a community. The atmospheric CO_2 level has been increasing steadily over a number of years (Houghton *et al*., 1991). It is believed that enhancement of atmospheric CO_2 will greatly increase the growth of C_3 plants (Kimball, 2002; Nowak, 2004). The growth of exotic invasive plants will increase more than the native C_3 because of specific growth traits that help them to use more CO_2 (Grotkopp and Rejmanek, 2007; Leishman *et al*., 2010). Parthenium is considered as both a

$C_3$and C_4 plant (Rao and Rajendrudu, 1989; Devi and Raghvendra, 1994). Like in other countries, the grazing and pasturelands in Ethiopia are also dominated by grasses mostly which are C_4 plants. Thus, parthenium is likely to become more problematic in Ethiopia. Another possible effect of elevated CO_2 upon promoting the suppressive ability of the weed may be through promotion of its allelopathic potential against neighbouring plants.

1.3. Impact on Agriculture

Parthenium reduces yields of agricultural crops and forests, decrease water availability, causes costly land degradation, blocks transport routes, and contributes to the spread of diseases. It generates allelopathic effects in soils and outcompetes crops for available nutrients and moisture.

Parthenium infestation had detrimental effect on sorghum yield. In eastern Ethiopia, sorghum grain yield reductions ranged from 40% to 97% (Tamado *et al*., 2002b) and in 18.5-86.4% in common bean (Mitiku, 2011) due to parthenium infestation. In India, a crop yield reduction of up to 40% has been reported (Khosla and Sobti, 1981).

Parthenium weed is an environmental weed which can cause a total habitat change in native grasslands and forestlands. In India, the forest biodiversity is being reduced and the structure of many native plant communities are being altered (Pandey *et al*., 1993; Kumar and Rohatgi, 1999). In Ethiopia, native plant communities have been invaded, or are vulnerable to invasion by this exotic weed that could result in changes to the structure, species composition, abundance of native communities in grazinglands.In Australia it has become dominant species and excludes all beneficial forage plants resulting in monoculture of non-nutritious vegetative matter in which it is impossible to sustain cattle causing drop in productivity of pastures that has reduced the carrying capacity of farms up to 40 perecent (Chippendale and Penetta 1994) and 90% reduction in forage production in India (Nath, 1988). Parthenium in pastures reduces forage quality and yield, and increases management costs and reduce animal performance (Herlocker, 1999)**.**

2. CONCLUSION

Parthenium is an invasive weed that threatens agricultural production as well as livestock and human health, with a serious consequence on biodiversity. Therefore, controlling, managing, and ultimately eradication the weed must be a priority. To combat the menace of parthenium to biodiversity, agricultural production, human and animal health, environmental and economic losses, a sound management strategy has to be formulated. This should include prevention, implementation of biological methods like introduction of insect bioagents and competitive plants in large areas with severe parthenium

infestation on roadsides and non-crop areas. Herbicides and cultural methods may have limited scope only in crop fields and orchards. To contain the further spread of the weed and soil seed bank build up, parthenium plants should be utilized for mulching, composting, and production of biogas and paper. For grazing and pasturelands, herbicides as well as strategies for rehabilitation of the land with multi-purpose fodder species has to be developed. Above all, mass awareness and eradication programmes should be conducted.

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COPING WITH DROUGHTS IN KENYA: OPPORTUNITIES AND CHALLENGES FOR CLIMATE CHANGE MITIGATION

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ABSTRACT

Kenya is an agri-based economy that depends on rainfall performance with rain-fed agriculture supporting over 80% of the population. In the last two decades, the reliability of rainfall has been reducing due to changes in its amount, timing and distribution as climate changes. Food insecurity is now a recurrent phenomenon in most parts of the country and chronic in the arid and semi-arid areas due to frequent droughts. To survive the harsh climatic conditions, the affected communities employ various coping strategies. The current study examined the drought coping strategies employed by subsistence farmers in the semi-arid areas of Kenya in relation to mitigating climate change. Data were obtained from Mukogodo and Central Divisions of Laikipia County, Kenya. Time series was used to analyse rainfall trends. Data on effects of droughts and coping strategies were obtained through in-depth interviews. The inhabitants were aware of climate change with 90% and 10% of the respondents attributing the changes to human activities and divine forces, respectively. Rainfall showed a declining trend in Mukogodo Division but an increasing trend in Central Division. Nevertheless, the timing of the "long rains" and the length of the growing season in Central Division showed considerable changes. The consequences were food insecurity and livelihood destruction in the area. The coping strategies employed aimed at cushioning farmers against immediate problems but with minimal consideration of climate change mitigation.

Keywords: Climate change mitigation, coping strategies, food insecurity, livelihood, rainfall

1. INTRODUCTION

Agriculture is the cornerstone of the economies of most African countries. It employs about 65 percent of Africa's labour force, accounts for 30 to 40 percent of Africa's total gross domestic product (GDP), and 60 percent of its total export earnings. In Sub-Saharan Africa (SSA), agriculture accounts for 70 percent of employment and 30 percent of the GDP (IFPRI, 2009). Agriculture in Africa is mainly rain-fed and thus affected by climate vagaries, particularly droughts. According to UNFCCC (2007) one third of people living in Africa live in a drought-prone area with 220 million people being exposed to droughts every year. As a result, about 239 million people in SSA are food-poor (Bill and Melinda Gates, 2012). It is projected that by 2020, between 75 and 220 million people will be facing severe water shortages; yields from rain-fed crops could fall by 50% in some countries while net revenues loss from crops could fall by 90 percent (UNFCCC, 2007). Kenya's socioeconomic

development depends largely on rainfall performance since the economy is agri-based. Agriculture is vital in Kenya's socioeconomic development and poverty alleviation since it supports over 80 percent of the population. It directly contributes 26% of the Gross Domestic Product (GDP) and indirectly 27 percent through linkages with manufacturing, distribution, and service related sectors. In addition, it accounts for 60% of the export (Gitau *et al*., 2009).

Over 80% of the country falls in arid and semi-arid climates where the main source of livelihood is marginal agriculture, agro-pastoralism and pure pastoralism (Figure 1). Agricultural activities in these areas are hindered by frequent droughts and occasional flash floods. Reduced rainfall reliability has, in the last two decades, been experienced in these regions due to changes in its amount, timing and distribution as climate changes. Ministry of Environment and Mineral Resources (2011) observes that there has been a general decline in rainfall during the main growing season i.e. March, April, and May. Drought is now a perennial problem in Kenya with chronic vulnerability being concentrated in the arid and semi-arid lands (ASALs). Agricultural production has been declining in the ASALs. As a result, famine cycles have reduced from 20 years (1964-1984) to 12 years (1984-1996), to two years (2004-2006) and a yearly basis (2007/2008/2009/2010/ 2011 (GoK, 2010). Food insecurity is now a norm in most parts of the country and has become chronic in the ASALs.

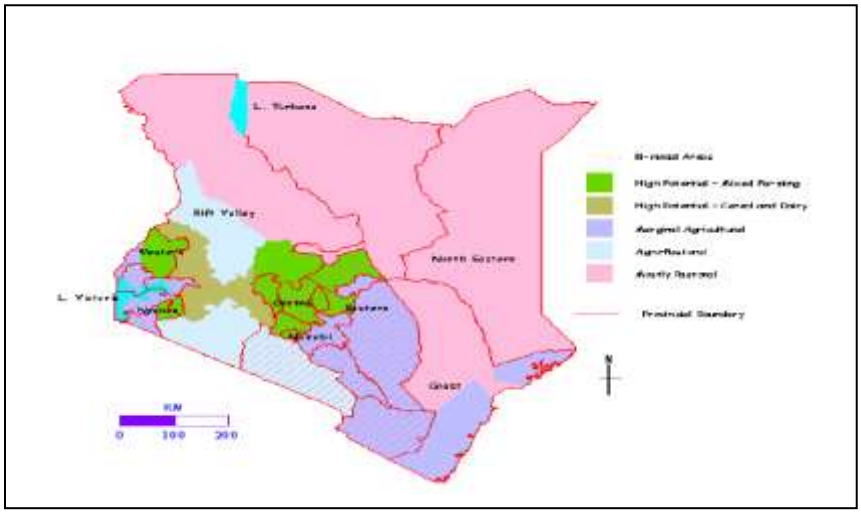

Figure 1. Production Systems in Kenya (Source: USDA, 2004)

To survive the harsh climatic conditions, adaptation and mitigation strategies have been put in place at national, local, and household levels. Adaptation strategies involve all actions aimed at coping with climate changes that cannot be avoided and at reducing their negative impacts. Adaptation strategies are also meant to enhance the capability to capture any benefits of climate change. Adaptation is thus crucial in

protecting livelihoods and food security in many developing countries (FAO, 2008). Mitigation measures on the other hand, are long-term efforts that seek to prevent or slow down the negative impact of a disaster. Climate change mitigation measures involve reducing the concentrations of greenhouse gases, either by reducing their sources or by increasing their sinks (UNFCCC, 2009). In simple terms, mitigation reduces the rate and magnitude of climate change and its associated impacts whereas adaptation reduces the consequences of those impacts (WTO, 2009). Though different, adaptation to and mitigation against climate change are very much intertwined in that an action in one may have important implications for the other. That is, the adaptation strategies undertaken by a community may have importantimplications for mitigation strategies and vice-versa. For instance, poor agricultural practices can be directly responsible for 14 percent of total greenhouse gas emissions. Deforestation currently accounts for an additional 18 percent of emissions (World future council, 2012). Greenhouse gas emission leads to warming of the surface temperature which in turn affects the climate. This paper highlights the climate change mitigation opportunities and challenges posed by drought adaptation strategies in the semi-arid Laikipia County, Kenya.

2. OBJECTIVES OF THE STUDY

(i) Establish rainfall trends and drought occurrences in Laikipia County
(ii) Examine the drought coping strategies
(iii) Examine the opportunities and challenges for climate change mitigation provided by the adopted coping strategies

3. STUDY AREA AND METHODOLOGY

Data for the study was obtained from the semi-arid Central and Mukogodo divisions of Laikipia County, Kenya. The divisions lie in the eastern side of Laikipia County between longitudes 36^0 34" and 37^0 24" East and between latitudes 0^0 02" South and 0^0 33" North covering an area of approximately 3,353.8 square kilometres (Figure 1). Rain-fed agriculture is the main source of livelihood for the 142,000 inhabitants of the divisions. Mixed farming (crop and livestock) dominated agricultural activities in the Central division while pastoralism was the main activity in Mukogodo division. Unfortunately, droughts, which are inherent in the study area, affect rain-fed subsistence agriculture.

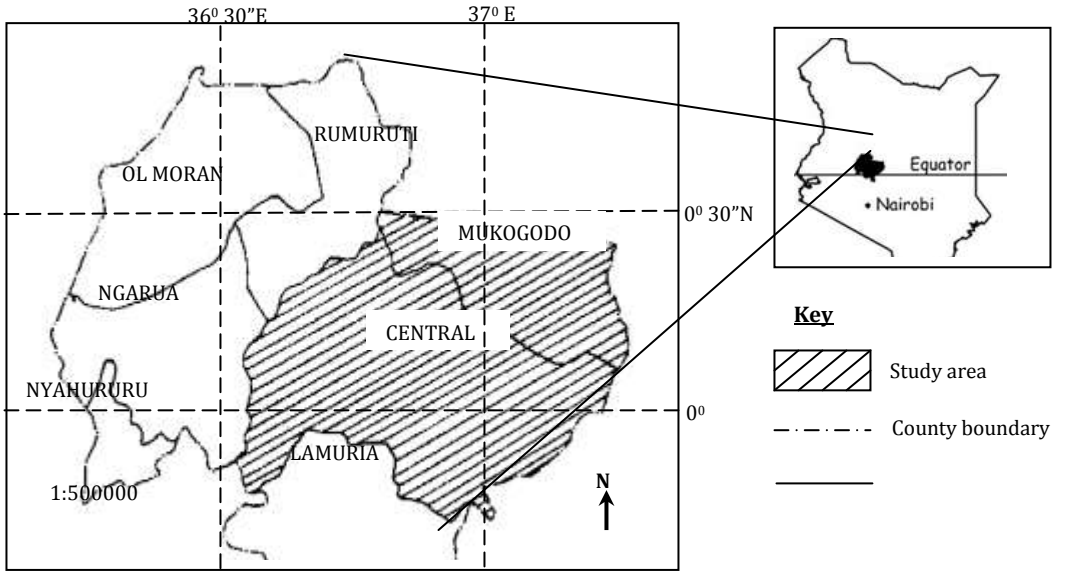

Figure 2. Location and size of Laikipia County

The data on drought coping strategies were collected using in-depth interviews. A total of 384 households practising rain-fed subsistence agriculture were interviewed. Rainfall was used to delineate droughts since it is the single most climatic parameter that affects agriculture in the study area. Annual rainfall totals for a period of 31 years from 1975-2005 was obtained from Laikipia Airbase meteorological station and Mpala Ranch station for Central and Mukogodo divisions, respectively. The mean annual rainfall for Central division was 636.6 mm and 507.8 mm for Mukogodo division. The study considered that drought occurred when annual rainfall was below the mean. The length of the drought period was obtained by summing up the number of drought years. Coefficients of variation were used to establish the year-to-year variation in annual rainfall in the study area while drought intensity was calculated by subtracting the annual rainfall total for a given year from the mean annual rainfall. Drought intensity was expressed as a percentage as shown below:

$$DI = \frac{x - \bar{x}}{\bar{x}} \times 100\%$$

Where DI = Drought intensity

x = Annual rainfall for a given year

$\bar{x}$ = Mean annual rainfall for the study period (1975-2005)

4. RESULTS

4.1. Rainfall Trends and Drought Occurrences

Rainfall in Central and Mukogodo divisions varied markedly (28 and 43% for Central and Mukogodo divisions, respectively). Annual rainfall showed a very slight increasing trend in Central division (Figure 3). However, rainfall during the main growing season, i.e. March, April, and May (MAM) showed varying trends. In the month of March (beginning of growing season), rainfall showed a declining trend while in the months of April and May it showed increasing trends (Figure 4). In Mukogodo division, annual rainfall showed a declining trend (Figure 5).

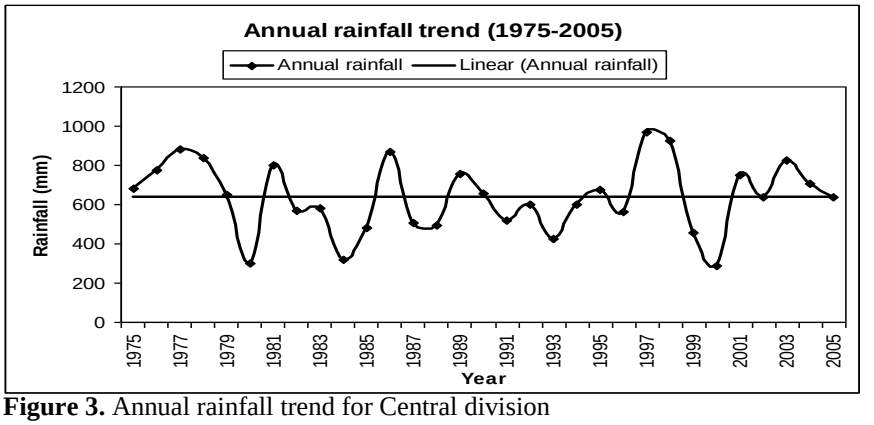

Figure 3. Annual rainfall trend for Central division

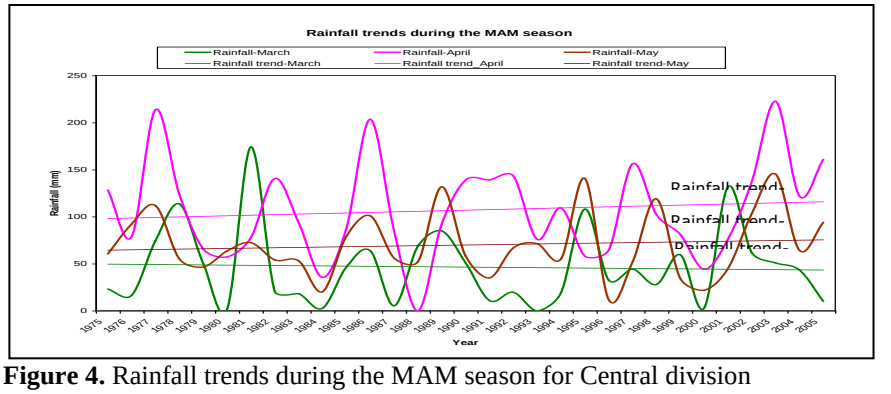

Figure 4. Rainfall trends during the MAM season for Central division

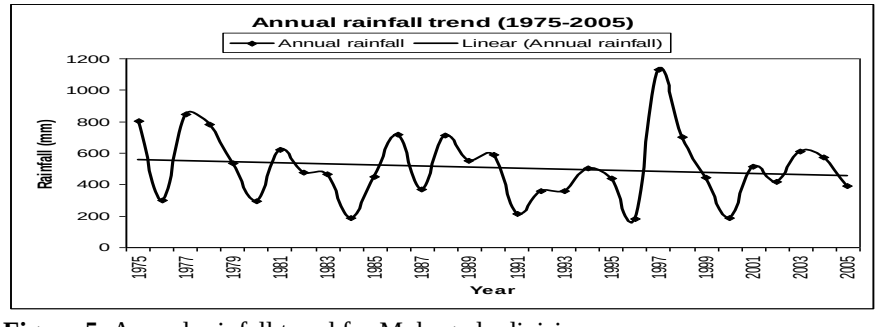

Figure 5. Annual rainfall trend for Mukogodo division

Laikipia County is prone to frequent droughts. Respondents defined drought as a reasonably long period of time with rainfall deficit that caused human suffering. Most of the respondents (90%) linked the frequent occurrence of droughts to climate change due to human activities. They stated that rainfall patterns had changed being characterized by late onset of rains and shortened growing periods. They attributed the changes to destruction of vegetation cover, particularly deforestation. To about 10 percent of the farmers, droughts were divine in nature. Unfortunately, the understanding of the science behind climate change was very low among the farmers with less than 10 percent being able to link greenhouse gases and climate change.

Statisticsof rainfall for the 31 years under study (1975-2005) revealed that 45.2 percent (14/31) and 54.8 percent (17/31) were drought years in Central and Mukogodo divisions, respectively. Droughts occurred in 1980, 1982, 1983, 1984, 1985, 1987, 1988, 1991, 1992, 1993, 1994, 1996, 1999 and 2000 in Central division. In Mukogodo division, droughts occurred in 1976, 1980, 1982, 1983, 1984, 1985, 1987, 1991, 1992, 1993, 1994, 1995, 1996, 1999, 2000, 2002 and 2005. These droughts differed in their characteristics spatially from year to year. The intensity of the drought in Central division ranged from 5.5 to 54.9 percent below the division's mean annual rainfall during the 1994 and 2000 droughts, respectively. Mukogodo division had drought intensities that ranged from 1.0 to 63.7 percent below the division's mean annual rainfall during the 1994 and 1996 droughts, respectively. The duration of droughts ranged from 1-6 years. Mostly droughts occurred in runs of 2-6 years. In Central division, 85.7 percent of the droughts occurred in runs of 2-4 years while 70.6% of the droughts in Mukogodo division occurred in runs of 2-6 years. The longest drought duration, which lasted for 6 years, occurred in 1991-1996 in Mukogodo division (Table 1).

Table 1: Drought durations in Central and Mukogodo divisions (1975-2005)

Central Division			Mukogodo Division		
Drought Year	Total annual rainfall (mm)	Drought duration	Drought Year	Total annual rainfall (mm)	Drought duration
1980	300.7	1-year drought period	1976	302.3	1-year drought period
1982	571.8	4-year drought period	1980	297.2	1-year drought period
1983	579.8		1982	476.6	4-year drought period
1984	318.7		1983	466.8	
1985	481		1984	188.5	
1987	505.9	2-year drought period	1985	448.1	
1988	495.6		1987	371.9	1-year drought period
1991	519.2	4-year drought period	1991	214.6	6-year drought period
1992	600.5		1992	360.7	
1993	425.4		1993	359.4	
1994	601.5		1994	502.9	
1996	562.2	1-year drought period	1995	439.4	
1999	453.8	2-year drought period	1996	184.2	
2000	287.1		1999	443	2-year drought period
			2000	186.9	
			2002	420.2	1-year drought period
			2005	389.3	1-year drought period
Mean annual rainfall		636.6 mm	Mean annual rainfall		507.8 mm

Source: Field data, 2008

4.2. Drought Coping Strategies

In the effort to cushion against food insecurity and rural vulnerability, farmers in Central and Mukogodo divisions had evolved a number of drought coping strategies. The section that follows examines the adopted strategies.

4.2.1. Minimum and zero tillage methods

Minimum and zero tillage methods were practiced by 72.3% of the farmers in Central division as a water conservation strategy. It involved making shallow holes for planting using machetes (*pangas*). During weeding, farmers slashed weeds in between the crop rows instead of tilling the land. As a coping strategy, Mati (2005) observed that the practice had been successfully used by subsistence farmers in Laikipia, Machakos and Nyando Counties of Kenya.

4.2.2. Agroforestry and rangeland management

Agroforestry involves the integration of trees and shrubs with crops. Farmers in Central division intercropped agricultural crops with *Grevillea robusta* (locally known as mukima) and fodder trees (alley cropping) and also planted trees along the boundaries. About 80% of the respondents stated that the primary reason for the planting trees was to provide fuel wood. Other reasons stated included providing shade for the crops and maintaining soil fertility (50%), providing timber (30%) and supplementary feed for livestock (20%). Fodder trees were specifically planted as supplemental feed for livestock. They stated that feed from fodder trees increases milk production. Though planted in small numbers, about 70% of the farmers had fodder trees in their farms. The most common fodder trees were *Calliandra* and *Sesbania sesban.* According to World Agroforestry Centre and UKAID (2010), the number of farmers growing fodder trees increased from 6,000 in 1995 to over 200,000 in 2005 in East Africa. Fodder tree can be fed to livestock for up to 20 years since they can withstand repeated pruning. Farmers largely depend on fodder trees as the most reliable source of livestock feed during drought years. In Musul Ranch in Mukogodo division, the Maasai pastoralists engaged in bee keeping activity through the Mukogodo Beekeepers and Environmental Conservation Group (MBEKEC). The group had set aside 810 ha of land as a conservation area with no livestock grazing, to improve the natural environment for bee keeping.

4.2.3. Extensive agriculture

To increase the harvest, 50% of the subsistence farmers increased the cultivated area by between 30 and 60% following a dry year. With fewer farm inputs, farmers sought to increase crop yields through extensive farming. Additional farming area was obtained through clearing of natural vegetation near wetlands (referred in Kikuyu as

"witemere" – get yourself a share) and in the nearby forested area such as Mount Kenya and Timau areas.

4.2.4. Establishment of feed reserves

Pastoralists in Mukogodo division preserved the raised grounds or the hilly areas and the forested areas as dry season grazing areas. This allowed natural regeneration of pasture during wet years and during mild droughts. The feed reserves included Kopiyo, Siol, Sieku, Ngare ndare, Norpanga, Kipsing, Mt. Oldonyo Ng'iro, Naserian, Tambarua and the Mukogodo forest reserves. Pastoralists were prevented from grazing in these areas for a period of time. This is a common strategy among pastoralists in other parts of Kenya and world in general such as the Sukuma of Tanzania, the Tuareg of Ahaggar in Algeria, the Il Chamus, Turkana and Rendile of northern Kenya, the Tilemsi of Mali and the Berbers of Morocco (Niamir, 1990). For example, the Turkana pastoralists preserved the Loima Hills (Barrow *et al*., 2002).

4.2.5. Small-scale irrigation

Small-scale irrigation was carried out in Central division and was practised by 20% of the farmers. About 2% carried out farming activities in irrigation schemes which included Gitero irrigation scheme (600 ha), Mia Moja irrigation scheme (140 ha), Mukima irrigation scheme (200 ha) and Nguataniro irrigation scheme (360 ha) (Kairu, 2002). About 18% practised small-scale irrigation at household levels. Other major small-scale irrigation schemes in the Kenya arid lands include the Elgeyo-Marakwet system in Keiyo and Marakwet Counties, the Pokot irrigation system in West Pokot County, the Mwatate irrigation system in Taita-Taveta County and the North Iveti Hills irrigation system in Machakos County (Akong'a and Kareithi, 1998).

4.2.6. Increasing the number of livestock during the inter-drought periods

Increasing the number of livestock during inter-drought periods through restricted commercial sales or slaughtering is a common practice among the pastoralists (McCabe, 1990; Ngaira, 1999). In addition, pastoralists in Mukogodo division increased their herd sizes through purchasing (40%) and natural increase (60%). The aim was to recover the lost herd during drought periods. To pastoralists, large livestock population acted as insurance against loss of the entire herd to droughts.

4.2.7. Increasing the number of sheep and goats (shoats) in the herds

The number shoats have been increasing at a higher rate than cattle in Laikipia County in general. Between 1999 and 2001 for instance, UNEP and GoK (2006) observed that the overall rise in livestock numbers by 4.1% in the county was caused by increased number of shoats since cattle population declined by 26.9%. The Maasai

pastoralists in Mukogodo division were deliberately replacing the traditional cattle-dominated with shoat-dominated herds. This was for three main reasons: First, shoats are more resilient to droughts; second, they have a higher reproduction rate (average gestation period for shoats is 150 days) than that of cattle (average gestation period for cattle is 280 days). Thus, shoats replaced the lost herds during severe and extreme droughts quicker than cattle; and third, shoats are easily sold during drought events providing pastoralists with the necessary cash to buy grains from crop farmers. In 95% of the Maasai pastoralists' herd, 75-80% was shoats while 5% of the Maasai pastoralists kept shoats only. A similar trend has been observed among the pastoralists in other Sub-Saharan African Countries (Toutain *et al*., 2010). For instance, the Borana pastoralists in Ethiopia have reduced the number of cattle while at the same time increasing the number of shoats in their herds (Akillu and Catley, 2010). While increase in livestock numbers causes overgrazing, the feeding behaviour of shoats accelerates the loss of vegetation cover. The ecological impact of the overgrazing is loss of biodiversity.

4.2.8. Feeding livestock with tree twigs and leaves

During drought periods, livestock were fed with twigs and leaves from selected tree species. In Mukogodo division, twigs and leaves from *Euclea divinorum* (known as Olkingei by the Maasai pastoralists), *Acacia lahai* (Oltepesi), *Olea africana* (Lorien) (Plate 1) and Olkerosha trees were fed to livestock. Cutting was done in a careful and selective manner. However, as drought shocks increased beyond pastoralists' coping mechanisms, the cutting of the twigs and leaves had become increasingly non-selective, inhibiting proper tree growth and sometimes drying up of some trees. Sixty-eight percent of the patchy distribution of trees in the county especially near the homesteads in Mukogodo division was attributed to this practice by Maasai pastoralists.

Plate 1. Destroyed trees through non-selective cutting

4.2.9. Charcoal burning

Farming activities, particularly crop growing, were less promising and most farmers (80%) produced barely enough food from their farms. To meet the deficits, some farmers (28%) in Central division engaged in non-farm activities which included small-scale businesses (groceries, shops, hotels, and hawking) and selling of firewood and charcoal burning. About six percent of these farmers engaged in the latter (Plate 2). Firewood collection and charcoal burning was largely practised by families living near Mukogodo forest. In addition to pastoralism, about half of the 30% who engaged in other economic activities in Mukogodo division practised selling of firewood and charcoal burning. This practice led to destruction of forests and vegetation cover.

Plate 2. Charcoal burning in Central division

4.2.10. Burning grazing fields for regeneration of pasture

The Maasai pastoralists used fire to clear unwanted trees and shrubs so as to allow the growth of an improved sward of grass. The carefully regulated fire regime altered the composition of the pasture at the same time enhancing re-growth of more nutritious and palatable grasses.

5. DISCUSSION

Rainfall amount was lower and more varied in Mukogodo than in Central division. This is due to the proximity of the division to the low-lying arid northern corridor of Kenya. As a result, the division is more prone to severe droughts compared to the Central division. The climate of Mukogodo division was suitable only for pastoralism. Though annual rainfall showed a very slight increasing trend, a condition suitable for crop production, in Central division the length of growing period appeared to be shrinking due to decline in the March rainfall. This phenomenon caused delayed planting which affected crop farming. Thus, crop and livestock farming in the study area were largely threatened by frequent droughts.

The 1980's and 1990'swere characterized by prolonged droughts. The drought durations were shorter for Central division spanning up to four years and longer in

Mukogodo Division spanning up to six years. The Central division experienced two prolonged droughts each spanning four years, i.e. 1982-85 and 1991-94. Similarly, Mukogodo division had two prolonged droughts, one spanning four years (1982-85) and the other spanning six years (1991-1996). The prolonged droughts were of large spatial extents since they affected not only the divisions concurrently but also most other parts of the country. For example, the 1984, 1991-92, 1994 droughts were declared as national disasters by the government of Kenya. The year 2000 drought was as a result of LaNiña weather event that affected the Greater Horn of Africa (GHA) in 1999-2000. Other notable droughts with high intensities occurred in 1980 and 1984. The 1996 drought in Mukogodo division had eight months with no rain and was referred to as *rameiolakiralokidongoi* (the drought that killed everything) by the Maasai pastoralists.

In an attempt to adapt to droughts, there was little or no consideration for mitigation of climate change due to limited knowledge on mitigation measures. However, a number of opportunities and challenges for mitigating climate change through various drought-adaptive strategies emerged. The dominant option for climate change mitigation in agriculture is through sequestration of carbon in soils (Desjardins, 2012). Carbon sequestration refers to the processes that remove carbon from the atmosphere. In Central and Mukogodo divisions, various practices aimed at coping with droughts provided opportunities for mitigating climate change through carbon dioxide sequestration. For instance, minimum and zero tillage resulted in soil carbon gain. These methods minimize soil disturbances that deplete soil carbon, which results in high levels of emissions to the atmosphere (Dahal and Bajracharya, 2010). Desjardins (2012) and IPCC (2007) observed that soil carbon stocks are considerably depleted by farming through soil disturbance during tillage. Soils can sequester as much as 20% of carbon emissions annually (Cheserek, 2010) if proper agricultural practices such as minimum or zero tillage methods can be adopted. Over the next 25 to 50 years, estimates indicate that properly managed agricultural soils could be a potential sink of carbon that can amount to as high as 30 to 60 gigatonnes globally (Dahal and Bajracharya, 2010).

Land management practices that increase the yield and biomass productivity increase soil organic matter content which helps in carbon sequestration. Thus, all coping strategies that involved conservation and/or improvement of vegetation cover in the study area enhanced carbon sequestration. These strategies included establishment of dry-season grazing reserves, agroforestry, and rangeland management. The thick vegetation cover including trees and thicket in the grazing reserves and the new plant biomass in agricultural lands under agroforestry enhances carbon dioxide (CO_2) sequestration (FAO, 2008). For instance, with the assuming mean carbon content of above ground biomass of 50%, one hectare under agroforestry can store 9, 21, 50, and 63 gigatonnes of CO_2 in semi-arid, sub-humid, humid, and temperate regions,

respectively (Rao*et al*., 2007). Through small-scale irrigation, more yields were obtained from smaller areas and for less efforts. In addition, it encouraged the growth of new plant biomass in otherwise bare land. Thus, smaller areas were cleared of vegetation while at the same time more crop biomass was added restoring CO_2 pools. IPCC (2007) observes that expanding agricultural production through effective irrigation enhances carbon storage in soils through increased yields and residue returns. Under mixed farming system, farmers used livestock manure during planting. Artificial fertilizers were infrequently used. The use of livestock manure enhanced the reduction of methane (CH_4) while at the same time less usage of artificial fertilizers reduced nitrous oxide (N_2O) emissions.

On the other hand, some of the adopted drought coping strategies posed challenges to the mitigation of climate change by increasing the amount of carbon dioxide in the atmosphere. These strategies to a large extent involved destruction of vegetation cover. Extensive agriculture, for instance, led to the conversion of vegetated and forested areas to cropland, reducing the amount of carbon sequestered. Batjes (1996) and IPCC (2007) observed that intensive farming, which includes efficient use of fertilizers, better irrigation, and use of high yielding crop varieties, increases productivity on the existing croplands and reduces carbon dioxide emission. Other strategies that enhanced reduction in CO_2 sequestration included charcoal burning and firewood collection, burning grazing fields for regeneration of pasture, increasing the number of livestock during inter-drought periods, increasing the number of shoats in the herds, and feeding livestock with tree leaves and twigs. Trees possess about 20% carbon by weight and biomass of forest acts as a carbon sink. This carbon is stored in the form of wood and vegetation through carbon sequestration. Decomposing plant matter acts as carbon store (Trumper, 2009). Globally, deforestation accounts for 18% of emissions (World future council, 2012). Strategies that induce soil erosion cause an estimated emission of carbon of about 1.1 gigatonnes per year (Dahal and Bajracharya, 2010).

6. CONCLUSION AND RECOMMENDATIONS

The main threat to agricultural activities in Laikipia County was drought. Rainfall in Mukogodo division had a higher year-to-year variation and showed a decreasing trend. In the Central division, rainfall, though varied from year to year, showed an increasing trend. However, decreasing rainfall amounts during the beginning of the main growing season causeda shortened growing period. Thus, poor rainfall in the study area affected subsistence rain-fed agriculture. The adopted drought copping strategies enabled farmers to survive the harsh climate. Unfortunately, farmers had little or no idea about climate mitigation strategies save for planting of trees and therefore put no consideration on the effects of the adopted strategies on future climate. Though the adaptation measures were important in dealing with the current

and irreversible impacts of climate change, mitigation measures should be the focal point in reducing the long-term impacts.

The study recommends that an efficient mix of adaptation and mitigation strategies that limit the short and long-term impact of climate change should be encouraged. Such strategies involve prevention and removal of maladaptive strategies that enhance rural vulnerability in the long run. Strategies that involve conservation or improvement of vegetation cover, particularly agro-forestry, are most appropriate. This is because they are of economic importance to rural livelihoods and at the same time enhance carbon sequestration.

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ADAPTATION OF TRIBAL COMMUNITY FOR BIODIVERSITY CONSERVATION AND SUSTAINABLE DEVELOPMENT: A CASE STUDY OF NANDA DEVI BIOSPHERE RESERVE, INDIA

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ABSTRACT

This study was conducted in Nanda Devi Biosphere Reserve (NDBR), Central Himalaya, India which is well known for its rich biodiversity of flora and fauna. Tolcha and Marcha sub-communities of Bhotiya tribes are the main inhabitants in the region. These communities have strong faith and belief in traditional health care system using medicinal and aromatic plants (MAPs). Therefore, an attempt has been made to understand the challenges and new perspectives of MAPs and to quantify the economic dependency of local tribes on MAPs. The study also focussed on the sustainable harvest methods for biodiversity conservation in the region. The results showed that all the ethnic groups/tribal communities equally use the wild edible plants for medicinal as well as traditional purposes. Fifteen villages of Tolcha (10) and Marcha (5) were studied. It was found that 13 plant species are harvested from the wild based on their economic and medicinal importance. The prominent plant species collected were*Angelica glauca* (701±17.116), *Pleurospermum angelicoides* (499.75± 19.602), and *Artemisia maritima* (81± 2.447). Of the total harvest of MAPs, Garpak villagers recorded the highest quantities (622kg/year) followed by Tolma (583.5kg/year), and Bampa (82 kg/year). The villages that are interior with no or little road and transportation facilities were found to suffer from lack of market access for their produce. Farmers depending more on MAPs and natural resources were vulnerable and not getting remunerative returns. Therefore, for better conservation and sustainability of MAPs in this highly fragile ecosystem, a well-defined regulated marketing system and weather proof transportation facilities are needed. A comprehensive area development programme with emphasis on MAPs reduces migration and increases income and standard of living of the tribal communities. As tribal communities live with limited exposure to education and modern infrastructural facilities, output from MAPs support their families in terms of both income and health. In the extent of livelihood strategy and vulnerability, grass-root planning has to be strengthened on priority basis for enhanced sustainability and empowerment of tribal populations.

Keywords: Aromatic plant, biodiversity, Himalaya, medicinal plants, tribal population

1. INTRODUCTION

The Himalaya hotspot is home to the world's highest mountains, including Mt. Everest. In India, the Himalaya occupies 18% of the total geographical area and 6%

of the total population and spans over 12 states of the country (Nautiyal *et al*., 2005). The Himalayan biodiversity is severely threatened by natural and anthropogenic measures. Various factors (biological and social) in the Himalaya are eroding the rich biological diversity and have led to the expansion of xerophytic conditions. Uttarakhand state, centrally located in the Indian Himalayan mountain chain is significant for its biodiversity, where conservation efforts have been undertaken for a long time. Conservation of biodiversity by local communities being a part of the social system in this region, various programmes have been implemented for the conservation of biological resources in the Indian Himalaya under the protected area network (Rawat and Rawat, 2010).

Nanda Devi Biosphere Reserve (NDBR) in Central Himalaya is one of the biodiversity hotspot having a diverse ecosystem and harbours a wide range of medicinal and aromatic plants (Hajra and Balodi, 1995; Samant *et al*., 1996). Myers *et al*. (2000) proposed conserving biodiversity hotspots (BHSs) as a solution of protection and sustainability of biodiversity. Convention on Biological Diversity (CBD) states that the systematic approach of medicinal and aromatic plants (MAPs) conservation plays a vital role in environmental management and development through traditional as well as scientific practices (Uniyal *et al*., 2006; Aase and Vetaas, 2007; Kumar *et al*., 2011).

In this region, Tolcha and Marcha sub-communities of Bhotiya tribes are the main inhabitants living in harmony with nature (Maikhuri and Ramakrishnan, 1992, Maikhuri and Gangwar, 1993). Traditionally, the cross-border trade with Tibet was the main source of income for the Bhotiya tribal communities. However, after the Indo-Chinese war, trade with Tibet was banned in 1962 (Silori, 2001). The convention on wild biological diversity, and convention on international trade in endangered species (CITES) of wild fauna and flora identified that the major threats of MAPs are over-exploitation of biodiversity including rare and endangered MAPs. The convention also proposes to regulate and prevent over exploitation of valuable biodiversity species and heritage. Anthropogenic pressure (human-induced land use change), however, results in the exploitation of MAPs which has the largest effect on biodiversity and survival of many species of MAPs that are on the verge of extinction (Kala and Srivastava, 2004; Wallington *et al*., 2005; Kala, 2011). Sustainable management of medicinal plant resources is important not only for their value as a potential source of new drugs but also due to the reliance of health on traditional medicinal plants. However, in recent years, the commercial demand for herbal drugs in national and international market and its dependence on the wild has led to rapid depletion of MAPs in the NDBR area. The over exploitation of MAPs and negligence of post-harvest technology strategies resulted in further reduced harvests. The present study focussedon sustainable harvesting pattern, ethnobotanical uses and market analysis of MAPs by the Bhotiya tribal community in Niti valley of the NDBR.

2. METHODOLOGY

2.1. Study Area

Nanda Devi Biosphere Reserve (NDBR) covers 5860.69 km^2 (Nanda Devi National Park and Valley of Flowers National Park) as a core zone representing one of the biodiversity rich protected areas in the Western Himalaya (30°16' to 30°32' N and 79°44' to 80°02' E). The area is a catchment of river Ganges. The soils are generally well-drained, dark, loam to sandy loam. Out of the 47 villages present within the buffer zone, 15 villages of Chamoli district, viz., Tolma, Suki, Laung, Bhallgaon, Jhelam, Malari, Niti, Ghamshali, Garpak, Phagati, Dronagiri, Jhuma, Bampa, Kaga and Farakia, were studied (Figure 1). The local people depend on agriculture–forest-based economy. The location of human settlement lies between 2180 to 3600 m above sea level in the region of Central Himalaya (Maikhuri *et al*., 1996; Nautiyal *et al*., 1998, 2002, 2003).

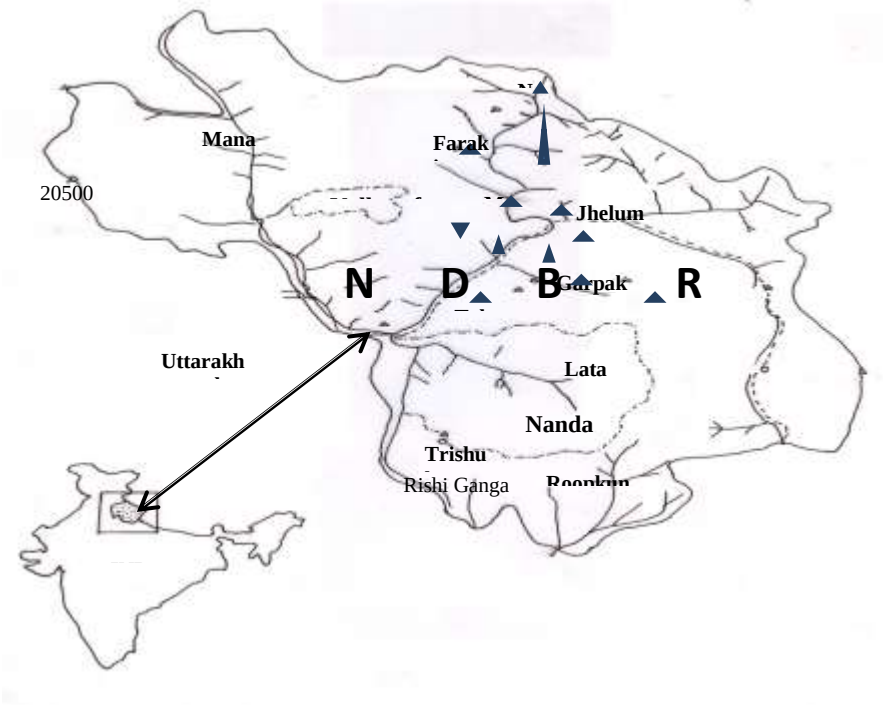

Figure 1. Map of the study area

2.2. Climate

The year consists of three distinct seasons, namely summer (April-May), rainy (June-September) and winter (October-March). Monthly minimum and maximum temperatures range between 2°C and 27.2°C, respectively. June-August is the hottest months of the year with an average temperature of 16.4 °C and 27°C. Average

rainfall was about 936.6 mm/year and about 43% of annual rainfall was recorded over a short period of two months (July–August) with a strong monsoon influence (Figure 2).

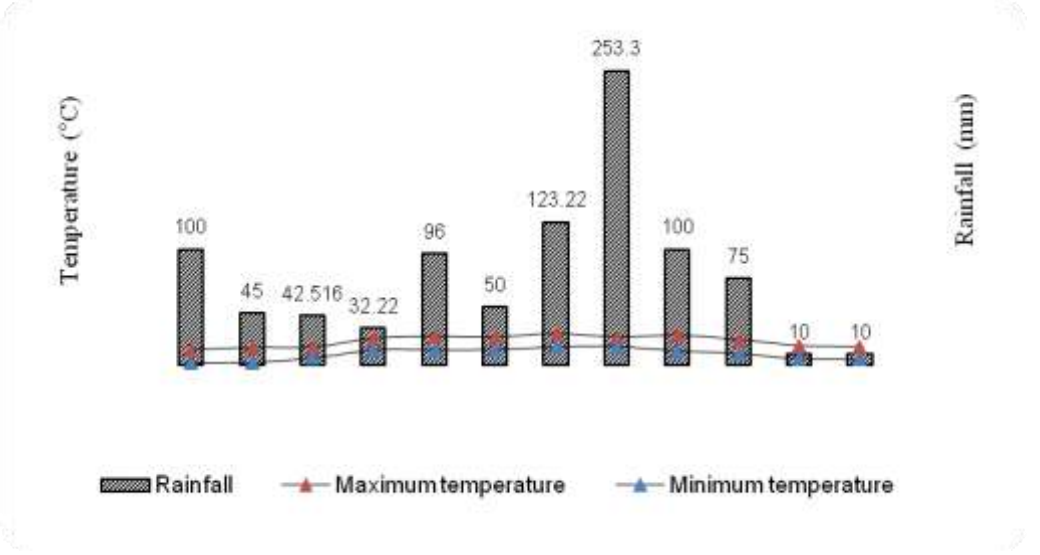

Figure 2. Temperature (minimum and maximum) and rainfall data of the study area

2.3. Socioeconomic Background

Tolcha and Marcha sub-communities of Bhotiya tribes are the main inhabitants of the Niti valley of NDBR. The major occupation of these communities is sheep and goat rearing. Out of 15 villages, Tolcha encompasses ten and Marcha five villages with a total population of 3344 members with 613 households (Kandari *et al*., 2012). These villages usually practise traditional transhumance to the lower altitudes outside the buffer zone during the severe winter months (November-February), while they spend the time spanning from March to October in their respective villages in the buffer zone. With the changing times, many households of Tolma, Suki, Bhallgaon and Phagati villages have now permanently settled in the buffer zone itself and almost stopped transhumance.

2.4. Ethnobotanical Study and Market Analysis

Indigenous people, actively engaged in traditional health care practice were interviewed to document their unique knowledge on the medicinal value of these species. The fifteen households from each village were surveyed and interviewed to collect information on various aspects of medicinal plant collection/cultivation; plant parts used, market channels and the price at which they would sell the products to village agents. Information was also gathered on problemsthe peoples faced in sustainable marketing the products. Information on plant local names, mode of uses, and collection methods of each species was captured.

3. RESULTS AND DISCUSSION

From the present study, it was found that due to high economic importance and use in day to day life, local people harvest 13 plant species heavily from the wild, namely, *Angelica glauca* Edgew, *Arnebia benthamii* (Wall. ex G. Don), *Rheum emodi* Wall. ex Meissn., *Pleurospermum angelicoides* (DC.) C.B. Clarke., *Picrorhiza kurroa*Royle ex Benth., *Morchella esculenta, Saussureacostus* (Falc.), *Artemisia maritime* L., *Nardostachys jatamansi*DC., *Prinsepia utilis* Royle, *Betula utilis*D. Don, *Dactylorhiza hatajeria* (D. Don) Soo, and *Allium stracheyi*Baker (Table 1).

Table 1. Economic and Medicinal Values of Species Collected from the Wild

S. No	Name of the species	Vernacular name	Traditional uses and Medicinal Uses
1	*Angelica glauca* Edgew,	Choru	Used as spice, stomach disorder and diarrhoea
2	*Arnebia benthamii* Wall. ex G. Don	Baalchadi	Used for colouring the food, used as spice
3	*Rheum emodi* Wall. ex Meissn	Dolu	Used in internal injury
4	*Pleurospermum angelicoides* (DC.) C.B. Clarke	Chippi	Used as spice and condiments, decoction of root is used to cure stomach disorder, headache and typhoid
5	*Morchella esculenta*	Guchhi	Used as food, decoction of fried fruit is used in cold and cough
6	*Saussurea costus* (Falc)Lipch	Kuth	Root is used to cure tooth ache.
7	*Picrorhiza kurroa* Royle ex Benth	Kutki	Roots are used to cure stomach-ache, fever, typhoid and jaundice.
8	*Artemisia maritima* L.	Purchu	Leaves are used as aromatic essence.
9	*Nardostachys jatamansi*DC	Jatamansi	Rhizome is used to cure blood pressure, jaundice and heart disease.
10	*Allium stracheyi* Baker	Jimbu pharan	It is cooked as leafy food and used in medicine and health care system by the traditional societies in various ailments and also considered important for clinical use.
11	*Dactylorhiza hatajeria* (D. Don) Soo	Hathajari	Paste prepared from tuber is applied externally to cure wounds and cuts, fever, dysentery.
12	*Prinsepia utilis* Royle	Bhainkal	Seed oil is used to reduce body pain and muscular pain and root paste is used to heal wounds.
13	*Betula utilis* D. Don	Bhojpatra	Bark is used as traditional tea and to cure cancer.

Harvesting of MAPs varies from village to village according to their availability and uses. *Betula utilis* and *Rheum emodi* were collected from all villages. However, *Artemisia maritime* and *Prinsepia utilis* were collected only by five villages (Figure 3).

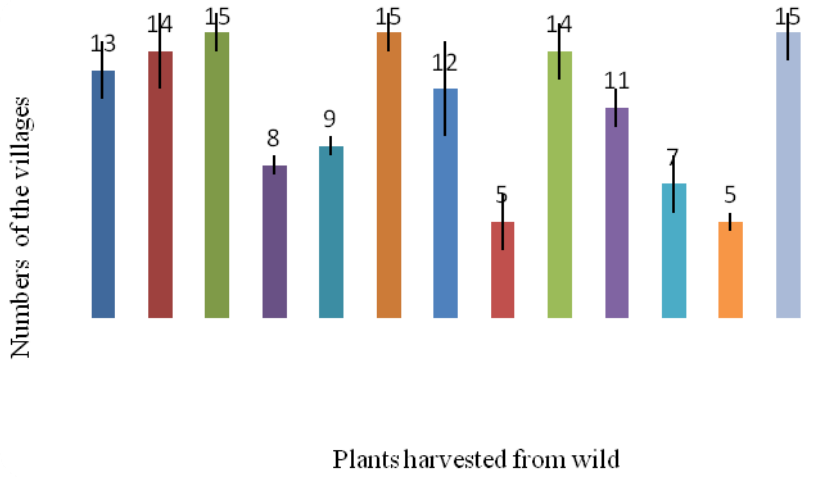

Figure 3. Number of medicinal plants harvested from the wild

The prominent species collected from the study area were *Angelica glauca* (701±17.116/kg) followed by *Pleurospermum angelicoides* (499.75± 19.602/kg). There is also a strong sentiment and belief that MAPs collected from the wild has a greater medicinal andnutritional value than those collected from plants cultivated commercially (Kala, 2006). Of all the MAPs collected, *Artemisia maritima* accounts for the least volume (81± 2.447) due to its scarcity in the study area (Figure 4).

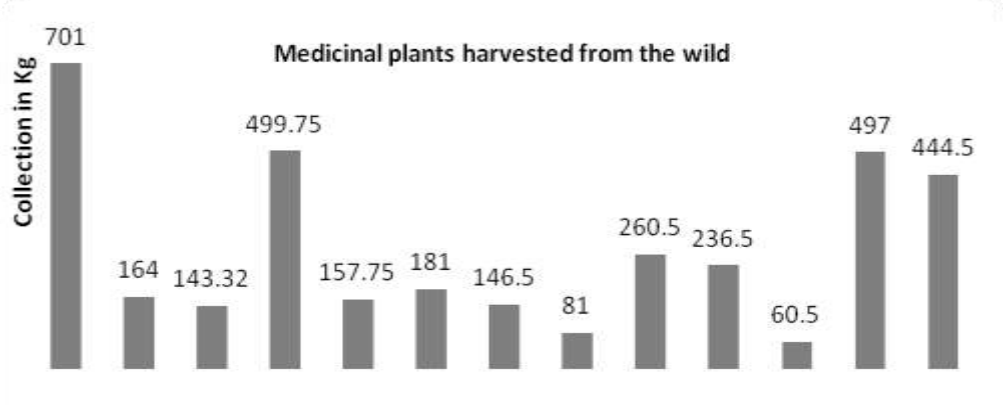

Figure 4. Quantitly of medicinal plants collected from the study area

The highest amount (622kg/family) of MAPs was collected by Garpak villagers followed by Tolma (583.5kg/family). The lowest amount (82 kg/family) of MAPs was collected by Bampa harvest. It is observed from the present study that there was a lowest overall collection of MAPs from the forest by the villages that are along the roadsides as the accessibility for harvest is convenient. In contrast, the availability of medicinal plants as well as peoples' dependency on them increased with increase in distance and remoteness (Kandari *et al*., 2012, Phondani *et al*., 2010, Kandari and Omprakash, 2009). The villages that are located in the interior with no or little road

and transportation facilities are prone to marketing problems and have lower opportunities to sell their products.

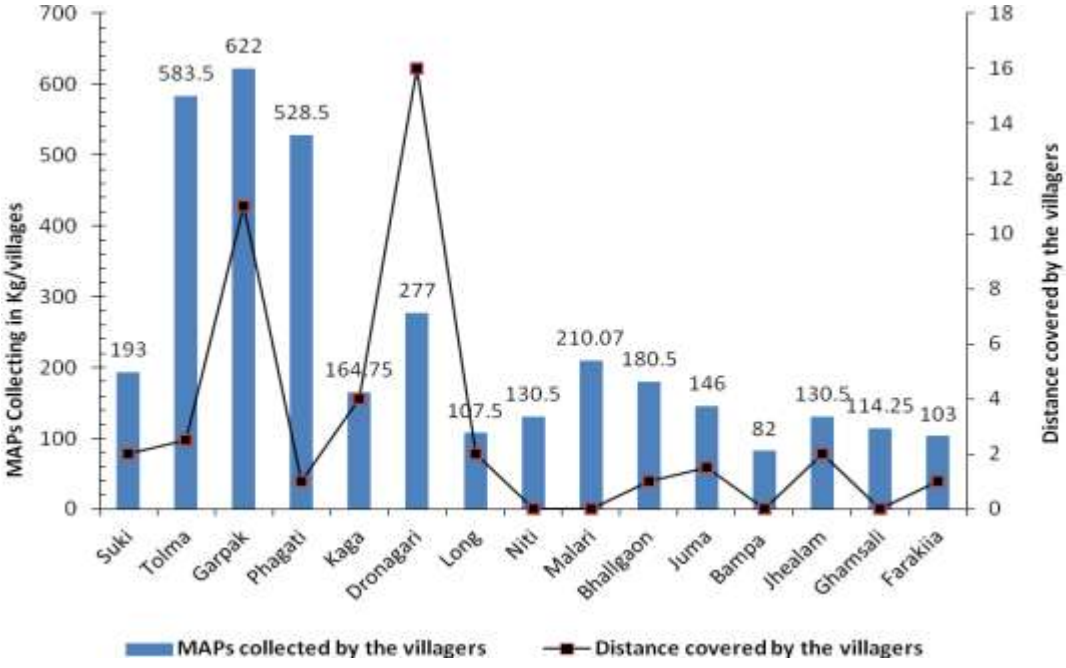

Figure 5. Medicinal plants collected from the wild and the average distance covered by the villagers

Source of Livelihood

Based on the computation of data, the income and contribution by thirteen MAPs harvested from the wild are summarized in Table 2. It was observed that, Garpak having highest income from the MAPs (US $ 405682/family/year) and contribute about a maximum of 57% household income (Table 2). On an average followed by Tolma with 26.34%. The villagers believe that their cultivation techniques are quite primitive, resulting in poor yield and quality of the materials. The villagers having view that cultivation of MAPs having several constraints e.g. biotic (traditional cultivars, long life cycle, susceptibility to pests and diseases), abiotic (low soil fertility, low rainfall etc).

Table 2. Monetary input and percentage of contribution in family income from medicinal and aromatic plants in the valley

S. No.	Villages	Total Number of Household	Total quantity of MAPs/per household/year/kg	Average income of family/year in US $	MAPs contribution in households income in %
1	Suki	42	4.60	53.948	17.98
2	Tolma	26	22.44	263.473	26.34
3	Garpak	9	69.11	811.364	57.95
4	Phagati	28	18.88	221.593	22.15
5	Kaga	11	14.98	175.833	14.65
6	Dronagari	49	5.65	66.367	5.53
7	Long	21	5.12	60.098	6.67
8	Niti	75	1.74	20.428	2.04
9	Malari	155	1.36	15.911	1.3
10	Bhallgaon	41	4.40	51.685	3.69
11	Juma	20	7.30	85.702	8.57
12	Bampa	37	2.22	26.018	2.16
13	Jhealam	27	4.83	56.743	4.05
14	Ghamsali	45	2.54	29.807	1.86
15	Farakiia	27	3.81	44.786	3.73

Ethnobotanical uses and Gaps in Market channel

There are three main stakeholders involved in the collection of raw material ie., consumers, industry and the primary producers. It was observed that traders play a major role in village economy by providing a needed source of credit, cash marketing and assistance to the villagers. Sometime on the other end of the scale, certain powerful traders force collectors to sell exclusively to them. Due to collection of small amount of MAPs the collectors/farmers sell to the middlemen/or villagers instead of directly sell to the wholesaler or processor (Figure 6). External market of MAPs exerts the greatest pressure on forest resources in this region (Maikhuri *et al*., 2002). Due to appearance of marketing opportunities, there is a great pressure on the forest resources. Middlemen initially buy the product and then move it to the next stage in market channel. Many collection agents/farmers at farm level are not aware of final price paid by the industry or processor.

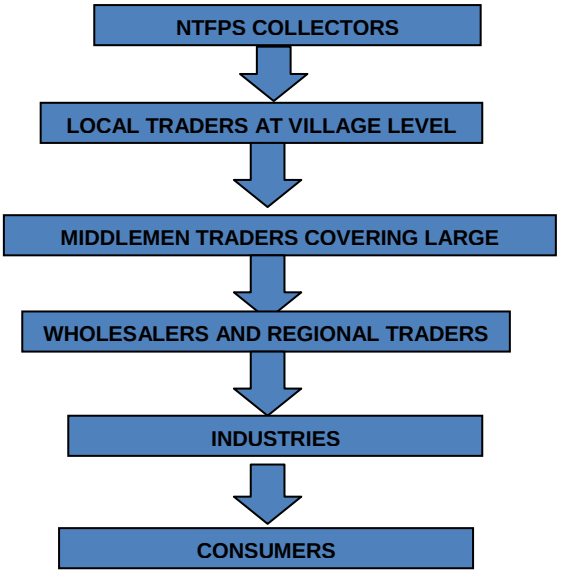

Figure 6. Market channels for MAPs

In MAPs and others NTFPs, the buyers usually set the price and collection/villagers respond to the price. Price of medicinal plant usually depends on the market demand. The wholesaler or the village agent sells the product to market chain with 75% profit at every step of market chain (Table 3). In many cases the information about the market demand and the actual prices of MAPs are not disclosed and open. The farmers who collect MAPs actually do not know the consumer need and is observed that, the longer the marketing chain, the less likely the information available to the collector. Sometimes the consumer may pay 3 to 4 fold higher price of the product over the actual price paid to the villagers.

Table 3. Price of medicinal plant raw material (US$/kg)

S.No	Medicinal Plants	Levels in the market channel		
		Price in $/kg from villager	Price in $/kg Village agents	Price in $/kg Wholesalers
1	*Morchella escculenta*	80	120	204
2	*Angelica glauca*	2	3	5.1
3	*Pleursosprmum angelicoides*	2.4	3.6	6.12
4	*Rheum emodi*	1.6	2.4	4.08
5	*Arnebia benthamii*	4	6	10.2
6	*Allium stracheyi*	5	7.5	12.75
7	*Picrorhiza kurroa*	3.6	5.4	9.18
8	*Artemisia maritima*	1	1.5	2.55
9	*Nardostachys jatamansi*	5.6	8.4	14.28
10	*Dactylorhiza hatajeria*	6	9	15.3
11	*Prinsepia utilis*	0.4	0.6	1.02
12	*Betula utalis*	0.6	0.9	1.53
13	*Saussurea costus*	1.4	2.1	3.57

Farmers depending more on MAPs and natural resources are vulnerable and are not getting enough remunerative returns (Maikhuri *et al*., 2002). Information on flow of product is important not only for marketing analysis, but also for an assessment of the sustainability of the market for the medicinal plant cultivation. Therefore, conservation and sustainability of MAPs in this highly fragile ecosystem, a well-defined regulated marketing system and weather proof transportation facilities are needed as MAPs is a major livelihood option in this region. The far-flung villages have easy access to interior MAPs in the forest and they depend more on forest resources for their daily health care needs.

4. CONCLUSION

The study showed that the majority of household harvest wide ranges of MAPs from the wild for their day to-day medicinal use. Local people/tribal farmers should be encouraged to cultivate MAPs in order to increase production and to reduce the pressure of population in the wild and their natural habitat. The illegal and unsustainable harvesting should be discouraged for sustainable development and high productivity. Research on post harvest methods and storage practices will minimize the damage associated with harvest activities and conserve the biodiversity in the region. The government should focus on public-private collaboration to promote the cultivation of MAPs by the small farmers. The current study also concludes that the farmers in interior areas who are not having easy access to road and transport facility are finding MAPs as less remunerative and more risky. Therefore, to conserve biodiversity of the region, Government has to develop good infrastructural and more

transportation facilities, and link the tribal farmers/MAPs farming community to the mainstream.

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THE LOSS OF BIODIVERSITY AND CARBON STOCKS IN ASEBOT FOREST AND ITS IMPLICATIONS FOR CONSERVATION

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ABSTRACT

Biodiversity provides free of charge services that are vital to billions of peoples in the world and is critical for the wellbeing of the society. This study aimed to assess the status of vegetation and carbon stock potential in the dry Afromontane forest (DAF) of Mount Asebot between February and March 2011. Data were collected using transect lines and sample plots which were laid down along with the slope gradients. Data on above ground biomass, below ground biomass, wood/leaf litter, stumps, and dead standing/felled trees were collected. Species diversity and dominance of trees and shrubs were determined by using biodiversity indices. A total of 65 plant species were identified in this remnant forest. *Podocarpus falcatus, Olea africana, Ficus sur, Olea capensis* and *Junperus procera* were the most dominant species in the area. Diameter at Breast Height (DBH) ranging from 10.5 cm to 73.6 cm with the height of 7 m to 44.8 m. The common species of shrubs are *Cumbretum molle, Dodonaea viscossa, Teclea nobilis, Euclea racemosa* and *Carissa edulis*. The total carbon stocks reserved in the forest was also estimated as 203.3, 20.7 and 117.2 tons of C ha^{-1} in the living biomass (vascular and non-vascular vegetations), non-living carbon sources (litters, dead standing trees and fallen logs) and in the surface soil, respectively. Loss of biodiversity and habitat destruction is a common practice and affects the livelihoods of the communities in the area. Therefore, an immediate intervention is needed to enhance biodiversity conservation as a mechanism to reduce the impact of climate change and improve the livelihoods.

Keywords: afromontane forest, biodiversity indices, climate change, trees and shrubs

1. INTRODUCTION

The forest diversity continues to decline rapidly in the world, despite the fact that legally established protected areas cover an estimated 13 percent of the forests (FAO, 2010). The dry Afromontane forests are either *Juniperus-Podocarpus* forests or predominantly *Podocarpus* forests, both with broad-leaved species, occur in the Northwest and Southeast Highlands of Ethiopia, especially on the plateau of Shewa, Welo, Sidamo, Bale, and Harerge at altitudes ranges from 1500 to 2700 m (Demel, 2005). A large number of species in dry Afromontane forests (DAF) of Ethiopia store significant quantities of seeds in the soil in contrast to the situation in most tropical rain forests, dry lowland forests and savannas (Demel and Granström, 1995). In addition, DAF accumulate large quantities of persistent seeds of herbaceous species

in the soil (Demel, 2005). Therefore, conservation with regeneration was noticed as a practicable conservation strategy in DAF.

Loss of biodiversity is common in Asebot district. This is because of the fact that communities living around the area are dependent on the limited resources found in this remnant forest for their livelihoods. Human activities accelerated the depletion of biodiversity and destruction of habitat. But the area is playing a key role in maintaining the remnants of habitat/ecology of the Afromontane forest, pay for reduced emission of green house gases, and provision of ecosystem services. It also plays a vital role for livelihood diversification to the local communities who consider the forest as their primary sources of goods. Therefore, the objective of this study was to demonstrate status of the forest and initiate development of the forest resource through reduction of carbon dioxide emission by deforestation and degradation (REDD) and maintain the species and ecosystem diversity.

2. MATERIALS AND METHODS

2.1 Study Sites

The study was conducted around Asebot Silasse Monastery (founded in the 12th century), which belongs to the Ethiopian Orthodox Church (EOC). The area is located in west Harerge zone of Oromiya region, 300 km East of Addis Ababa. The forest is laid with altitudes of 1700-2500 m. The average annual temperature varies between 18°C-25°C and the annual rainfall between 700 and 1100 mm.

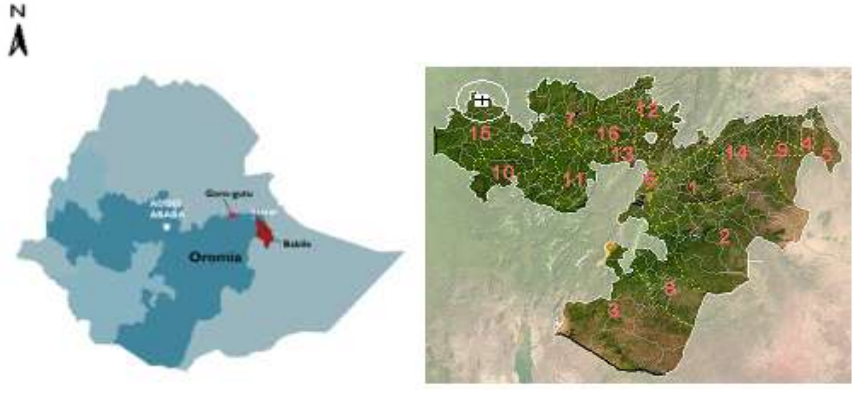

Figure 1. Map of the study area

2.1. Sampling Design

Data on the existing forest ecosystem and landscape features were collected between February and March, 2011. The study area was stratified into four major sub-areas (Eco-regions) based on aspects (direction of the hill stretch): northeastern, northern, southeastern, and the plateau. The relative coverage of each stratum has

been estimated after the thorough exploration of the total area of the vegetation and found as 20 percent, 24 percent, 25 percent, and 31 percent, respectively. They also stretched with altitudinal ranges of 1750 m to 2870 m. Sample plots are located subjectively along the transect lines running from bottom to top (slope gradient). Plot of 10mx15m for trees and shrubs, 1mx1m for herbs, and 15 cm x 15 cm for soil sample was established. The transect lines and the main sample plots were laid down along the slope gradients in taking care of the possible variations of flora pertinent to the change in altitude, within the same plot. Above ground biomass, below ground biomass, wood/leaf litter, stumps, and dead standing/felled trees were also considered in the assessment.Within each plots, three sub-plots were located to measure the litter layer.

2.2. Vegetation Inventory and Soil Sampling

The crown diameters of the trees were measured. In addition, percentage of canopy closure for bushes and tree vegetation were made based on direct observation and expert-judgment. Information on the local names of plants, medicinal values and other ethno-botanical values were recorder through elderly discussion. Transect walks method was applied for estimating the proportional coverage of herbaceous plants such as grasses and woody vegetation, when the patches of bushes are grown dispersed throughout the grassland. Unidentified plant specimens were collected and screened at Haramaya University (HU) Herbarium, and surface soil samples were analyzed at HU soil chemistry laboratory.

2.3. Field Measurements and Socio-economic Assessment

Diameter at breast height of live and dead standing trees, fallen logs, stumps, total tree height, species composition, canopy coverage, crown diameter and the diameter of the dead wood and snags (dead standing trees and stumps) were measured. Shrub biomass was estimated with a destructive methods and litter layer was collected from 1mx1m plot and weighed with the portable balance. Informal interviews and discussions with the local communities (residents of the monastery and lowlanders) were made regarding plants use values. In addition, field observations were employed to assess information on human-forest interaction.

2.4. Computed Biodiversity Indices

Species diversity and dominance were computed using Shannon's diversity index and Simpson's dominance index. Importance Value Index (IVI) was determined for each species. These diversity indices provide more information on biodiversity than species richness (Magurran, 1988).

2.5. Carbon Stock Estimation

The above ground biomass of the non-tree vegetation is estimated based on the green weight of destructive samples (cutting and weighing the shrubs and herbs) measured within the sub-samples (1 m x 1 m) dropped in the selected main sample plots. Above ground, biomass for trees and shrubs was estimated using the basal area of the plants. The values then computed using relevant allometericequation (Murali and Bhat, 2005) that combines the height and DBH of the trees to estimate the total above ground biomass (Table 4 and 5).

Table 1. Computation of carbon stock in tree vegetation

№	Descriptions	quantity	Computation
1	Area per sample	150 m^2	10 mx15 m
2	average height	17.56	measurement & calculation
3	total basal area in all sample plots	12.736	Totalling
4	total BA of trees per ha basis	40.4 (m^2/ha)	C **x** conversion factor
5	total BA of trees per ha basis	40.4 (m^2/ha)	C **x** conversion factor
6	trees above-ground biomass	287.20 (tc/ha)	**1** = 11.27 + 6.03 (BA) + 1.83 (height)
7	above-ground carbon stock in tree species	143.60 (tc/ha)	0.5 x 287.2
8	root biomass of tree species	74.67 (tc/ha)	**2** = 0.26 x 287.2
9	root carbon stock in tree species	37.34 (tc/ha)	0.5 x 74.67
10	total carbon stock in tree species	180.94 (tc/ha)	= h + f

[1](Murali *et al*., 2005) **2** = shoot to root conversion factor (IPCC, 2006)

3. RESULTS AND DISCUSSION

3.1. Species Composition and Important Value Index

The structures and distribution of vegetation varies under the four sub-areas (Eco-regions): northeastern, northern, southeastern, and the plateau. In the northeeastern facet of Asebot forest, trees are the major life forms and *Podocarpus falcatus* is the most dominant species (Figure 2). *Olea africana* is the least dominant species highly affected by selective tree cutting.

The adjacent disturbed forestland is invaded with exotic weed species and different grass species. The fragile soil structure is exposed to severe soil erosion. Sources of seed from the soil layer have been lost as a result of ground fire occurred in the last six years. Over these highly disturbed landscapes shrub and grass species share a large degree of vegetation cover, otherwise rock outcrops.

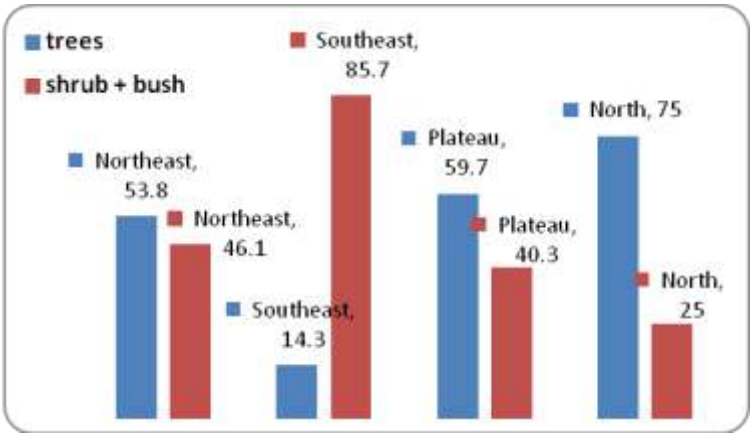

Figure 2. The proportion of trees and shrubs + bushes in each aspect

The Plateau in the upland consists of both acacia wooded grassland and high forest to the eastward direction. The dominant tree species are *Juniperus procera*, *Olea africana*, and *Psydrax schimperiana*. In areas with relatively sloppy landscape of the plateau, the dominant tree species are *Juniperus procera, Olea africana, Odocarpus falcatus*, and *Acacia abyssinica* (Figure 3).

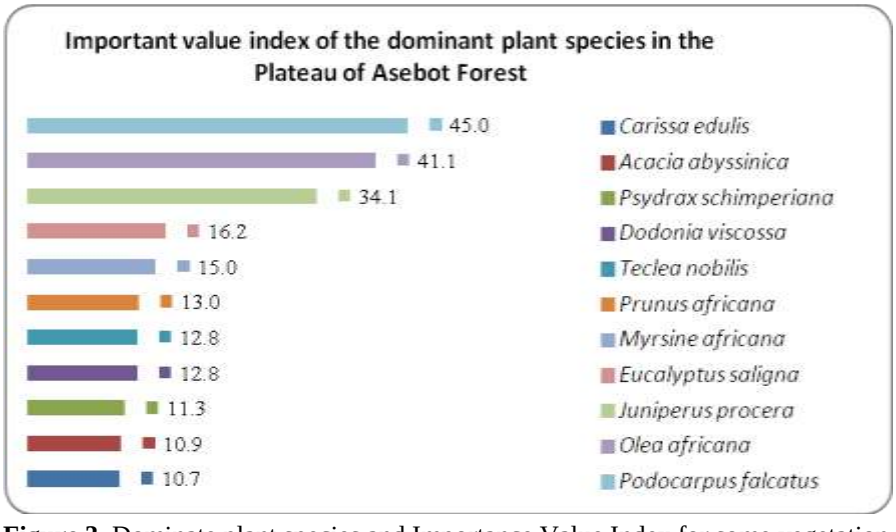

Figure 3. Dominate plant species and Importance Value Index for some vegetation in Plateau of Asebot Forest (Note that plant species listed at the bottom has highest IVI and the top has least IVI).

The north facets are squeezed to the valley bottoms. This form of forest ecosystem is common from the lowlands up to about 2300 m. The vegetation tree species in the upper storey of this facet are *Podocarpus falcatus, Juniperus procera, Celtis africana,Olea capensis, Olea africana, Teclea nobilis,* and *Psydrix schimperiana* (Figure 4).

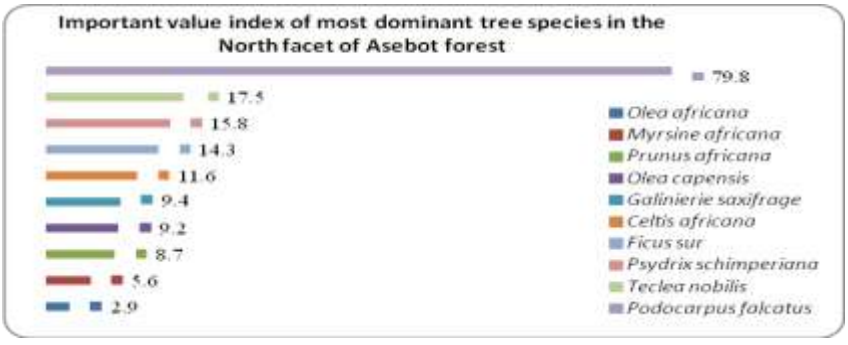

Figure 4. Dominate plant species and Importance Value Index for some vegetation in North Facet of Asebot Forest (Note that plant species listed at the bottom has highest IVI and the top has least IVI).

The Acacia wooded grassland (northeast facet) ecosystem, is also attributed with *Acacia abyssinica*, *Carrisa edulis*, *Myrisine africana*, *Cumbertum molle* and *Teclea nobilis* (Figure 5).

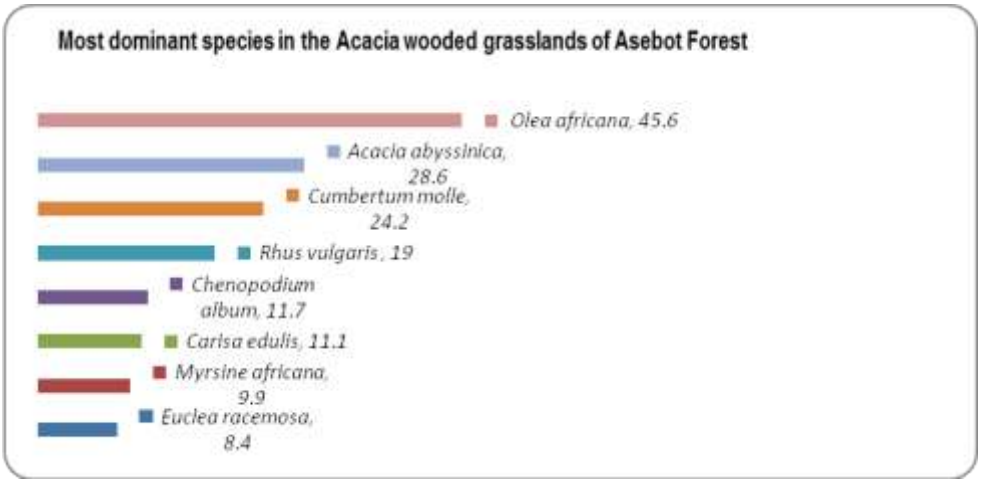

Figure 5. Dominate plant species and Importance Value Index for some vegetation in Northeast (Acacia wooded grassland) of Asebot Forest (Note that plant species listed at the bottom has highest IVI and the top has least IVI).

The most dominant species in the southeast facet is *Cumbretum molle* (Figure 6).

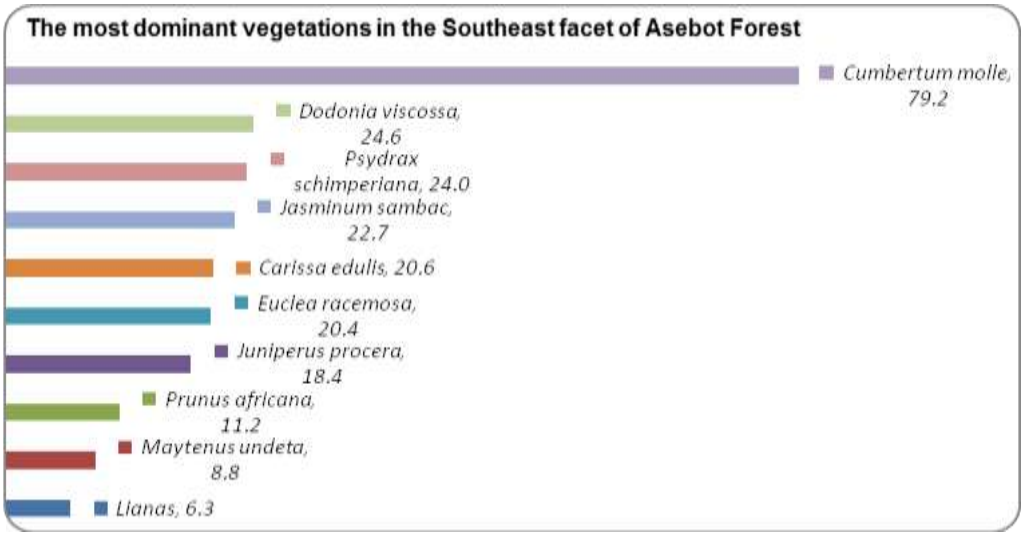

Figure 6. Dominate plant species and Importance Value Index for some vegetation in southeast facet of Asebot Forest (Note that plant species listed at the bottom has highest IVI and the top has least IVI).

3.2. Biodiversity Indices

Highest species richness was recorded from the plateau (n=29) and least from southeast (n=18) (Table 2).

Table 2. Biodiversity indices in Asebot Forest

Facet /Habitat	Species richness, S	Simpson's index of Dominance $D = \Sigma (pi)^2$	Shannon's index of diversity ($H = -\Sigma$ pi ln pi)
Northeast (Acacia wooded grassland)	25	0.7529	0.5271
Southeast	18	0.8299	0.5590
Plateau	29	0.8317	0.5179
North	24	0.8748	0.4862

Species richness in Asebot forest is relatively low as compared with other dry Afromontane forest of Ethiopia somewhere else. This might be due to absence of clear management structures regarding, unlike other nationally recognized forests such as in Menagesha suba forest, Gara Ades, Munnesa Shahemene, Wof –washa and others.

3.3. Regeneration Status of the Dominant Species

3.3.1. Naturally regenerated seedlings

Regeneration count in the plateau area was found high, however, is limited within the fragmented patches of the relics (Figure 7 and Table 3).

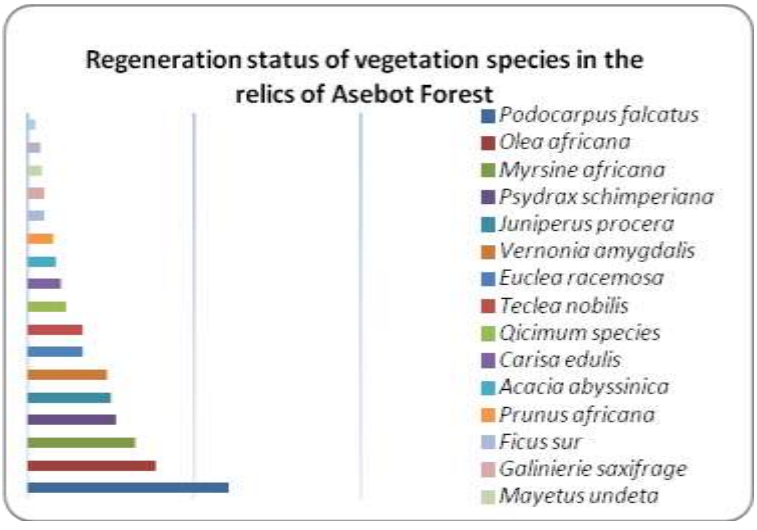

Figure 4. Density of regenerating seedlings in the relics of the Afromontane forest

Table 4. Species and density of trees in Afromontane forest

No.	Species name	Density (stems/ha)
1	*Podocarpus gracilier*	6000
2	*Olea Africana*	3800
3	*Myrsine Africana*	3200
4	*Psydrax schimperiana*	2600
5	*Juniperus procera*	2467
6	*Vernonia amygdalis*	2333
7	*Euclea racemosa*	1600
8	*Teclea nobilis*	1600
9	*Qicimum species*	1133
10	*Carisa edulis*	966
11	*Acacia abyssinica*	800
12	*Prunus africana*	733
13	*Ficus sur*	467
14	*Galinierie saxifrage*	467
15	*Mayetus undeta*	400
16	*Dodonia viscossa*	333
17	*Jasminum sambac*	200

Studies revealed that a large number of species in dry Afromontane forests (DAF) of Ethiopia store significant quantities of seeds in the soil in contrast to the situation in most tropical rain forests, dry lowland forests and savannas, (Demel 1996a, 1997d; Demel and Granström 1995). However in this Dry Afromontane forests, low number of seedling was counted. This could be due to the recurrent forest fire occurred in the past few years, which affected the seed source for regeneration.

Figure 8. Seedlings of *Juniperus procera* and *Podocarpus falcatus*

3.4. Estimated Carbon Stocks in the Remnants of Asebot Forest

The living biomass (tree and non-tree vegetations), non-living carbon sources (dead and standing and the dead and fallen woods and litter) and the soil contain 203.24, 20.7 and 117.2 (tc/ha), respectively, making the total amount of 341.6 tons of carbon/ha within the area (Table 4). This estimation is outcome, in fact, is consistent with the established earlier findings from the related assessment in the realm of estimating the carbon stock under the analogous conditions of the vegetation environment (FAO, 2006; Ramachandran *et al*., 2007; Varanasi in Misra, 1972).

Table 4. Estimated total carbon stock

№	Carbon pool	Quantity (tc/ha)	Percentage
1	Living carbon stock (both above ground & below ground biomass)	203.24	59.50%
	Tree vegetation	180.94	
	Non-tree vegetation	22.3	
2	Non-living carbon	20.7	6.20%
	Dead wood	17.7	
	Litter	4.6	
3	Soil carbon stock	117.2	34.30%
	Total C-stock	341.6	100%

On other hand, living biomass comprises of two major constitutes of vegetation biomass; tree vegetation and non-tree vegetations. Tree vegetation includes those woody plants that are attaining dbh (diameter at the breast height or at 1.3m height above the ground), at least, 10cm and the total height of 5 m or more. The non-tree vegetations are those plant species pertaining the life forms of shrubs, herbs, grasses, climbers and other forms vegetation formations.

As shown in the above table majority of the carbon stock is retained in the living carbon stock and the soil, however, the level is different across the area. Tremendous quantity of the soil stock carbon is already escaped from the adjacent landscape of the remnant forest because of recurrent fire damage. In the plateau stratum, which is closer to the monastery, the vegetation is relatively dominated with indigenous tree species such as *Podocarpus falcatus*, *Juniperus procera*, *Olea europaea, Celtis africana* and other companions with average DBH ranging from 10.5 cm – 73.6 cm and average height of 7 m - 44.8 m. The shrubs and bush formations of various species are the dominant types of vegetations at the lower and middle altitudes, along with the altitudinal gradients. The common species of shrubs in lower and middle altitudes, in all strata, are *Maesa lanceolata, Dodonaea anguistifolia, Tecleanobilis, Euclea shimperi, Carissa edulis* and other allying plant species.

3.5. Human Interference

The most important challenge faced by the monastery is fire (Figure 9) and encroachments to cut the indigenous tree species like *Juniperus procera*, *Oleaafricana, Podocarpus gracilier,* and *Celtis africana* for commercial purpose (Figure 10).

Figure 9. Remnants of Asebot's dry afromontane forest in the valley bottom of the northern facet (Gelagle and Hudad catchment)

Figure 10. Calling for rescue (*Podocarpus falcatus* with DBH, 0.61 cm and height, 52 m)

The most targeted and valuable tree species by the encroachers are *Juniperus procera, Podocarpus falcatus* and *Olea africana*. They are used for building materials and traditional agricultural implement.

4. CONCLUSION AND RECOMMENDATIONS

Asebot forest could be recognized as one of Ethiopia's Dry Afromontane biodiversity hotspot, threatened by human interference. The forest floor is richly stocked with carbon sources in the form of litter fall and snags (dead standing tree as well as felled woods), which is the potential source of carbon dioxide emission as a result of successive fire hazard. This preliminary base line study may call attention to REDD+ project to provide alternative source of income to the local community. The poor infrastructure facility and severe water scarcity take the most important driving force behind massive encroachment, which is targeting indigenous woody species. Therefore, institutional intervention is also needed to maintain the remnants of these dry Afromontane forests, in the form of in-situ reserve of gene pools, take the initiatives in providing alternative means of climate change adaptation and mitigation strategies from potential donors.

In general, the efforts of assessments and evaluation of the prevailing states of the forest, in views of carbon sequestration should be encouraged. In this attachment, the following recommendations are given herein; the government at various structural levels should encourage the intentions, the efforts and the practical activities related to the carbon trade-off business as the means of communication with various donors for securing the required fund the detailed survey for the assessment of the carbon stock in the Asebot monastery must be updated and launched soon to consolidate the crude findings the Hu must enhance its technical and material capacity to emerge as the leading institute to handle duties related to the carbon stock financing matters

HU must develop itself to the full-fledged level of handling missions and giving consultation services and rehabilitation recurrent vegetation survey should be carried out on the established permanent sample plots. Basic infrastructure should be provided, especially water and school, for example, construction of low cost community earthen dam at the bottom valley of the southeast facet the monastery should be supported for its effort in the conservation of the relics forest. The forest encroachment is strongly related with the socio-economic attribute of the local people. The social problems such as lack of infrastructure (absence of health services both for human and live stocks, lack of water supply, school, market place etc..). The low economic return from agricultural activities has forced the people to encroach the forest, however, some for extra cash from wood sell.

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COMPARISON OF PLANT SPECIES DIVERSITY IN THE AFRO-ALPINE ZONE OF BALE AND SIMEN MOUNTAINS

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ABSTRACT

The Great Rift Valley bisects the highlands of Ethiopia into the eastern and western massifs. Among the number of high mountains in the surrounding escarpments, two are protected and designated as National Parks: Simen and the Bale Mountains National Parks, which are also located in either side of the Great Rift Valley. The montane moorlands, the montane grasslands and the woodlands are major ecoregions in the mountains. Above 3500 meters elevation lie the high Ethiopian montane moorlands. The present study aims at comparing the plant species diversity between plant communities of the two Mountains. Data collection was done during the successive field works that held between 2007 and 2009. Systematic sampling was performed in each mountain from three different habitats, each having four replicates of plots. In addition to the three commonly used diversity indices (species richness, Shannon entropy and Gini-Simpson index) the method of rarefaction was applied to avoid the sample size biases in estimating species richness. Chao 2 index was also used to compute quadrat richness. Though Bale Mountains is larger in size and expected to harbor more numbers of afro-alpine plant species than Simen Mountains, the present study revealed out that the reverse is true. The most likely explanation to such a result may be variation in the topography and biogeographic history of the mountains.

Keywords: Afro-alpine, montane moorlands, montane grasslands, plant species diversity, woodland.

1. INTRODUCTION

The afro-alpine environment commonly known to lie between 3500 and 5000 m a. s. l. (Hedberg, 1964). Generally, the vegetation in this environment is dominated by tussock grasses and sedges, small-leaved shrubs (*Alchemill*a L. and *Helichrysum* Mill.) and the giant rosette plants of *Lobelia* L. and *Dendrosenecio* (Hauman ex Hedberg) B. Nord. (Hedberg, 1951). Although more than 80% of afro-alpine plant species are endemic to the area, Hedberg (1961, 1965) noted that their supposedly closest relatives occur in other temperate alpine areas than the lowlands in the region.

As part of the Arabian-Nubian shield, the formation of the Ethiopian highlands has history that dated back to the Neoproterozoic epoch, having meant Geologic age

between 0.87 and 2.1 (Stern, 2001; Kröner and Stern, 2004). The highlands began to raise 75 mya as magma from the Earth's mantle. Uplift of the Ethiopian highlands together with Arabia occurred on an extensive scale after the regression of the Red Sea towards the southeast in the late Mesozoic to early Tertiary (Westphall, 1975). This ecoregion, which contains about 70% of Africa's highlands, is bisected into the eastern and western massifs by the Great Rift Valley. The mountains that are located in Northwestern side of the Rift include: Simen Mountains, Mt. Choke, Mt. Guna, Mt. Abune Yossef and Mt. Birhan. Mountains situated in the Southeastern side are Bale Mountains, Mt. Kaka, Mt. Chilalo, Mt. Bada and Mt. Guge. The Bale and Simen Mountains are among the eastern biodiversity hot spot areas and designated as National Parks.

As part of the afro-alpine ecosystem, Ethiopian high mountains are characterized by three terrestrial vegetation zones: Ethiopian montane moorlands, Ethiopian montane grasslands and woodlands. The montane moorlands lie at the highest elevation. It is also considered as the largest afro-alpine region in Africa. Grassland and moorlandform this zone, which also includes abundant herbs and some shrubs that have adapted to the high mountain conditions. Giant lobelias and giant Saint John's wort (*Hypericum revolutum* R. Keller) are important elements of the high altitude flora of Ethiopia that have evolved peculiar adaptations in response to the climate of the afro-alpine environment. The everlasting flowers (*Helichrysum sp.*) are the other conspicuous plants of the habitats, their high reflective silvery leaves and dry, papery flowers allow them to survive the desiccation in the high mountains.

Fairly more floristic and faunal studies were undertaken in the afro-alpine environments of Bale and Simien Mountains than in the same ecosystems of other mountains of the country. Important analyses on the vegetation and ecology of this environment were performed by Hedberg (1962, 1964, 1975 and 1986).More ecological studies were performed on the vegetation of Bale Mountains (Weinert, 1981; Weinert and Mazurek, 1984; Uhlig, 1988, 1991). Puff and Nemomissa (2001, 2005) made taxonomic and phytogeographic investigation on the plants of Simen Mountains and the surroundings. Remarkable survey of the biodiversity was also conducted by WWF (2008). However, no vigour study has been done in assessment and comparison of the plant species diversity within and between Bale and Simen Mountains.

The present study aims to compare and contrast the plant species diversity between plant communities of Simen and Bale Mountains. The plant species composition in these mountains can be the best model to compare biodiversity between the West and the East cliffs of the Great Rift Valley.

Plant diversity between the two mountains may be different due to their geographical location. On the other hand, the similar climatic condition of the afro-alpine environment may compromise the geography. The study will mainly focus to answer the following questions: Are the diversities of plant communities in the afro-alpine environment of the two mountains different? If the plant species diversities of the two communities are different, which community is more diverse? What will be the implication of the result in terms of inferring phytogeography, phylogeography or bigeography and conservation status of the afro-alpine environment?

2. MATERIALS AND METHODS

2.1. Study Sites

Plant species were collected from two of the Ethiopian highlands, in which the first three highest peaks are located. The Simen massif, where the Simen Mountains National park is located is found in the northern limit of the Ethiopian highlands (Figure 1). It includes the highest peak of the country named Ras Dashen (4620 m a.s.l.). The Park includes spectacular landscape that is composed of rough mountain peaks and deep valleys dropping some 1,500 m (www.unesco.org). The park is significant to the global biodiversity because of its unique flora and fauna. Besides, it is the canter of the afro-alpine plant biodiversity and part of the Eastern biodiversity hot spot area. The Simen Mountains National Park was established in 1969. It was also recognized as world heritage since 1978 and inscribed in the List of endangered World Heritages in 1996.

The second and the third highest peaks in Ethiopia (Tulu Dimtu, 4377m a.s.l and Batu; 4307m a.s.l) are found in Bale Mountains National Park (Figure 1). The Park is the largest remaining alpine habitat on the African continent (www.africanadventure.net**;** www.selamta.net). It was established and gazetted as National park in 1970. The spectacularly undulating plains of the Bale Mountains are marked by numerous glacial lakes and swamps, which are also surrounded by higher volcanic ridges and peaks (www.balemountains.org). More interestingly, the Bale Mountains show clear demarcation of the vegetation zones.

The Bale National Park experiences 8 months of bimodal rainfall. The heavy rain season is between July and October while the small rain appears between April and June. The afro-alpine region of the mountain receives 1000-1400 mm annually. It is warmer in the wet seasons than the dry seasons. The lowest temperature on the highest plateau reaches -15ºC and the maximum can goes up to 26ºC. The rainy season in the Simen Mountains is between June and mid-September. The lowest temperature experienced in this mountain is -5C while the highest reaches up to 25ºC.

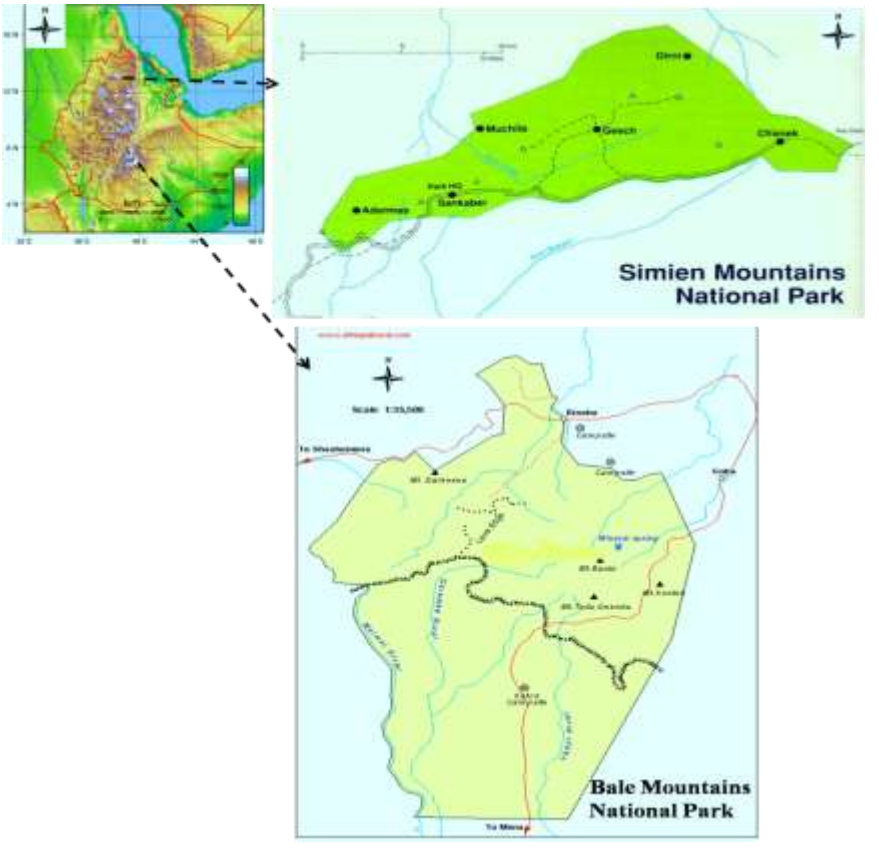


Figure 1. Map of study sites (Compiled from http//:www.ethiotravel.com)

2.2. Sampling and Field Data Collection

Sampling was carried out during the successive field works that held between 2007 and 2009. Systematic sampling of plants from three different habitats (Bog, Rock outcrop and Grassland) was performed in each mountain. Each of the habitats has four replicates of a 100 m^2 plot that summed up to 12 plots in each mountain. The samples from each plot assumed as a population. Distance and geographical barriers were taken into account to select the habitats for the purpose of reasonable sampling and comparison.

2.3. Data Analysis

Species richness seems a relevant and a well-behaved intuitive index to compute species diversity. However, this index alone cannot provide vigour figure of species diversity as it is affected by rare species. In other words, a diversity index must combine both richness and evenness (equitability) in order to give a reliable estimation of species diversity (Frosini, 2004). MacArthur (1965) noticed that the exponential of Shannon entropy more closely matches ecologists' intuitive concept of

diversity than the raw Shannon entropy. Yet the inverse Simpson concentration behaves reasonably, $1/(\Sigma pi^2)$, giving the same answer as species richness and the exponential of Shannon entropy.

Shannon entropy ("Shannon-Wiener index") considers species richness while the Gini-Simpson index assumes evenness (Magurran, 2004); however, both of them are non-linear (Peet, 1974). So, it is more efficient to use both indices and calculate their effective values to compare diversities of two areas. 'Effective or true' values of diversities are computed by taking the exponential of the diversity indices.

Indices were computed and converted in to their 'effective or true' values. Besides, the species richness was used to compare species diversity between the two mountains, and between similar habitats from the two mountains. Comparison of species diversity requires equal sample sizes. One method of avoiding incompatibility of measurements resulting from samples of different sizes is termed as rarefaction method (Sanders, 1968). It is to calculate the number of species expected from each sample if all the samples were reduced to a standard size (such as 1000 individuals). In other words, rarefaction is a procedure for analyzing species richness among collections, when all collections are scaled down to the same number of individuals. Species Diversity and Richness offers a number of rarefaction methods. Individual-based rarefaction uses pooled data for all of the samples within the data set or a community (Seaby and Henderson, 2007). It is computed in a way that all of the samples are summed to form a grand sample and then the average number of individuals in a single sample is calculated. The standard method for both the finite and infinite versions of the rarefaction curve of Heck *et al*. (1975) is then used to calculate the species number as the number of individuals increases.

Species richness increases with sample size, and differences in richness actually may be caused by differences in sample size. This problem can be solved by rarefying species richness to the same number of individuals. Therefore, the rarefaction method of measuring diversities provides vigour support to the other species diversity indices. Rarefaction methods, both sample-based and individual-based, allow for meaningful standardization and comparison of datasets (Gotelli and Colwell, 2001).

The similarity in species composition between two sites can be calculated using various estimators, among which Jaccard, Sørensen, Bray-Curtis (Sørensen abundance-based), and Morisita-Horn are the classic ones. These similarity indices are widely used. However, none of them corrects for the downward bias in observed species richness and similarities by accounting for the effect of undetected shared species. Chao *et al*. (2005) developed the indices (Chao2) that estimate asymptotic richness, which are based on the frequencies of rare species in the original sampling data. These indices are effective in satisfactorily adjusting the impacts of unseen

shared species. Hence, computing Chao2 also provides information about species richness of an area and is good to compare species diversity of two or more areas.

The diversity indices were computed using the conventional formulae and the application of PAST v 2.14 (Hammer *et al*., 2001) was sought to compute the statistical significant of the diversity indices (t-test), rarefaction and Chao2.

3. RESULTS

A total of 207 species of 116 genera, which belong to 43 families were used to analyze and compare the species diversity between Bale and Simen mountains. Asteraceae consist of the highest no of species (41 species) followed by Poaceae (27species) and Scrophulariaceae (12 species). Fabaceae, Lamiaceae, and Caryphylaceae are the next diverse families, each consisting of 10 species.

3.1. Species Diversity Comparison between Mountains

The species diversity analysis indicated that higher number of species encountered in the 12 plots of Simen Mountains than in the same number of plots in Bale Mountains. The result also indicated that the number of private species (Species that are not shared between the plant communities of the two mountains) in the plots of Simen Mountains is greater than that of the Bale Mountains (Table 1).

Table 1. No of species collected from three habitats (bog, rock outcrop and grassland) or recorded if not otherwise

Locations	No of species collected or recorded
Only from Bale Mountains	16 (8 %)
Only from Simen Mountains	72 (35 %)
Both from Bale and Simen Mountains	118 (57 %)
From Bale Mountains	135 (65 %)
From Simen mountains	189 (91 %)
Total no of species from both mountains	207

Likewise, the species richness analysis based on species count or frequency resulted in more counts in the plots of Simen Mountains than that of the Bale Mountains (Table 2; Figure 2A). Analysis of effective values for the species diversity provides values of 105 (Shannon entropy) and 90 (Gini-Simpson index) in Bale Mountains (Figure 2B). On the other hand, the effective values of these indices in Simen Mountains were 158 (Shannon entropy) and 138 (Gini-Simpson index). The statistical significance test for all the three indices between the mountains were a t-value of 30.56 and a p-value of 0.001069 with 95% confidence interval (0.58149, 0.77204).

Table 2. Comparison of the total plant species diversity between Bale and Simen Mountains

Diversity indices	Bale		Simen	
	Common diversity indices	Effective or True diversity values	Common diversity indices	Effective or True diversity values
Species richness/Species count	550	550	764	764
Shannon entropy	4.65	104.9	5.1	158.1
Gini-Simpson index	0.99	89.8	0.99	138.8

The individual rarefaction curve, presented in Figure 2C, indicated encounters of larger number of individuals in the habitats of Simen Mountains than that of Bale Mountains. The fact that each individual rarefaction curve becomes more and more flat as the sampling size increases also shows the performance of exhaustive samplings. The value of Chao2 (quadrat richness) for all plots was found to be 169.061 in Bale Mountains and 217.131 in Simen Mountains (Figure 2D). All the diversity indices clearly show that the species diversity in the sampled habitats of Simen Mountains is greater than those in Bale Mountains.

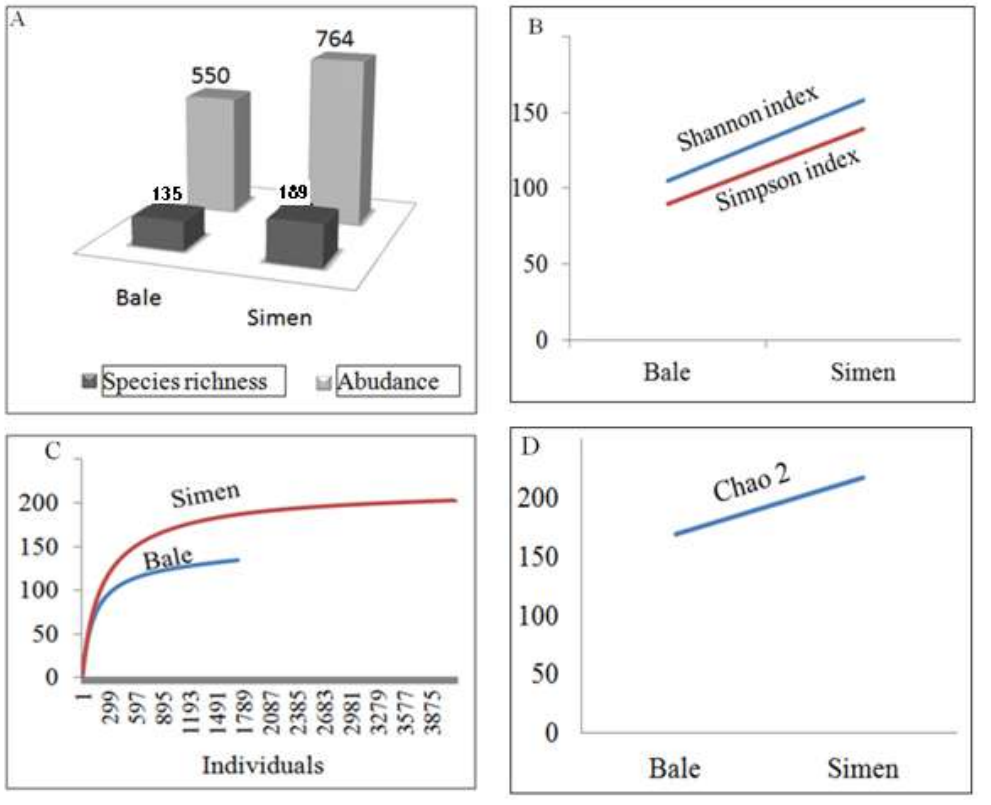


Figure 2. Species diversity comparison between three selected habitats in the afro-alpine zones of Bale and Simen Mountains. A) Graph showing the effective values of Species richness, B) Diversity curves from analysis of effective values of Shannon and Gini-Simpson indices, C) Rarefaction curve, and D) Chao2 graph based on diversity analysis, which takes rare species into account.

3.2. Species Diversity Comparison between Similar Habitats of the Two Mountains

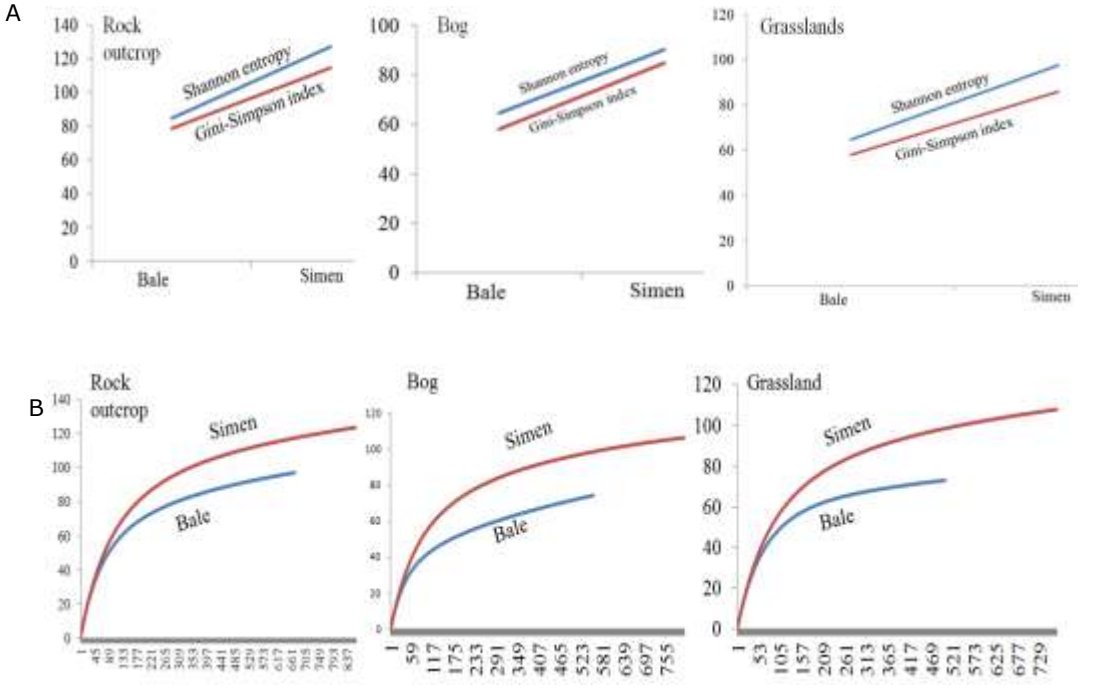
Species diversity analysis per habitat in each mountain provided 106 plant species that occur in boggy habitats of the Simen Mountains. Whereas, 75 plant species were collected and recorded from the same habitats in Bale Mountains. About 144 and 96 plant species were encountered from the rocky outcrop habitats in Simen and Bale Mountains, respectively. The analysis also indicated the occurrence of 114 plant species in grasslands of the Simen Mountains while 73 were from similar habitats of the Bale Mountains. The species count was also found to be higher in all the three habitats of Simen Mountains than it was from those of the Bale Mountains (Table 3, Figure 2A).

Similarly, effective values of Shannon and Gini-Simpson indices showed that Simen Mountains inhibit high biodiversity than that of Bale Mountains (Figure 3B). The

analyses of individual rarefaction also confirmed encountering of more and more individuals across sampling plots in Simen Mountains than in Bale Mountains (Figure 3C). The Chao2 (quadrat richness) value for the bog samples of Simen Mountains was found to be 122.627 while that of Bale Mountains was 130.309. The quadrat richness value in the rocky outcrops of Simen Mountains was higher (197. 337) than that of the Bale Mountains (110.824). Comparison of quadrat richness between the grasslands of the two mountains provided 173. 67 (in the plots of Simen Mountains) and 99.28 Chao2 values (in the plots of Bale Mountains) (Figure 4D). The analyses were statistically significant with lower p-values than the threshold (P = 0.05). Table 4 displays the detailed t- and p-values of the t-test analysis

Table 3. Comparison of plant species diversity between similar habitats of Bale and Simen Mountains

Diversity Indices	**Common Diversity Values**						**Effective or True Diversity Values**					
	Bog		Rock Outcrop		Grassland		Bog		Rock Outcrop		Grassland	
	Bale	Simen	Bale	Simen	Bale	Simen	Bale	Simen	Bale	Simen	Bale	Simen
Species richness/Species count	174	259	248	273	128	232	174	259	248	273	128	232
Shannon entropy	4.17	4.50	4.44	4.85	4.17	4.58	64.57	90.35	84.82	127.32	64.86	97.52
Gini-Simpson index	0.98	0.99	0.99	0.99	0.98	0.99	58.22	84.79	78.65	114.53	58.10	85.98



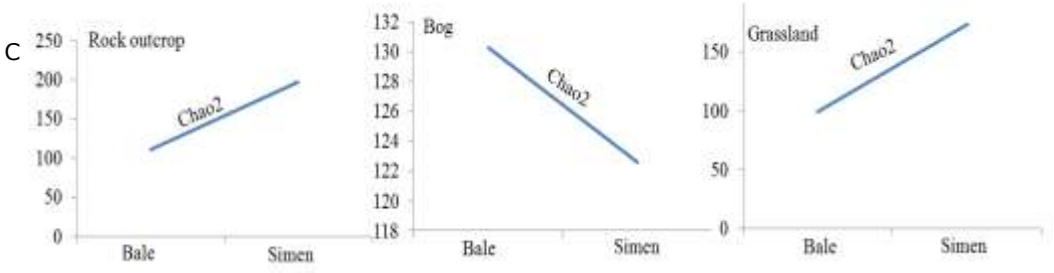


Figure 3. Plant species diversity comparison between similar habitats of Bale and Simen Mountains. A) Shannon and Gin-Simpson diversity curves based on analysis of effective values B) Rarefaction curves, C) Chao2 diversity cure based on species diversity analysis assuming the rare species encountered in each habitat.

Table 4. Statistical test values (t-values and p-values) of the diversity indices used to compare plant species diversity between similar plots of the Bale and Simen Mountains

Habitats	t-value	p-value
Rock outcrop	8.2	0.004
Bog	54.9	0.01
Grassland	15.9	0.005

4. DISCUSSION

The three diversity indices show a ratio of 3:4 diversity values between the plant communities in the afro-alpine zone of Bale and Simen Mountains. This value is very good evidence to the intrinsic plant species diversity in each of the two mountains. However, statistically significant higher species diversity was encountered in the studied habitats of Simen Mountains. The p-values computed to test statistical significance of the results are all less than 0.05 indicating that the difference in species diversity between the two Mountains is statistically significant. Therefore, the result supports higher plant species diversity in Simen Mountains than in Bale Mountains. The fact that more than 1/3rd of the total species, collected or recorded from the three habitats of the study area, are not shared with that of Bale Mountains is evidence about the high species richness and endemicity of Simen Mountains. Puff and Nemomissa (2001) have identified about 12 taxa that are endemic to Simen Mountain while 30 taxa of Ethiopian endemics occur in this mountain. The result from this study also confirms that the Simen Mountain is still centre of plant species diversity in the afro-alpine environment.

The richness in species and habitats might be the overall outcome of its great altitudinal, topographic and climatic variation. The diverse topography in Simen

Mountains might have contributed to the establishment of several niches that provide suitable environment for colonization and adaptation of new species at a faster rate. Nonetheless, environmental complexity alone may not determine the dimensions of niche variations and species diversity. Frequent and dynamic interaction among organisms and with their surroundings could also be factors (Connell and Orias, 1964) to such higher species diversity that observed in the Simen Mountains. The outcomes of this study do not support the positive spatial-richness correlation as it was inferred by Rosenzweig (2003).

5. CONCLUSION

Ethiopian highlands are long separated from the rest of the lowland areas, hence known for rich species diversity and endemics. The taxonomic revision of the afro-alpine flora in the East Africa by Hedberg (1951) included only about 280 species, which also added some of the lower altitude species. Therefore, the result obtained from the present study will add substantial information to the current plant taxonomy and ecology of the afro-alpine environment. Although the Simen Mountain is listed as one of the endangered biodiversity hot spots, it still shows significant plant species diversity.

More than 80% of the Simen Mountains was inhabited by humans prior to its inscription as world heritage. The Bale Mountains is also being inhabited by many pastoralists, agriculturalists and timber cutters during the last decades. Hence, the anthropogenic impact is affecting both mountains. With this respect, the results from this study may provide remarkable scientific evidence and apprehensive awareness to these biodiversity hotspot areas.

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POPULATION STRUCTURE AND REPRODUCTIVE SUCCESS OF *Aloe calidophilla* AND *Aloe yavellana* IN YAVELLO DISTRICT OF SOUTHERN ETHIOPIA

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ABSTRACT

A study was conducted on two Aloe species (*A. yavellana*, narrow endemic and *A. calidophilla*, near endemic) in Yavello district of southern Ethiopia. It was aimed to compare the population structure and reproductive success of these species with varying range of geographical distribution. Six quadrates measuring (5 m × 20 m^2) were established on naturally occurring populations following their time of flowering and fruiting (November to February, 2011-2012). In each quadrate, all the genets and ramets were sorted and marked. Each genet was recorded for the number of ramet (s) and each ramet was measured for rosette diameter and noted for state of flowering. Data on recruitments and mortality were also recorded. The clone size structure revealed that *A. yavellana* had greater density of genets (89), ramets (255), and multi-ramet (> 2) genets (64%) as compared to *A. calidophilla*. The populations of the species also displayed varying size structure of ramets defined in the 10 cm size class of rosette diameter (RD). The stage structure revealed low proportions of seedlings, juveniles and young adults stages compared to mature adults indicating dominance of long lived individuals in both species. Absence of seedlings in *A. calidophilla* indicated that the species relay more on vegetative propagation despite good seed set. Ramets in reproductive size class that were in state of flowering comprised 56.3% in *A. yavellana* and 46.2% in *A. calidophilla* in the study period. The mean number of capsules per raceme were (6.3±0.41) and (24±0.81) in *A. yavellana* and *A. calidophilla* respectively. Despite these variations in the extent of flowering and fruiting, the mean number of seeds per capsule was only slightly different. Mortality in the study period was low for both species and confined to ramets only. Based on the observed recruitment, survival strategies and mortality, it is reasonable to state that the *A. calidophilla* populations are nearly stable (stagnant) whereas *A. yavellana* populations are expanding for comparative purpose. Hence, appropriate conservation strategies have to be adopted for the studied species.

Keywords: Genets, population structure, ramets, reproductive success, vegetative propagation.

1. INTRODUCTION

The aloes are perennial plants that comprise herbs, shrubs and small trees. Most aloes are characterized by their thick and fleshy leaves with spiny margin. They have tubular flowers that are brightly yellow, orange or rarely white in colour. About 450

Aloe taxa are known today (Smith and Steyn, 2004). They are distributed mainly in the Sub-Saharan Africa and island of Madagascar. The majority of *Aloe* species occur in southern and eastern side of the African continent (Newton, 2004). Members of the genus *Aloe* have wide range of uses in medicine (e.g. in treatments of wounds and in reducing blood sugar and lipid levels); and also in commerce and horticulture (Mascola *et al.*, 2004).

In the flora of Ethiopia and Eretria, 46 species of *Aloe* have been described out of which (41, 89%) are endemic or near endemic indicating that they have high degree of endemism in the flora area. Only five species: *A. laterita, A. macrocarpa, A. rivae, A. secundiflora* and *A. vituensis* have wider distribution extending to east or West Africa. However, most other species have restricted distribution area and known from few localities and populations. The altitudinal distribution of aloes in the flora area is wide ranging from 500 m to above 3000 m (Sebsebe Demissew *et al.*, 2001; 2003; 2011).

Though not yet fully investigated and exploited for their use as in other parts of Africa, aloes in the flora of Ethiopia and Eretria may have potential economic and ecological values. For example, there are recent reports that the leaf gels from *A. debrana* and *A. trichosantha* are used in the manufacturing of sucks for coffee export. It has also been reported that *A. gilbertii* individuals are being used by the local community in rehabilitating degraded land (Fikre Dessalegn, 2006). *A. calidophilla*, a shrubby species with relatively wider range of distribution in the southern lowlands of Ethiopia and in the northern part of Kenya, is identified to be one of the commercial importances and listed among species that need conservation attention in Kenya (Wabuyele and Keyalo, 2008).

According to Carter (2001), many species of *Aloe* are threatened due to habitat destruction caused by urban and regional developments. A few species are collected for their use in medicine and cosmetic industry. Consequently, all species of *Aloe* (except *A. vera*) are in the CITES (Convention on International Trade on Endangered Species) list, clearly indicating their vulnerability (Newton, 2004). The red list assessment conducted on endemic vascular plant species in the flora of Ethiopia placed eighteen *Aloe* species in different IUCN threat categories. It was also identified that the threats to these endemic species have been caused mainly due to habitat destructions for agricultural expansion, urbanization, settlements, development construction such as roads and overgrazing (Friis *et al.*, 2003). Some of the narrow endemic *Aloe* species evaluated (e.g. *A. pulcherrima, A. monticola, A. harlana* and *A. yavellana*) which occur as small population and with very restricted distribution area were categorized as rare.

There is no doubt that plant species that are endemic and rare with a potential economic value but under threat are of conservation priority (IBC, 2004). However,

in order to design appropriate conservation strategies and decision making, information on the causes of rarity are crucial. The reasons for rarity of a given plant species might be twofold: linked to the biology of the species such as population structure and reproductive strategies and also the ecology of the species distribution area (Reveal, 1997). Consequently, this study was focused to compare the population structure and reproductive success of two selected *Aloe* species: *A. calidophilla* (identified as commercially important and with relatively wider distribution range) and *A. yavellana* (narrow endemic and rare) so as to suggest appropriate conservation strategy.

2. MATERIALS AND METHODS

2.1. The Study Area

This study was conducted on the natural populations occurring in Yavello district in Sidamo (SD) floristic region (see figure 1). Yavello is located in southern part of Ethiopia, about 590 km from Addis Ababa on the road to Moyale at 4° 53' N; 38° 04' E and elevation of 1910 m. The district mainly falls within the so called *Acaccia-Commiphora* woodland and scrubland vegetation type with scattered remnant forests. Data on the labels of herbarium specimens at the National Herbarium (ETH), Ethiopia and published literatures (Reynolds, 1966; Sebsebe and Gilbert, 1997) were consulted to trace the distribution area of the studied species. The populations of *A. yavellana* and *A. calidophilla* co-occur in the study area, thus selected for comparative purpose.

Figure 1. Map showing the study area, arrow indicates Yavello district within Sidamo floristic region.

2.2. The Species Studied

2.2.1. Aloe yavellana Reynolds

It is a shrubby species with straight to slightly curved leaves; narrow endemic, restricted to only two localities (near Yavello town and in the north-eastern slopes of Mega Mountain) in Sidamo floristic region. In these localities the species occurs inside remnants of *Juniperus* forest, on rocky slopes and in more disturbed areas near to roads between 1600 and 1900 m. The flowering time starts

2.2.2. Aloe calidophilla Reynolds

It is a shrubby species with strongly re-curved leaves; near endemic with wider distribution ranges occurring in different localities in Sidamo and Gamo Gofa floristic regions in Southern Ethiopia and also in Northern Kenya. In these localities the species found grow in woodlands, bush lands or open wooded grasslands often on dark soils at alt, between 1300 to 1600 m.

A **B**

Figure 2. Individuals with infruitscences of a) *A. yavellana*; photo taken at 5 km from Yavello on the road to Konso, Alt.1600m, b) *A. calidophilla*; photo taken at 35 km from Yavello on the road to Hagremariam, Alt.1300m

2.3. Data Collection and Analyses

2.3.1. Population structure

Population structure of *A. calidophila* and *A. yavellana* were obtained from the naturally occurring populations in the Yavello district. Six quadrates of 5 x 20 m² were established, three for *A. calidophila* and three for *A. yavellana* populations. The

quadrates were circumscribed using plastic rope and four wooden pegs fixed at each corner. Each individual clone consisting of one genet and one to several ramets was sorted and marked. Marking was done on the leaves with double numbers (G-R) by a water proof marker starting bottom left corner of the quadrate. Here 'G' stands for putative genet and 'R' stands for the individual ramet. A genet was defined as an individual that is derived from a seed comprising one to several ramets. A ramet was defined as an individual (or, the vegetative offshoot) connected to a single underground rhizome of the genet. In each quadrate, the following population attributes were recorded at genet and ramet levels. Each genet was recorded for the number of ramet (s) and each ramet was measured for its rosette diameter (RD) and noted for state of flowering. Data on recruitments (i.e. small seedlings and vegetative offshoots) and mortality (i.e. dead genets and ramets) were also recorded.

These data were analyzed for the population structure, i.e. the size structure and developmental stage structure. The size structure of the populations was investigated by the clone size and size of ramets. The size of a clone was determined by the abundance of ramets per genet and presented as frequency distribution of the genets and ramets per genet (Figure 3). The size of a ramet was determined by the size expressed by its rosette diameter. Accordingly, ramets were classified by 10 cm size class of their rosette diameter (RD) and the relative frequency (%) distribution of ramets in each size class was established (Figures 4 and 5). In order to investigate stage structure of the populations of species, all the genets in the quadrates were assessed for their developmental stages. The number of ramet (s) per genet and/or the size of ramet as expressed by their rosette diameter were employed as criteria to define stage classes. Accordingly, genets were characterized by four developmental stage classes: seedlings (genets with one ramet and RD < 10 cm), Juveniles (genets with one ramet and RD between 10 cm and 30 cm), young adults (genets with one ramet and RD > 30 cm (flowering size)), and mature adults (genets with two or more ramets). The stage structure of the populations of a species was presented as proportions of genets in each life stage class (Figure 6 and 7). In the analyses and presentation of the data on the population structure, Microsoft Excel office 2007 was used.

2.3.2. Reproductive success

Reproductive success of the two species was investigated and compared using data on recruitments, flowering, fruiting and seed sets. Recruitments by the two alternative recruitment strategies (sexual vs. asexual) means were compared as proportion of the small seedlings and vegetative offshoots recorded in the sampled populations (Table 1). Extent of flowering was assessed and compared as proportion ramets in state of flowering and non flowering in reproductive size class. Fruiting was evaluated from six randomly sampled racemes per species. Accordingly, each raceme sampled was counted for number of capsules. The degree of fruiting was

compared as average number of capsules per raceme. Seed set data were obtained from twenty randomly selected capsules per species. Each capsule selected was counted for number of seeds and extent of seed production was investigated and compared as mean number of seeds per capsule in the species studied (Table 2).

3. RESULTS

3.1. Population Structure

The size structure by clone size, i.e. number of genets and ramet (s) per genet investigated (Figure 4). It was found that *A. yavellana* populations contained the greater number of genetic individuals (genets) (n=89) as compared to *A. calidophilla* populations (n=68). Similarly, the total numbers of vegetative offshoots (ramets) of *A. yavellana* populations were (n=255) and *A. calidophilla* (n=207). On the other hand, in the populations of *A. yavellana* genets that comprised only one ramet (single ramet genets) account 36 percent, as compared to *A. calidophilla* populations that had 46.3% single rameted genets. Out of the total genets recorded in the populations of two species, multi-ramet genets (2-12) comprised 64 percent, and 53.7 percent for *A. yavellana* and *A. calidophilla* populations, respectively. Simple correlation showed that the two species populations are different in the extent of clone formation (Figure 3).

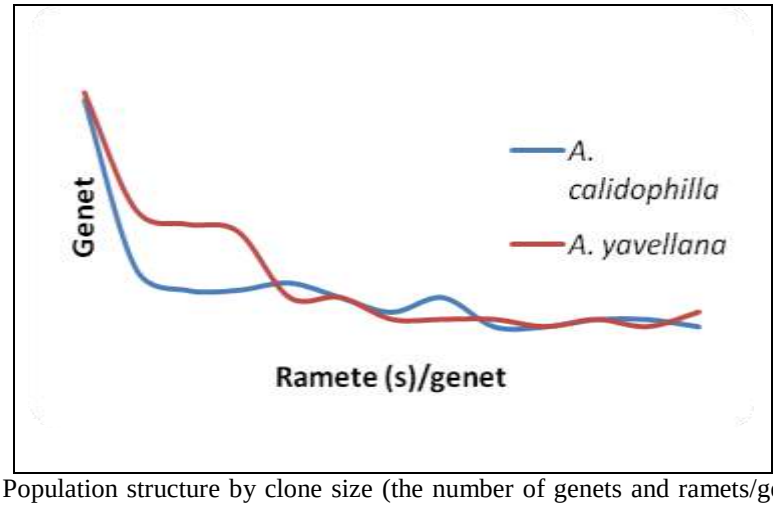

Figure 3. Population structure by clone size (the number of genets and ramets/genet) for *A. calidophilla* and *A. yavellana*

A. yavellana and *A. calidophilla* populations also displayed varying distributions of ramets in the size classes defined by 10 cm of their rosette diameter (RD). In *A. yavellana* populations, ramets with rosette diameter less than 30 cm (small sized) comprised 30.97 percent; between 30-90 cm (medium sized) comprised 63.15

percent; and above 90 cm (large sized) comprised 5.88 percent. On the contrary the size class distribution of *A. calidophilla* populations revealed 25.10 percent and 41.57 percent for ramets with rosette diameter less than 30 cm (small sized) and between 30-90 cm (medium sized), respectively. Large sized category of (> 90 cm) rosette diameter comprised 33.33 percent of the ramets recorded. Therefore, the proportion of ramets in small and medium sizes outnumbered (94.2 percent) in *A. yavellana* populations as compared to *A. calidophilla* whose populations had greater proportion (74.9 percent) of ramets in medium and large size classes

The genets in the populations of *A. yavellana* and *A. calidophilla* were classified into four developmental stage classes namely seedlings, juvenile, young adult and mature adult genets. The stage structure of *A. yavellana* displayed that 11 percent of genets were at seedling stage and the remaining 8 percent, 16 percent, and 65 percent were at juvenile, young adult and mature adult stages, respectively (Figure 4).

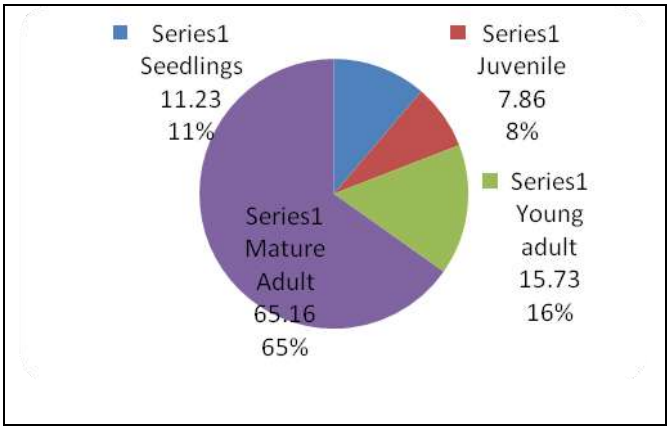

Figure 4. Proportion of genets in the four life stage classes defined (seedling, juvenile, young adult and mature adult) in the populations of *A. yavellana*

The stage structure of *A. calidophilla* populations, on the contrary, revealed that none of genets were at seedling stage and few in juvenile (4 percent). The remaining 42 percent and 54 percent were at young adult and mature adult stages, respectively (Figure 5).

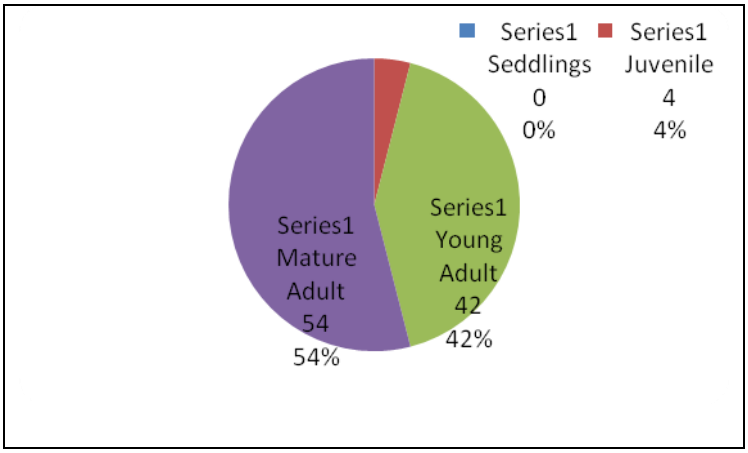

Figure 5. Proportion of genets in the four life stage classes defined (seedling, juvenile, young adult and mature adult) in the populations of *A. calidophilla*

3.2. Reproductive Success

Of the total small recruits recorded in the quadrates, 72.7 percent were due to vegetative propagation and the remainder (27.3 percent) was due to seedling establishment in *A. yavellana* populations. However, the recruits recorded in the quadrates were all due to vegetative means and seedling establishment were not observed in *A. calidophilla* populations (Table 1). Therefore, *A. yavellana* and *A. calidophilla* differ both in their strategies of recruitments. *A. yavellana* can produce genet ramets (n=12) by seedling establishment and ramets (n=32) by vegetative propagation indicating that the species had shown combined strategies of recruitment. *A. calidophilla*, on the other hand, entirely produced new ramets (31) vegetatively revealing absence of recruitments from seeds.

Table 1. Summary of data on recruitments of the populations of *A. yavellana* and *A. calidophilla* recorded in their respective quadrate

Species	Quad rate	Recruits from seeds	Recruits from veg. prop.	% Recruitment from veg. prop
A. yavellana	1	9	16	12
	2	3	5	32
	3	0	11	72.7
A. calidophilla	1	0	14	0
	2	0	7	31
	3	0	10	100

The extent of flowering of ramets in *A. yavellana* and *A. calidophilla* populations was investigated by the proportions of ramets in state of flowering and non-flowering in the study period. The total proportion of ramet's flowered were 34.9 percent and 26.5 percent in *A. yavellana* and *A. calidophilla* populations, respectively. When compared ramets in reproductive size class that were in state of flowering and non-

flowering, 56.3 percent in *A. yavellana* and 46.2 percent in *A. calidophilla* had produced inflorescence (s) in the season of study (Table 2). Ramet size relationship to flowering of ramets in the populations of *A. yavellana* and *A. calidophilla* had shown remarkable variations. It was found out that ramets that flowered in the populations of *A. yavellana* (90.7 percent) were mostly the medium sized ramets between 40 to 90 cm RD and the remaining flowered ramets (9.3 percent) had RD > 90 cm RD. None of the ramets whose rosette diameter < 40 cm RD produced flower in the season and hence the minimum size to be attained by the ramet in the populations produce flower is 40 cm. On the contrary, out of the total flowered ramets in the *A. calidophilla* populations, 12.7 percent had RD between 60 to 90 cm and 87.3 percent had RD above 90 cm. As opposed to *A. yavellana*, minimum flowering size of ramets was found to be 60 cm RD.

Table 2. Extent of flowering, fruiting and seed set in *A. yavellana* and *A. calidophilla*

Species	Ramets flowered(%)	Capsule/raceme (Mean ±SD, n=6)	Seed/capsule (Mean ±SD, n=20)
A. yavellana	56.3	6.3± 0.41	35.1± 0.29
A. calidophilla	46.2	24± 0.81	37.3± 0.30

The mean number of capsules produced per raceme were (6.3±0.41, n=6) and (24±0.81, n=6) in *A. yavellana* and *A. calidophilla* populations, respectively. Despite the variations in the extent of flowering and fruiting, the mean number of seeds per capsule of *A. yavellana* (35.1±0.29, n=20) and *A. calidophilla* (37.3±0.30, n=20) populations studied (Table 2). However, seed production varied from capsule to capsule.

5. DISCUSSION

The population structure provides a snapshot of the current demographic situation, from which some insights can be drawn (Widyatmoko and Norton, 1997). The population structure of *A. yavelllana* and *A. calidophilla* showed variations in their clone size. Analysis from sampled populations revealed that *A. yavellana* had greater number of both the genets and ramets. It also had greater number of multi-ramet genets as compared to *A. calidophila*, which had greater number of single ramet genet. Variations in the number of genets and ramets/genet might be attributed to the relative magnitude of the two modes of reproduction and hence indicative of whether the species rely more either on vegetative propagation or seedling recruitment or both as a strategy to maintain their population. *A. yavellana* populations which had highest number of genets, ramets and multi-ramet genets might recruit both from seeds and vegetative propagation. This was also supported by the recruitment data in the quadrates established for the study (Table 1). In clonal plants like aloes, a genet can

be viewed as a population of ramets and the size of the clone is therefore determined by the number of ramets. The clone size of the genets that make up the population has some indicative of the probability of the survivorship of individuals, because increased rate of clonal growth increases the probability of genet survival. In other words, clonality compensates for the loss of parts of plants due to disturbance and can thereby considerably enhance genet longevity and prolong population persistence over long periods of time (Pandey and Shukla, 2001; Witte *et al*., 2011). Thus, it is possible to state that genets in the *A. yavellana* populations that displayed large proportion of multi-ramet (2-12) might have the greater tendency to live longer. Similar finding was reported in the populations of *Aloe pulchrrima*in (Fikre, 2011).

Size structure is the most conspicuous aspect of population structures and driven by genetic or internal factors. The observed variations in the size structure of ramets might also be resulted from the action of external factors to which their members have been exposed during or even before the study period. For example, size specific deaths, and such factors as competition together can account for much of the variation in number of individual ramets in different size class distribution (Crawley, 1997).

The life stage structure distribution showed that the number of genets varied in the four life stage classes (seedlings, juveniles, young adults and mature adults) recognized. Mature adults account greatest proportions (65.2 percent in *A. yavellana* and 54 percent in *A. calidophilla*) as compared to young adults, juveniles, and seedlings. Besides, the populations of *A. calidophilla* had only few juveniles and none of the genets was at seedling stage. Nordal *et al*. (1997) on *Papaver radicatum* reported that, "A high number of seedlings and juvenile plants may be indicative of dynamic vegetation under establishment, whereas, a low number of seedlings and a high number of old rosettes would characterize a senescent population." Accordingly, it is reasonable to state that *A. calidophila* populations with none of genets at seedling stage, few juvenile genets but again with greater proportions of mature individuals fit to the second phenomena. Wabuyele (2000) reported a greater proportion of 'juvenile' and 'young adult' classes as opposed to the 'seedling' and 'mature adults' on the population structure of maculate aloes in Kenya and Ethiopia.

When the two species studied were compared by their recruitment strategies, *A. yavellana* combined recruitments both from seedling establishments and vegetative suckers as opposed to *A. calidophilla* that solely depend on vegetative means despite good seed set. The aloes, being clonal plants, strongly benefit from their capability to reproduce asexually as well as sexually. Although most aloes produce high numbers of seeds, establishment of recruits is only occasional and dependent on several ecological factors. If they become successful to recruit from seed, the seedling can persist almost indefinitely as the mortality risk of genets is spread among their ramets. Hence, the long-lived perennial habit of the aloe plants leads to the

predominance of older plants in aloe populations (Midgley *et al*., 1997). Therefore, survival of clonal perennials like aloes depends on population pressure on adult persistence and seedling recruitment. Thus, slightly increased rates of adult mortality or decreased rates of seedling recruitment might potentially cause local extinction. Accordingly, *A. calidophilla* populations with low rates of rejuvenation from seed might be subjected to difficulty in maintaining its populations provided that the prevailing mortality (e.g. eight of the ramets found died) and destruction of their habitats are unabated. However, recruitment ability by vegetative means or clonal growth is again important because of better survival relative to seedlings of offspring in new and sometimes difficult environments for reduced population turnover and dependence on seeds (Douhovnikoff *et al.*, 2004).

The flowering of ramets in relation to their size showed that number of flowered ramets varies in different size classes in studied species. In many species, the probability of flowering is also size dependent, so that plants must exceed a critical threshold size before flowering (Klinkhamer *et al.*, 1987) and should attain a minimum of 40 to 60 cm to flower in *A. yavellana* and *A. calidophilla*, respectively. The analysis made on the status of flowering and non-flowering of ramets showed that the proportion of non-flowering ramets is large (65 percent) as compared to flowering ramets in *A. yavellana* whereas *A. calidophila* had (73%) of non-flowering ramets indicating that both species have moderately low rate of flower production for comparative purpose. Clonal plants are often characterized by reduced sexual reproduction (flowering, fruiting and seed production) compared with non-clonal species. Factors causing plants to make the switch from sexual to clonal growth are generally correlated with suboptimal environmental conditions (Beatty *et al*., 2008). Consequently, local population dynamics of many species may depend heavily on clonal reproduction (Weppler *et al*., 2006). Thus, both *A. yavellana* and *A. calidophilla* perform better by vegetative reproduction (ramet sprouting) to maintain their populations. However, ecological forces including human activities can modify the entire extent of their narrow geographic range, may leads to their extinction. Rare species confined to only one or a few populations, such as *A. yavellana* have a greater chance of becoming extinct because the probability of all populations becoming extinct is higher as a result of environmental disturbance.

5. CONCLUSIONS

The population structure of *A. yavellana* and *A. calidophilla* revealed that *A. yavellana* had greater number of both the genets and ramets. They also had greater number of multi-ramet genets. This might be due to effective clonal growth (vegetative sprouting) and seedling recruitment in *A. yavellana*. The stage class distribution in studied species showed low number of seedling and juvenile and a high number of young and old rosette (mature adults) indicating dominance of long

lived and old individuals. Absence of seedling recruitment in *A. calidophilla* in the season indicated that the species rely more on clonal growth that ensure the longevity of genet survival despite good seed set. Hence, *A. yavellana* and *A. calidophilla* differ in their extent and strategies of recruitments. This might be due to the difference in the viability of seed, i.e. the presence of active and viable seeds in *A. yavellana* and viable of seeds of *A. calidophilla* needs further investigation. Mortality in the season was found to be low in both species and confined only to ramet level.

Based on findings from recruitment and associated survival strategies, it is reasonable to state that the populations of *A. calidophilla* are nearly stable whereas *A. yavellana* populations are expanding in the season of study for comparative purpose. However, the statement must be taken cautiously for it is difficult to fully predict the future fate of the populations of the two species by taking into only one season data. Therefore, further research has to be conducted stretching for over long periods on the recruitment, survival and mortality.

Therefore, from the tremendous potential benefits of aloes and existing threats thereof it is suggested that the species should be conserved by both *in-situ* and *ex-situ* conservation strategies.

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BIODIVERSITY AND ECOSYSTEM SERVICES OF LAKE TANA WETLANDS, ETHIOPIA

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ABSTRACT

This review paper presents the results of research from several years and field observations on ecological status of the Lake Tana wetland ecosystem in relation to the socio-economic issues. The Lake Tana wetland is known for its rich biodiversity. It has over 200 species of native and migratory birds, over 85 aquatic and wetland macrophyte species, and 26 species of fish. Traditional agricultural practices, deforestation, dramatic increases in over fishing, siltation, and related problems threaten the sustainability of Lake Tana. The newly constructed drainage from the shoreline of Bahir Dar town (south) is also a potential source of pollution of the lake by municipal and industrial wastes. The lake is a unique habitat for globally threatened flocks of cyprinds (endemic stock) that require special protection. The water level of the lake over the last 10 years has dropped by about 1-2 m. The invasive water hyacinths have caused difficulty in shipping and fishing since 2011. Managing the wetland along the shorelines and Feeder Rivers is a sound strategy to improve the possible solution to reduce eutrophication of the lake and the impending destruction of the biodiversity of the lake. The first measure to be taken is re-vegetation of the river shorelines degraded by human activities. Management strategies should also comprises both bio-phyical and socio-economic aspects with emphasizing on issues like adoption of watershed/ecosystem approach at policy levels, integration of income generation with conservation activities, sharing of responsibilities and benefits among local stakeholders, and institutional capacity building for environmentally and socio-economically sustainable development of the lake.

Keywords: Cyprinds, fish, macrophyte, municipal and industrial wastes, pollution, re-vegetation

1. INTRODUCTION

Wetlands comprise 6 percent of the earth's surface. One percent (345,000 km^2) of Africa's landscape is covered by wetlands (Leykun Abunie, 2003). In Ethiopia, wetland covers about 2 percent (13,699 km^2). With the exception of coastal and marine related wetlands, all forms of wetlands are represented in Ethiopia. More than 50 percent of these wetlands are major lakes (7,444 km^2) and the rest are swamps and marshes (Afework Hailu, 2005).

Healthy ecosystems are a fundamental requirement for sustainable development and biodiversity conservation. Biological resources support human livelihoods, and make it possible to adapt to changing needs and environmental conditions. Wetland livelihood systems provide multiple services, satisfying the needs of the local

community while providing fundamental ecological services for the larger catchment population. Fishery, livestock husbandry, small-scale agriculture, and wetland biomass harvesting are the main livelihood activities for people living in river and lake regions. The ecotones between lakes and terrestrial ecosystems are crucial for protection of the lake ecosystem against anthropogenic impacts. The transition area has the same function for a lake as the membrane has for a cell: it prevents, to a certain extent, penetration of undesirable components into the lake.

Wetlands are of value because they play an important role in maintaining environmental quality, sustaining livelihoods, and supporting biodiversity. However, recently the wetland biological resources have been severely affected due to both natural and human elements, resulting in a decline of the wetland system's ecological functions and self-restoration ability. Furthermore, demographic changes and increasing poverty have led to more invasive activities which have damaged the overall resource values. Nowadays, rain-fed agriculture has become increasingly unreliable due to untimely and erratic rainfall patterns. Therefore, poverty-related pressures, encroachment, and misguided development schemes have led to environmental degradation that has compromised basic ecosystem services (e.g. fish habitat, chemical and sediment retention). If this trend continues, the future livelihoods and food security of millions of people will be at risk.

Besides multi-functional values, wetlands are the most productive ecosystem in the world. For example papyrus in tropical Africa can produce 143 tonnes/hectare as compared to maize and sugar cane (60 -70 tonnes/hectare). Lakeshore areas are highly productive and their macrophytes are a very important component in the trophic component. In addition, macrophyte vegetation serves as an ecological buffer zone, which moderates changes in the shore areas of the lake by regulating nutrient and sediment flows, and recycling. The various macrophyte species in the shore areas are not distributed at random; each has its microhabitat, especially on water level gradient. This paper presents the status of Lake Tana shore area in terms of land use and biodiversity and elucidates the condition of the functions and services of the ecosystem.

2. THE STUDY AREA

The topography of Lake Tana shore varies along the catchment. Altitude in the catchment ranges from 1784 m above sea level south of the lakeshore to 3712 m above sea level in the other part of the lakeshore. The average annual rainfall in Chokie Mountains reaches 2000 mm. Dembia, Fogera and Kunzila floodplains are located in the north, east and south west side of the Lake, respectively. The town of Bahir Dar, which is the capital of the Amhara Regional State, is found at the extreme

southern gulf of the lake. The town of Gondar is located at the northern head region of the lake (Figure 1).

About 38% (5000 km^2) of the catchment constitutes extensive seasonal flooded plains. Of the total floodplain, 58% (3500km^2), including the lake holds wetland ecosystems. In general, wetland comprises 22% of the lake catchment. Five major permanent rivers, Gilgel Abbay (Small Blue Nile), Gumara, Rib, Megech, Dirma as well as more than 30 seasonal streams feed the lake whereas the Blue Nile River is the only outflow from the lake (Figure 1).

2.1. Summary of Major Fauna and Flora

Lake Tana is also a major world cultural and archaeological site. It is recognized by IUCN as an international bird site with more than 300 bird species (Shimelis Aynalem, 2007; Nega Tassie, 2007; Negash Atnafu, 2009), above 26 species of fish (de Graaf, 2003; Eshetie Dejen, 2003), 105 major macrophyte species (Aragaw Ambachew, 2009; Yezbie Kassa, 2010), 85 and 25 species of phytoplankton and zooplankton, respectively (Ayalew Wondie and Seyoum Mengestu, 2006; Eshetie Dejen *et al*., 2003).

The main feeder rivers are considered as part of the lake because they constitute spawning grounds for the *Labeobarbus* species during the wet months. Communities like Negede Weyto living along the lakeshore area largely depend on fishing and other wetland products for their livelihoods.

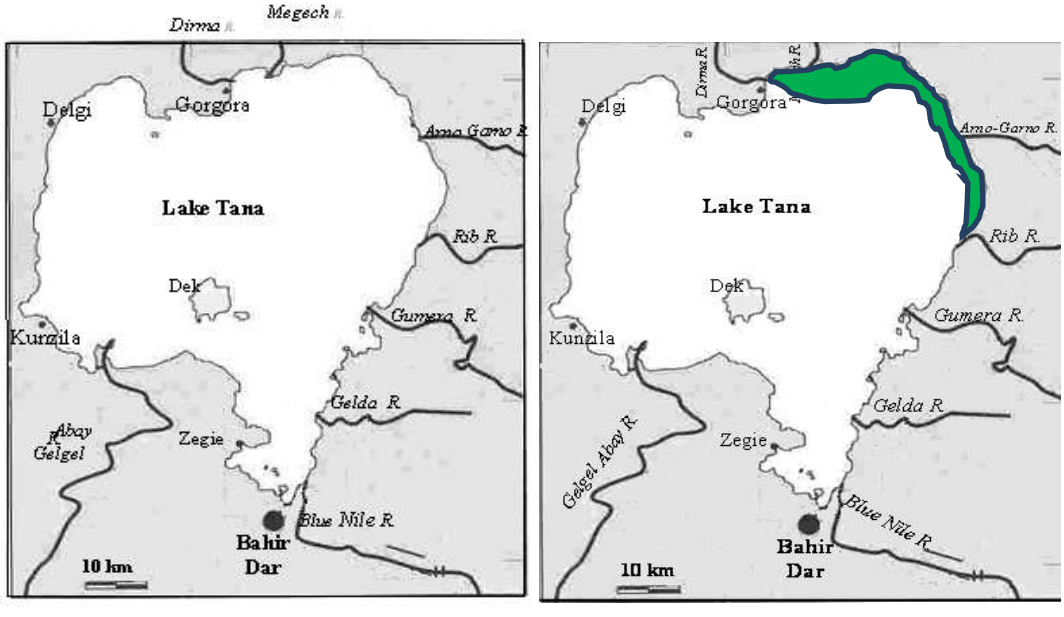

Figure 1. Lake Tana with its drainage baseline and water hyacinth infestation shorelines (shaded at the right)

2.2. Habitat Characterisation

Three habitats with distinct characteristics have been identified (Figure 2). **Sand beach:** dominated by sand mining, fish landing sites, and pastureland. **Rocky Bank:** shore area forest dominated by coffee, fishing, firewood, hilly dryland, monasteries, and urban shore area. **Muddy Bank:** including sediment loaded river mouths dominated by farm and pastureland (e.g. rice, teff and maize cultivation). Although annual and exotic vegetation is common, shoreline hippo-grass, phragmites, typha, and papyrus swamps are dominant in the river mouths.

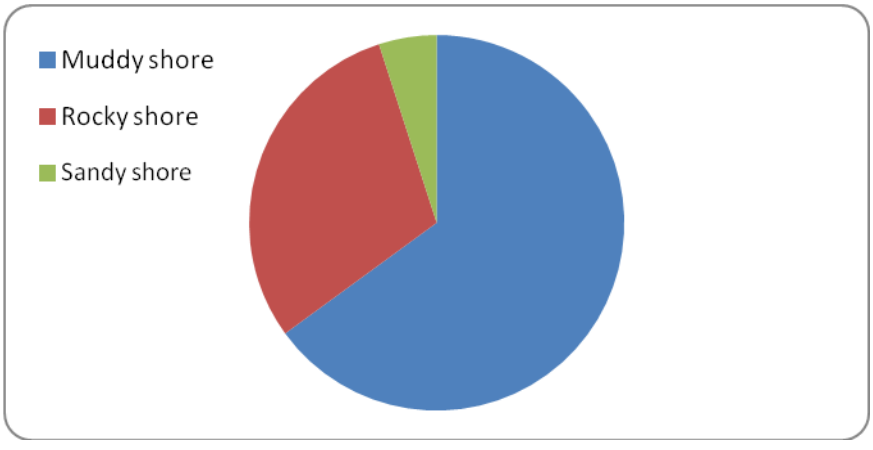

Figure 2. Percent of habitat classification in Lake Tana shore area

2.3. Shoreline Vegetation

Three dominant plant communities were identified so far throughout the shore area of the lake, namely, trees such as S*cigzyium* spp. (Dokima), *Memysops* spp. (Eshe) and shrubs dominating the rocky shore areas, *Scirpus* and *Polygonium* species dominating the north eastern shore area, and *Papyrus* and *Typha* dominating the south-western shore area of the lake. The occurrence and abundance of *Scirpus* spp. in the north and east habitats explains that this species is known to be tolerant of shallow water and waterlogged soils as compared to *Typha* and *Cyperus* spp.

Among emergent vegetation, *Papyrus* and *Typha* are limited to the south-western side of the lake while *Echinochloa* sp. and *Scirpus* sp. are common in the northern side of the lake. In Lake Tana, no exotic plant and animal species have been recorded for the last two years. In 2011, an invasive and damaging exotic floating plant appeared in the north-eastern lake shore, which is called water hyacinth (*Eichhorinia crassipes*).

Among environmental variables, water turbidity (clarity), lake water level, turbulence and nitrogen concentration are most important. In Lake Tana, water level from the shore area dropped during the dry season exposing the bare land from 0.5 – 1 km distance from the lake. As a result, the exposed land was cleared of emergent vegetation and put to agricultural use. Since there are no significant spatial differences in the major physico-chemical parameters among the different sides of the lake water, habitat sub-stratum and land use activities are the major operators. Submerged and floating macrophytes recorded are limited in number. They are also quite different in habitat selection or adaptation. Unlike *Ceratophyllum* species, which is available across the lake shore with a wide range of tolerance to habitat differences, *Nymphea* species grow best in habitats that have wind protection (calm condition), shaded, and with clear water. In the shallow calm depth of the shore area in the lake, especially at the river mouths, head of blue Nile river and pocket sites at the west zone, *Pistia spp*. (water lettuce) and *Sagittaria spp.* (common arrowhead) are common.

The commercial fishery consists of an endemic flock of large *Labeobarbus* spp. (Cyprinidae), *Oreochromis niloticus* (Cichlidae), *Clarias gariepinnus* (Clariidae), and *Varicorhinus beso* (Cyprinidae). In Lake Tana, fishery activity is highly affected by habitat degradation as compared to resource depletion. The wetland farming systems provide multiple services, satisfying the needs of the local community (food security, livelihoods) while providing fundamental ecological services for the larger catchment population. Wetlands also provide tradable goods and livelihoods. *Papyrus* and *Cattail* are the main wetland products used for fuel, thatching (houses, pest watching tukul, granary, kraal), as raw material for crafting (raincoat, mat, broom, basket, boat, carpet, etc.), ceremonial (as carpet on holidays and for festivities), for mulching nurseries, compost making, and as fodder (Barbier *et al*. 1997).

The catchment has critical national significance as a development corridor in the region and the country at large. It has also huge potential as source of water for irrigation to grow high value cash crops as well as for livestock production. The catchment has also high potential for the development of hydroelectric power with the prospect of exporting power to neighbouring countries. It has also high potential for ecotourism and other livelihood strategies outside farming. The ecotones between the lake and the terrestrial ecosystem are vital for protection of the lake ecosystem against anthropogenic impacts. Non-point or diffuse pollutants from the environment will inevitably flow towards the lake. Therefore, it is essential a buffer zone that will transform and/or absorb the pollutants entirely or partially. This will significantly reduce the overall irreversible negative effects on the lake ecosystem. Natural wetland treatment against domestic and municipal wastewater can remove up to 80% of suspended solids, 60% to 80% of organic matter, and 20% to 60% of nitrogen, 20% to 80% of phosphorus (Sisay, 2010).

3. CHALLENGES AND CONSEQUENCES

In the last two decades, human population pressure associated with climate change and emerging development schemes, have led to a decline in the wetland system's ecological functions and self-restoration ability. Beside the impact of agricultural and urbanization, the strong interest in hydropower, floriculture, and irrigation has culminated in the diversion of Tana-Beles and the damming of inflowing rivers such as Megech, Rib, and Gumara.

3.1. Major Existing and Potential Threats

Major threats to wetlands in Ethiopia include conversion to agriculture by draining or over-harvesting of the water, appearance of invasive species, introduction of perennial vegetation and overgrazing. On top of that, lack of clear awareness among the public and policy makers, coupled with the absence of clear policy directions on wetlands (Hailu, 2005). Seven major threats to lakes of the world include accelerated eutrophication, invasive species, toxic contamination, overfishing, water diversion, acidification, and climate change. Institutions and institutional arrangements for addressing these issues and for implementing a watershed approach is just beginning to emerge on lakes around the world (Borre *et al*., 2001).

3.2. Agricultural Activities

Wetland resources have been degraded due to high demand for agricultural land and home energy use, resulting from high population pressure. The major causes of biodiversity destruction through cultivation are poor methods of production systems, which result in loss of alternative livelihoods of the local community. This in return leads to low wetland product yield. Hence, local communities become both agents and victims of wetland ecosystem degradation (Yitaferu *et al*., 2004).

Wetlands in Lake Tana catchment are now threatened by sedimentation (silt load) as a result of upstream intensive agricultural activities and deforestation. The effects of non-point sources pollution such as agricultural runoff are greater than point sources of pollution. Above all, the surprising thing is a shift in farming practices. Earlier, farming occupied the upland of the mountainous areas following the long history of highland settlers of Ethiopia. In the last two decades, with the increase in population pressure and limitation of resources (land, water), farming shifted to wetlands including riverbanks, channel banks, and shoreline of lakes (Abunie, 2003). This is depicted in Figure 3 for Lake Tana.

Figure 3. A shift of farming practice from upstream mountains and hills to downstream riverbanks and lake shore areas in Lake Tana Cachment: steep slope farming at Sekela (upper) cultivating Lake Tana shore area (bottom-left) and Gumara river bank cultivation (bottom right)

Rice cultivation has become a major crop in Fogera and Dembia floodplains. The use of fertilizers and pesticides to maximize rice yields has had a significant impact especially on the floodplain wetlands (Wollala and Shesher) and to a large extent on the Lake. Shesher and Wollala floodplains (surface area estimated at 2000 hectares) are fragile wetlands highly threatened by drainage meant to convert the land to teff (*Eragrostis abyssinica*) and rice fields (Negash, 2009). Drainage of wetlands is usually achieved by altering surface flow and lowering the elevation of the surface outlet and altering the downstream waterway through channelization or ditching.

When the lake water recedes during the dry season, landless young farmers cultivate the shore area of the lake by deforesting even to the extent of burning the hydrophytes (macrophytes). The conversion of the wetland to agricultural land results in alteration or loss of spawning grounds for lacustrine fish and breeding places for wetland birds.

Cultivation, coupled with burning, causes loss of the regeneration potential of the macrophytes and a decline in biodiversity, especially *Papyrus* (*Cyperus papyrus)* and *Juncus(Juncus effuses)*. Upstream agriculture caused siltation associated with runoff from the cultivated land lack of littoral vegetation in the buffer zone at the downstream increased turbidity (e.g. secchi depth diminished even to the extent of 10 cm). Increased turbidity causes a decline in the photosynthetic zone and inhibits fish predation, which in turn leads to lower productivity of the Lake (Shiferaw, 2009).

The area of river inflow (river mouths) was formerly a swamp consisting of river channels flowing into the lake through a marshy area dominated by *Papyrus* (*Cyperus papyrus)* and *Typha* (*Typha latifolia*). Three to four decades ago, these areas were a genuine swamp but now they are marginally swamp or in some cases the swamps are entirely lost (Figure 4).

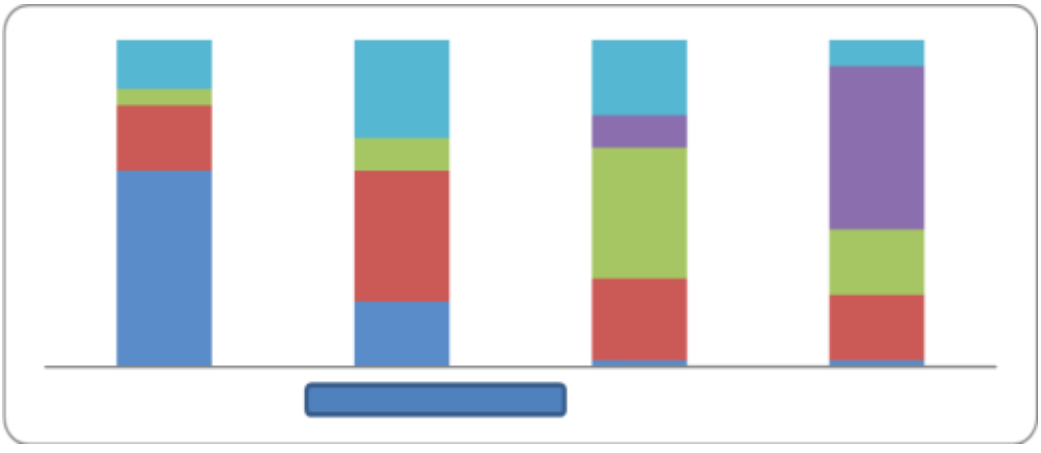

Figure 4. Trend of shore area macrophytes in the North eastern Lake Tana (Cyperus and typha spp.; floating grasses spp.; *Polygonium and Scirpus spp*.; *Eichhornia sp*.; Others)

3.3 Urbanization and Industrialization

Wetland degradation in Ethiopia is closely linked to the development of urban centres. The composition of storm water varies greatly, depending on the surrounding land use. For example, urban runoff may contain soil particles, dissolved nutrients, heavy metals and petroleum products. A variety of industrial wastes coming from food processing, slaughtering, chemical manufacturing, and landfill leachates, are pose serious threats to wetland ecosystems. Growing urbanization and unplanned tourism development activities around the lake in absence of adequate infrastructural facilities have negatively affected the Lake Tana's recreational values. Industries within the wetlands such as Bahir Dar, Hawassa, and Arba-Minch pose a risk to the normal functioning of the lakes in the vicinity of the town, and impair the capability

to clean wastewater and reduce siltation. In addition, establishing industries within and in the vicinities of cities and towns due to poor urban planning, leads to discharge of very toxic chemicals into wetlands, leading to loss of biodiversity.

Bahir Dar with a population of over two million, is located just in the vicinity of Lake Tana and the outlet of Blue Nile. There is no appropriate waste treatment system even at the municipal level. About 40% of the inhabitants are totally without toilet (Adane, 2005). Most municipal wastes and industrial wastewater are directly discharged in to the receiving water bodies .

The current development trend of the town is to increase residential, manufacturing and storage functions of the land at a cost of wetlands. This is why the type and source of pollution is complex. Analysis of sample of the waste removed showed 10% of the total weight as non-compostable manufactured material (plastic, glass and metal). In comparison, 50% of Indian municipal solid waste is organic (Gebremariam, 1994; Ayalew Wondie, 2009). A summary of key indicators in the major effluents of Bahir Dar town and the receiving water bodies is presented in Table 1.

Table 1. Major concentrations of effluents from Bahir Dar town and Lake Tana (Ayalew Wondie, 2009)

Indicator	Concentration in major effluents (Range)	Concentration in Lake Tana around Bahir Dar (Range)	Standard (Natural)	Source
Turbidity (NTU)	350 -1000	20 -28	< 10	Dejen, E (2003) Adane, Y (2005)
Conductivity (□ S/cm)	325 – 985	115 – 148 125 – 270	----------	Dejen, E (2003) Adane, Y (2005) Wondie, A (2008)
PO_4 (mg/l)	85 -205	0.5 -2.0	< 5	Wondie, A (2007) Adane, Y (2005)
pH	6.0 – 8.5	6.5 -8.5	6.0 – 9.0	
NO_3-N (mg/l)	320 – 756	0.1 -1.0	< 45	Wondie, A (2007)
TDS (mg/l)	120 – 465	63 – 135 75 – 160	< 1000	Adane. Y (2005) Wondie, A (2008)
Heavy metals				
Iron	0.9 – 1.7		< 1.0	Wondie,A (2008)
Lead	0.08 – 0.8	----------	< 0.1	
Chromium	0.94 – 2.8		< 2.0	
DO (mg/l)		5.9 – 7.3	> 3.0	Wondie, A (2006)
BOD (mg/l)	250 – 300	> 20*	< 3.0	Wondie, A (2008) Adane, A (2005)
Chlorophyll a (□ g/l)	----------	3.34 - 12.0	< 20	Wondie, A (2006)
Total coliforms (ind/100 ml)	> 100	----------	0 - 10	Adane, Y (2005)

* at point of discharge

3.4. Overexploitation of Wetland Resources

A number of construction activities underway in Bahir Dar and Gondar towns stimulate a high demand for brick making, coupled with sand-mining, leading to misuse of wetlands. Such businesses are often established in disregard to the required environmental safety regulation and measures. The activities of these businesses inevitably lead to the formation of pits accumulating stagnant water. The water harbours disease-carrying vectors such as mosquitoes, which transmit malaria and snails, which transmit schistosomiasis.

Overexploitation of Lake Tana watershed resources can also be exemplified by extensive traditional shore/lacustrine/reed boat fishing, over-fishing, and siltation. This problem exacerbated by overgrazing by cattle especially during the dry season, overharvesting and unwise use of *Papyrus* and common cattail reeds to the extent of digging the rhizomes as domestic fuel (Aragaw, 2009).

3.5. Population Pressure

About five million people live in the Lake Tana catchment. Fogera and Dembia floodplains are used for extensive rice cultivation (Wondie *et. al.,* 2010). Over 50% of the youth are landless (BoFED, 2009). The only pieces of land free of ownership are wetlands around the riverbanks and lakeshores. Therefore, this landless young generation currently creates pressure on the remaining wetlands to fend themselves through agricultural activities (crop production). For this purpose, youth burn, deforest, and drain the wetlands in the catchment. The local governors also condone this activity. In contrast, such exploitive conversion of wetlands to agricultural lands is condemned by elders, who apparently, owing to lifetime experiences, understand the benefits derived from the wetlands and the impending dangers of the change poses.

3.6. Inadequate Institutional Capability

Institutional inefficiency in terms of cooperation and coordination among stakeholders has hindered efforts to manage the lake resources sustainably. Although a number of institutions exist such as Ethiopian Wetland and Natural Resource Association (EWNRA), Ethiopian Wildlife Conservation Authority (EWCA), the Environmental Protection Authority (EPA), the Institute for Biodiversity Conservation (IBC), there is no specific authority committed to the conservation and management of the lake, implying "tragedy of the commons"**.** Interests in hydropower energy, irrigation, unplanned shoreline recreation, navigation, and fishery are the common activities usually conflicting with the conservation of the lake ecosystem.

3.7. Change in Water Level Fluctuation

Lake Tana is shallow (an average depth of 8 m) and is the only lake which serves as a means of transport for more than 10,000 people living on the islands. Conflicting activities such as power generation and lake water pump irrigation in association with global climate change has resulted in shrinkage the water level. The water level declines in most of the months of 2009 in comparison to 1998 and the decline in the month June was deeper (Figure 9). The opacity of the lake intensified and water-borne diseases have proliferated. A time series analysis indicates a decrease in area due to high internal loading of sediments (IWMI, 2008).

3.8. Habitat Alteration Effect on Species Composition

Increased turbidity resulting from destruction of ecotone or buffer zone area causes shallowing of the euphotic zone in the littoral areas of the lake and implies a sharp decline in water quality. This directly poses problems on the local tourism-based economy.

Nutrient pollution and associated eutrophication of freshwaters threaten the ecological integrity and the services provided to humans by lakes. Major indicators of pollution/eutrophication include high concentrations of chlorophyll-***a***, phosphorus, and high levels of algae that are inedible to zooplankton (Wondie and Akoma, 2008). Consequently, the ecosystem of Lake Tana has undergone substantial changes. Currently, the yield of *Labeobarbus* has declined substantially, followed by *Catfish* and *Tilapia* species, with which the lake once teemed (Figure 5). The changes have also caused by alteration of the breeding ground for migratory *Barb* species on riverbanks due to siltation and loss of breeding site for *Tilapia* as a result of degradation shoreline vegetation. This may lead to the total collapse of commercial fish production in Lake Tana (Eshete Dejen, 2005).

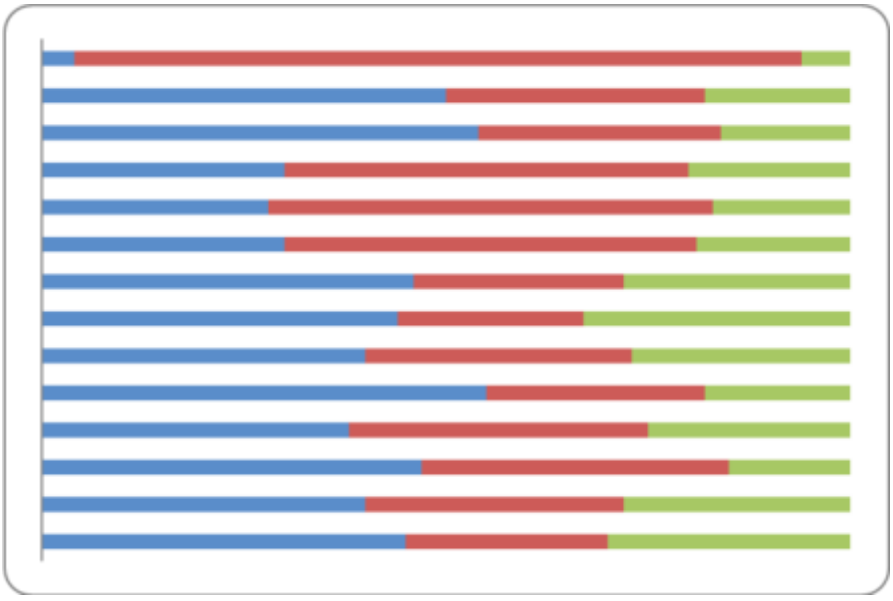

Figure 5. A ten-year fish catch variations in Lake Tana (left bar: *Catfish*; centre: *Nile tilapia*; and right bar: *Labeobarbus*)

Due to the environmental degradation, the composition of phytoplankton in Lake Tana has changed (Figure 5). Massive blooms of algae in the southern gulf have developed, and the phytoplankton has become increasingly dominated by the potentially toxic *Cyanobacteria.*

3.9. Water Hyacinth

Three to four decades ago, Lake Tana had a *Typha/Papyrus* shoreline with wide swampy beaches. However, in the last ten to fifteen years, *Papyrus* has become limited to the southern gulf with its associated huge sediment load. Now, water hyacinths have taken over about 10% of the lake shoreline (Figure 1).

Although no one is sure exactly when the water hyacinth first entered the lake, it most certainly transported down the Megech River which empties into Lake Tana. In last one to two years, the weed has appeared even in some pocket grazing and farm wet areas (personal communication) (Figure 6).

Since the occurrence of the weed, there have been no significant changes in physico-chemical properties of the lake water. However, the weed has affects the human population in several ways. There are economic impacts when the weed blocks motor and reed boats, tangling their nets and access. The effects on transportation and fishing are immediately felt (Figure 7). These include physical interferences at fish landing sites, grazing and farmland may suffer clogging of irrigation pumps.

Figure 6. Extensive water hyacinth infestation at the mouth of Megech River

The proliferation of the weed was apparently promoted by effluents from urban origin probably from Gondar town as well as from inappropriate farming practices, which may have resulted in accumulation of nutrients in the water bodies.

Figure 7. Fishers with their-reed boat/traditional/ in the infested areas

3.10. Recommendations

- Delineation (eco-zoning) of buffer zones of the lake shoreline and riverbanks should be made on the basis of habitat character and ecological services using phyto-technology. Any man-made construction should be avoided in defined distance from the lake shoreline and river bank to keep the ecotone intact.
- Alternative livelihoods should be promoted with integrated aquatic farming systems, such as finger pond farming, cage culture, local tourism income

generation and forage harvest. In the urban area biogas, compost and other business on waste management can also be considered.

- Appropriate wastewater management system should be developed, and west water should not be dumped to the lake.
- The role of protection should be reinforced by proper legislation and strict regulations of fishing, etc.
- Increase public awareness on the danger of polluting water bodies through training and peer-group discussions.
- Re-vegetation of the catchment.
- Establishing partnership with stakeholders to tackle the problem.
- Promoting research to support evidence-based policy making on the management of the wetlands.

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IMPACT OF HUMAN ACTIVITIES ON THE SUSTAINABILITY OF LAKES AND THEIR BIODIVERSITY: THE CASE OF LAKE ADELE, HARAMAYA DISTRICT, EASTERN ETHIOPIA

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ABSTRACT

Lakes are one of the natural resources used by humans and other living things. They provide water for consumption, habitat for fish, aquaculture, irrigation, power generation, transportation, recreation, and a variety of other domestic agricultural and industrial purposes. Therefore, we should use such valuable resources properly and sustainably. However, humans are interfering in the existence of natural resources, and negatively affecting its biodiversity. This case study was conducted in 2011on Lake Adele, which is located in East Hararghe Zone of Ethiopia, to assess the impact of human interference on the lake and its biodiversity. The study was conducted through personal observation and by interviewing local farmers and other residents in the area. Descriptive statistics was employed to analyse the data. The results of the study showed that human activities such as over-abstraction of water from the lake for irrigation purposes and siltation due to poor agricultural practices and land degradation in the watershed have led to the shrinking and seasonality of the lake, loss of biodiversity, and the risk of drying up completely appeared imminent. Climate change is also another major factor that contributed to the reduction in the volume of the lake due to high temperatures that led to excessive evaporation. In conclusion, over-abstraction of the water for irrigation and human consumption and poor land use system in the watershed, coupled with climate change, have caused significant reductions in the volume of the lake and led to loss of biodiversity.

Keywords: Lakes, biodiversity, human impact over-abstraction, climate change, irrigation watershed

1. INTRODUCTION

The total environmental impact of mankind on the ecosystem as a whole depends both on the total population in a given area, which in turn depends on what resources are being used, the nature of the resources and most importantly the carrying capacity of the ecosystem. Therefore, proper use of the resources in sustainable ways is mandatory to mitigate their loss. Sustainable management or careful resource management in agriculture, manufacturing, industry is important (Clark, 2006).

In Ethiopia, human activities, such as land use, agriculture expansion, irrigation, removal of excess water from the source, mismanagement of watersheds associated with rapid population increase have caused or accelerated many changes in the lakes

(Zinabu, 1998). The major degradation problems that lakes in Ethiopia are facing at the moment have, to some extent, been studied over the last ten years.

However, few studies have been done to explore the problems that Ethiopian lakes currently confronting in the face increased human population pressure and competition for resources to survive as well as a result of climate change. Therefore, the study was aimed at exploring the impact of human activities on the sustainability of Lake Adele and its biodiversity.

2. MATERIALS AND METHODS

2.1. The Study Area

The study has been conducted on Lake Adele, which is located in Haramaya district, east Hararghe Zone of Ethiopia. The area is situated at the distance of about 480 km from the capital, Addis Ababa, in the easterly direction. Lake Adele covers about 300 ha of land. The lake is surrounded by small hills and derives its water directly from rainfall and several small streams that drain from west and north catchments and floods from adjacent watersheds (Bird Life International, 2009). The lake shore is gently sloping so that a considerable area of land has become shallowly inundated during and immediately after the rainy season. During the 1960s, much of the areas around the lake were dominated by thick vegetation, predominantly bushes and climbers, and the lake itself had extensive beds of sedges, reeds, and bulrushes. However, currently most of this vegetation has been reduced and even lost due to conversion to agricultural land. The habitat now comprises short grasses, grazing meadows, and cultivated fields of sorghum. There are also some large *Eucalyptus* trees. Water from the lake was and is abstracted to irrigate perennial crops particularly *Catha edulis* Forsk.(khat), and vegetable crops. The lake is also a source of drinking water for the local people and their animals. The lake is used also for fishing. The area near the lake shore has been almost totally converted to agricultural and grazing land.

2.2. Data Collection and Analysis

Data were collected by interviewing local farmers and other residents of the area. Focus group discussion was conducted with elderly farmers and other residents. Secondary data were collected to assess the existing biodiversity and its loss from the lake. The secondary data were obtained from previous research. Species identification was done through observation and biomass and chlorophyll content measurements were determined in laboratory. The data were analysed using descriptive statistics.

3. RESULTS AND DISCUSSION

85% of the respondents attributed the decline in the volume of Lake Adele to human activities around the lake shore and watershed. Amongst the factors the respondents mentioned, using water from the lake for irrigation purpose, destruction of the vegetations in the catchment, and siltation were the major ones. In addition, the respondents also lamented that occurrence of drought for the last three consecutive years (i.e. from 2007 to 2010) contributed to the reduction in the water volume and shrinkage of the lake. The other 15 percent of the respondents commented that the main reason for the shrinkage of the lake was climate change that occurred for the previous three to seven years, which was manifested in increased temperature and drought. However, 85 percent of the respondent argued that climate change could not have been the main cause for the problem, and emphasised that human activities were indeed the major factor behind the reduction in the volume of the lake.

According to the respondents, the shrinkage of the lake poses huge challenges to the existence of humans, domestic animals, phytoplankton, zooplankton, fish, birds, and others. Some phytoplankton species which existed in the lake in the past were reported by the respondents to have disappeared.

A total of 21 species belonging to 6 classes of phytoplankton wrer identifed (Table 1).

Table 5. Major phytoplankton species in Lake Adele

Phytoplankton group	Botanical name
Cyanophyceae Cyanobacteria (Blue-green algae)	*Cylindrospermopsis africana* Kom. and Kaling *Planktolyngebya tallingii* Kom. and Kaling *Planktolyngebya contorta* (Lemm.) Anagn. and Kom. *Microcystis aeruginosa* Rab. *Anabaena circinalis* Rab. Psuedoanabaena sp. *Raphidiopsis sp*.
Chlorophyceae (Green algae)	*Pediastrum simplex* Meyen *P. duplex*Meyen *Scenedesmus armatus* Chod. *Scenedesmus dimorphus* (Turp.)Kutz. *Scenedesmus quadricauda* (Turp).Breb. *Chlamydomonas reticula*
Bacillariophyceae (Diatoms)	*Thalassiosira sp*. *Nitzschia vermicularis* (Kutz.)Grun. *N. rostellate*. *Rhopahodia sp*.
Dinophyceae(Dinoflagellates)	*Peridinium sp*.
Cryptophyceae (Cryptomonads)	*Cryptomonas obovata* Skuja
Euglenophyceae (Euglenoids)	*Phacus longicauda* (Ehr.) Duj. *Lepocincilis sp.*

The biomass of the species in the lake reaches about an average of 40.5 mg Chl a m^{-3}. The number of species identified and their biomass contents indicated that the lake was productive and experienced moderate temperature, with rich nutrient contents. The species composition and diversity of phytoplankton of Lake Adele are smaller than those found and recorded in Lake Babogaya, which was 32 (Yeshiemebet, 2006) and closer to that recorded in Lake Kuriftu, 25 (Zelalem, 2007). However, the phytoplankton species diversity of Lake Adele is much lower than that of the Ethiopian Rift Valley Lakes such as Ziway, with about 67 species, Lake Hawassa, with about 70 species, and Lake Chamo, with about 44 species (Elizabeth and Willen, 1998).

In Lake Adele, only one species of fish, *Clarius mossambicus* was identified and even this one may have been introduced from the nearby Lake Haramaya. Surprisingly, the number of this fish species was declining and completely disappeared in April and May.

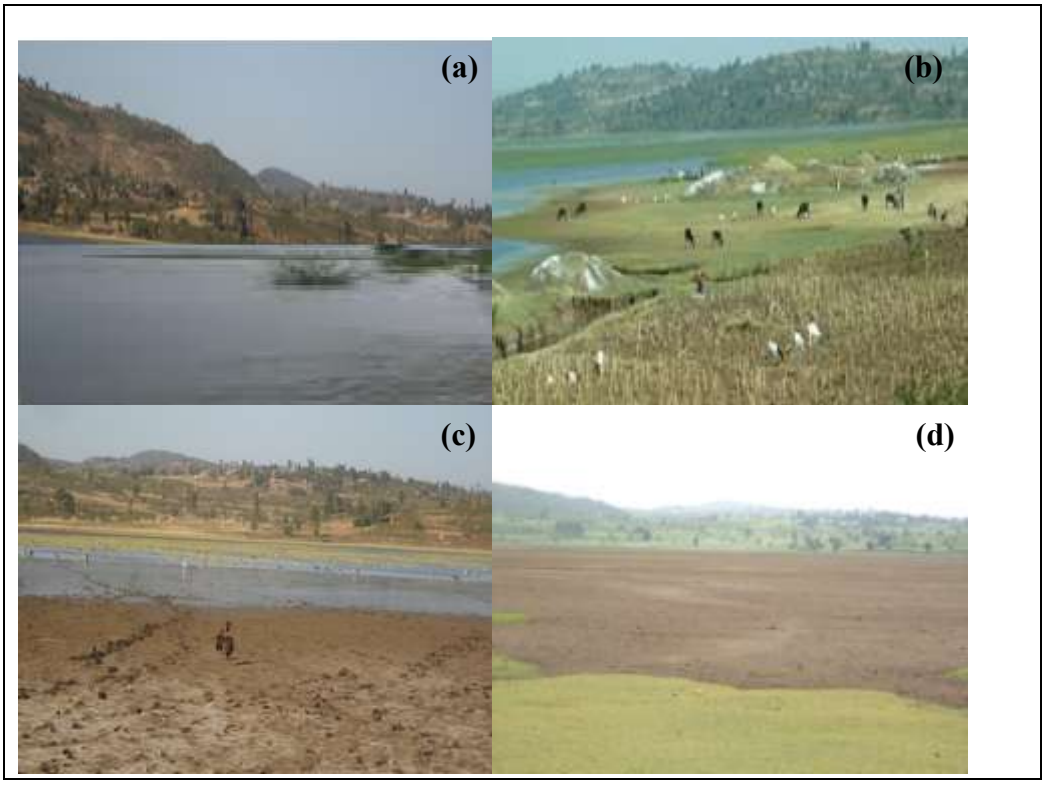

Figure 1. Partial view of Lake Adele during rainy (a); autumn (b); dry (c); and winter (d) seasons in 2011

Figure 4. Diversion of water from Lake Adele through pipes to temporary pond (a); agricultural farmland (b); farm area (c); and water collected for irrigation purposes (d)

During the study period, the lake was used for several purposes, including as a source of drinking water for humans and animals, irrigation, and fishing. The respondents commented that there was stiff competition among the farmers to use the lake for irrigation. Farmers having farmland near to the lake constructed temporary ponds, installed pumps and abstracted the water from the lake using motor pumps (Figure 3). The direct diversion of water from the lake was indicated to be responsible not only for the reduction in the volume of water but also for loss of biodiversity of the lake, including zooplankton and phytoplankton.

Moreover, some species of fish disappeared completely during the drying period whilst a number of bird species migrated to other areas. For the fish, somehow, the ponds served as a temporary shelter such that farmers often kept them in diverted water wells when the lake dried up and returned them to the lake when it refilled after the rainy season.

Local authorities have recognized the threats posed by human activities to the lakes in eastern Ethiopia and have given instructions to control the activities of farmers around the lakes. In addition, environmental conservation and rehabilitation

activities, particularly physical and biological measures to reduce the rate of soil erosion and siltation have also been recommended (Bird Life International, 2009).

4. CONCLUSION AND RECOMMENDATIONS

The results of the study have demonstrated that utilization of water from Lake Adele was unwise and inappropriate, resulting in marked reduction in the volume of water. The problem is particularly related to over utilization of the water for irrigation purpose as well as siltation of the lake from the surrounding watershed due to destruction of vegetation and land degradation. This has resulted in the dwindling of the water of the lake and loss of biodiversity. It could be concluded that the Adele Lake has faced unprecedented danger of disappearance as a water body and loss of biodiversity mainly due to human activities, which have been exacerbated by climate change. The results of the study imply that concrete strategies should be designed to protect the lake from exploitation and ultimate disappearance through participatory environmental education, conservation, and the wise utilization of the water of the lake.

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EXPLOITATION OF LAKE TANA'S ENDEMIC FISH DIVERSITY

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ABSTRACT

Lake Tana, the source of the Blue Nile, is situated on the basaltic plateau of the north-western highlands of Ethiopia, covering an area of about 3050 km^2. Lake Tana sub-basin harbours unique biodiversity and provides livelihood for communities living in the catchments. For example, twenty of the 28 fish species of Lake Tana are endemic and also the aquatic birds around the lake are numerous (215 bird species). Lake Tana and Beles sub-basin are considered to be growth corridors by the Federal and Regional Governments of Ethiopia. Hence, several development projects (dam building and irrigation projects) are being studied and/or implemented. The multipurpose nature of the lake has predisposed it to an intensive human pressure, risking loss of biodiversity and livelihoods of the peoples who depend on it for survival. This situation has been aggravated by the prevailing climate change. This paper elucidates the biodiversity resources of Lake Tana, challenges, opportunities, andmanagement options for its sustainable utilization and development.

Keywords: Aquatic ecosystem, Beles sub-basin, biodiversity, Blue Nile, catchment, overfishing

1. ENVIRONMENTOF LAKE TANA

Lake Tana is Ethiopia's largest lake (3050 km^2) and is situated in the north-western highlands at an altitude of approximately 1800 m above sea level. The lake is believed to have originated two million years ago by volcanic blocking of the Blue Nile River (Mohr, 1962). It assumed its present shape through blocking of a 50 km long quaternary basalt flow, which filled the exit channel of the Blue Nile River (Chorowicz *et al*., 1998). However, there are strong evidences that Lake Tana had dried up between 25000 and 10000 years ago (Lamb *et al*., 2007). It is shallow (maximum depth 14 m, mean 8 m) and meso-oligotrophic. Several large and small rivers including Gumara, Ribb, Megech, Gilgel Abay, Arno Garno and Dirma (maximum length 60 km) enter the lake, and the Blue Nile is its only outflow.

The eastern and southern shores of Lake Tana are covered with swamps, especially near river mouths, dominated by papyrus (*Cyperus papyrus*), *Typha latifolia* and Waterlilies(*Nymphaea* species). Fig tree or 'Warka' (*Ficus sycamorus*) often grow close to the shores. The dominant macro-invertebrates in Lake Tana are mollusks, insects, and crustaceans. The zooplankton includes copepods, cladocerans, and rotifers. Brunelli and Cannicci (1940) reported 26 zooplankton species, but a study

by Tesfaye Wudneh (1998) recorded less diversity (17 species). It is evident that zooplankton diversity has declined in Lake Tana during the last seven decades.

Amphibians, especially anurans are present in the lake, particularly in the marshy shore areas. Nile Monitor (*Varanus niloticus*) is the largest reptile in the lake and it is claimed by some farmers that there are also phytons (*Phyton sebae*). Crocodiles are absent from a large part of the lake, since the temperature is too low for them to survive.

The aquatic birds around Lake Tana are numerous. A total of 215 bird species have been documented (Shimelis Aynalem and Afework Bekele, 2008). This constitutes about 25% of the total number of 861 bird species in Ethiopia. Piscivorous bird species include residents such as little grebe (*Tachybaptus ruficollis*), Great white pelican (*Pelecanus onocrotalus*), Great and long tailed cormorants (*Phalacrocorax carbo* and *P. africanus*), Darter (*anhinga rufa*), many species of heron (*Ardeola* spp., *Egretta* spp., and *Ardea* spp.) Hammerkop (*Scoppus umbretta*), and African fish eagle (*Haliaeetus vocifer*). Egyptian goose (*Alpochen aegyptiaca*), spur-winged goose (*Plectropterus gambensis*) and Pygmy goose (*Nettapus auritus*) are the most conspicuous non-piscivorous aquatic birds. Palearctic migrants that depend on the lake include Osprey (*Pandion haliaetus*), Great black headed, Lesser black headed, and Herring gulls (*Larus ichthyaetus, L. fuscus*, and *L. argentatus*), and whiskered and white-winged black terns (*Chlidonias hybridus*, and *C. leucopterus*). The wetlands and the islands around and within Lake Tana are known to be one of the Important Bird Areas (IBAs).

Hippopotamuses are present in the lake in good numbers while other animals are also claimed by farmers to have been seen in some areas. The mammalian gene pool of the lake and its sub basin seems to be threatened. Apart from the Vervet monkeys (*Cercopithecus aethiopicus*) most of the other mammalian species are either vulnerable or critically endangered locally.

1.1. **Fish Species**

Nineteen of the 28 fish species of Lake Tana are endemics. This speciation was possible because for ca. 5 million years the lake has been isolated from the lower Blue Nile basin by 40 m high falls, 30 km downstream from the Blue Nile outflow.

One cichlid, *Oreochromis niloticus* (Nile tilapia), the most widespread tilapia species in Africa, occurs in the lake. This species is predominantly herbivorous, feeding on macrophytes, algae and detritus. The catfish family (Clariidae) is also represented by one species, *Clarias gariepinus* (African catfish), which is the most common member of its genus. This species is a facultative piscivore, also feeding occasionally on

zooplankton, benthic invertebrates and algae. The obscure loach, *Nemacheilus abyssinicus* (Balitoridae), is very rare in the lake but has been observed in a small stream close to Lake Tana and in large parts of the Ethiopian high plateau (Abebe and Eshete, 2012).

The largest fish family in the lake is the cyprinids which are represented by four genera: *Varicorhinus*, *Garra*, *Labeobarbus*, and *Barbus*. *Varicorhinus* is represented by a single species *V. beso*, which feeds by scraping algae from substrates, and which is a common species in the rivers and lakes of the Ethiopian Highlands. The genus *Garra* is represented by four species in Lake Tana: *G. dembecha* Boulenger which is common and generally distributed in the Ethiopian Highlands, *G. dembeensis*is found on the northern part of Lake Tana. Two endemic species, *G. regressus* and *G. tana* have been recently described by Getahun (2000). All the four species are herbivorous. Fifteen large (max. 100 cm length) hexaploid barbs (*Labeobarbus* spp.) belong to a unique species flock of endemic cyprinids; surprisingly eight of these are piscivores (Nagelkerke and Sibbing, 2000). The adult *Labeobarbus* are generally pelagic, whereas the juveniles usually live in the littoral zone with macrophytes and/or in the adjacent wetlands. One non-endemic labeobarb species is present, *L. intermedius*, a generalist that feeds mainly on macrofauna and benthic invertebrates. It can be found all over Ethiopia in lakes and rivers. The fish community also includes three diploid species of small (<10cm) barbs: *Barbus humilis*, *B. pleurogramma* and the recently discovered *B. tanapelagius*. The last two species are endemic to Lake Tana with *B. pleurogramma* mainly present in the wetlands around the lake and *B. humilis* is a littoral species. However, *B. tanapelagius* is common in the large pelagic zone of the lake.

1.2. Role of Rivers and Wetlands for Fish Production

Most African barbs occur in rivers. In general, large *Barbus*, including lake dwelling species, are considered to be riverine spawners that migrate upstream to spawn, over short periods, in shallow gravel beds within fast flowing, small rivers.

In Lake Tana, the prevailing, actual differences in the reproductive characteristics and spawning patterns of African barbs need to be investigated. Detailed information on gonad development, peak breeding period, spawning area and size at maturity of each of the 15 species was, until recently, scarce, fragmented and sometimes unreliable due to limited sampling. The scanty information available is restricted to the southern part of Lake Tana and the Gumara, Ribb, and Megach Rivers.

The general requirements for *Barbus* spawning include highly oxygenated water and gravel beds. This is due to their critical importance in the development of eggs and larvae. These rivers are well oxygenated upstream by rapids and also have tributaries

which are suitable grounds for spawning. Recently, due to excess erosion and sediment load from the catchments. These requirements are not meet and hence the spawning grounds are unfavourable for the eggs and larvae. Final maturation and spawning of *Labeobarbus* spp. occurs in the tributaries and for some large species possibly at gravel areas in the far upper reaches of the rivers' main channels. This has been deduced from the distribution of running females. Moreover, some pools across the main river channels serve as a habitat for feeding and reproduction of river-resident *Labeobarbus intermedius* and *L. nedgia*.

The river mouths and the surrounding wetlands of Lake Tana are important habitats for reproduction and feeding of the three commercial important fish species. If seasonal flood plains are lost as a result of the dam or any other intervention, there will be substantial losses to the fisheries of floodplain river-lake ecosystems. It is, therefore, advisable to maintain the existing annual flooding of the wetland areas.

2. FISHERIES

An estimated human population of two million resides on the islands and around Lake Tana. Historical accounts show that the indigenous people who lived around the lake belong to the ethnic minority Negada-Weyito. Fish used to be the main food source for this and other poor communities living on the islands and areas surrounding the lake. Lake Tana is one of the few African lakes which have not yet been damaged by introduced fish species or major sources of pollution. Prior to 1986, Lake Tana fisheries consisted only of artisanal, predominantly subsistence reed boat fishery. This type of fishery was limited to the shore areas and targets the native Nile tilapia, Beso and *Labeobarbus* using locally-made fish traps and gillnets (length 15-20 m).

Fishing in Lake Tana started around the 18th century by the Negada-Weyito community; the other poor members of the communities gradually adopted the activity. In 1986 the Lake Tana Fisheries Resource Development Programme (LTFRDP) was started by a Dutch non-governmental organization the Inter-church Foundation Ethiopia (ISE-Urk) in collaboration with the Ethiopian Orthodox Church and the Ministry of Agriculture. The assistance programme targeted the poor fishermen around the Bahir Dar Gulf area and nearby islands by introducing modern fishing gear and motorized boats.

The LTFRDP created new opportunities for the fishers, extending their fishing area from the shore to deeper, offshore waters and, more importantly, to distant river mouths. Moreover, with the increase in catch, fish processing, marketing and net-making activities emerged as job opportunities for the surrounding communities.

Currently, four major types of fishery exist, characterized by the following specific combinations of gear and fishing crafts:

1) the motorized gill net (mesh sizes 10-12 cm) fishery based in Bahir Dar and now expanding into 10 bordering districts;
2) the traditional reed-rafts-gillnet (mesh size 6 to 10 cm) around the lake and mainly in the southern part;
3) the traditional reed-rafts-gillnet (mesh size 10 to 12 cm) around the lake;
4) the chase and trap fishery (mesh size 6 to 9 cm) based in the southern part of the lake.

Gear such as long-line, cast net and traps are occasionally used but contribute very little to the total fish catch. The traditional reed boat fishery is still important for remote areas of the lake. Reed-boats normally carry only one fisher and catch is collected early morning. The catch from this fishery is sold at small markets in the village and used for household consumption. They target mainly tilapia fish species. Reed boat fishers are not organized into any association or cooperative.

The recently introduced motorized fisheries mainly target bigger markets. This fishery method uses engine boats with 100 m long gillnets of 10-14 cm stretched mesh size. The motorization programme was accompanied by the organization of the fishers into an association and subsequently with technical training in net-making, fish processing, and engine maintenance. The motorized boats are mainly steel boats. There are about 25 motorized fishing boats on the whole lake, most of which land their catch in Bahir Dar (either directly or via a collector boat).

The lake fishery has employed more than 3,000 individuals who are directly dependent on the major activities of fishing, marketing, and processing for their livelihoods. It is also providing employment opportunities for women and other landless people such as ex-soldiers as well as the fishers.

3. THREATS

3.1. Development Projects

Lake Tana and Beles sub-basins are considered to be growth corridors by the Federal and Regional Governments. Hence, several development projects (dam building and irrigation projects) are being studied and/or implemented. These include, among others, the Tana Beles inter-basin water transfer, Koga, Ribb, Megech, Gilgel Abay, and Gumara dams and irrigation projects. Some of them block the feeder rivers to store water; some pump water through tunnels and some pump water directly from the lake for irrigation purposes. These projects may possibly pose serious threats to the water level, water quality, and biodiversity of the lake and the feeder rivers. Most of the fish fauna of the lake (the *Labeobarbus* spp.) are endemic and unique in the

world. They are also migratory in their breeding habit; they migrate to feeder rivers of Lake Tana during rainy seasons to breed. The planned dams are feared to block this vital migration of the fish and this may ultimately lead to the demise of this unique group of fish and decline in the fish stock of the lake. Environmental Impact Assessment (EIA) studies have been conducted for the different projects. If the development projects are to be undertaken, the mitigation measures and the management plans suggested in the various EIAs need to be strictly followed and implemented. Experiences to date, however, indicate that these measures and plans are not adhered to properly.

3.2. Overexploitation of the Fish Resources

Although a fishery policy is in place both at the federal and regional levels, its implementation is still at stake. Hence, lakes and rivers are considered free access resources where everyone has the right to exploit. Although there are registered and certified fishermen and their associations around Lake Tana, there are still a lot of illegal unregistered fishermen exploiting the fish resources. There is no or little regulation of the fishing gears. As a result, the fishery has started suffering from overfishing (recruitment and otherwise) at some parts of the lake, especially the southern part around Bahir Dar gulf. It has to be noted also that some of the *Labeobarbus* spp. have become very rare so that they have been proposed to be listed as endangered species by the International Union for Conservation of Nature (IUCN) (Abebe and Eshete, 2012).

3.3. Encroachment on the Wetlands and Shores of the Lake

As the flooding recedes, many people use the shores of Lake Tana for recession agriculture. The soil is fertile and there is enough moisture for growth of crops. Settlements are being consolidated and the encroachment on the wetlands increasing every year. There are also privately-run small-scale irrigation projects that use the lake's water.

The depletion of emergent macrophytes, through harvesting and burning as well as expansion of the submerged macrophyte stand, is a serious concern for the lake's existence. Problems in the watershed of the rivers that feed the lake have also become serious. Unless the riparian vegetation is maintained, it would be very difficult to prevent soil erosion and lake sedimentation. Even if dams are constructed and reservoirs are formed, they could easily be filled with sediments if the watershed is not properly vegetated and managed.

Deforestation for energy use and overgrazing caused by high density cattle are a major threat of Lake Tana that need an urgent solution by all concerned bodies. River-driven sedimentation is one of the most serious threats to the long term

ecological functions of the lake system. The negative effects are reflected by huge sediment deposits, shrinkage of the lake's volume and decreasing water holding capacity, reduced water quality, and habitat fragmentation and loss.

3.4. Institutional Capacity and Linkage

There is an obvious need for strong implementing agencies in order for regulations, policy issues, and EIA study results to be implemented properly. One of the major implementing agencies is the Environmental Protection Authority. It is imperative that this authority needs to be strengthened with the essential finance and manpower at the Federal and Regional levels for proper monitoring and evaluation of project proceedings and management plans.

It also appears that there is redundancy and repetition of efforts by different Government and non-Government institutions on the different projects that are taking place in and around Lake Tana. There should be a concerted action by all stakeholders towards mitigating the actual and potential environmental hazards facing the lake. The establishment of Lake Tana sub-Basin Authority that could coordinate all activities is an option to solve the problem.

3.5. Influx of Affluents

Small scale agricultural activities are taking place around Lake Tana. There is introduction of agricultural inputs, such as fertilizers, pesticides, and herbicides into the lake. Although the amounts and use of these inputs by farmers is small so far, the unregulated manner in which they are used is a threat to the health and sustainability of the water. Other chemicals like DDT residues and 'birbira' powders are easily being introduced into the lake and these in turn would affect the wellbeing of life within the lake.

In addition, wastes from the different sections of Bahir Dar town (e.g. Hotels, Hospital, Residents, etc) are, in most cases, discharged into Lake Tana directly. Setting appropriate sewerage systems could solve or mitigate the danger of the pollution of the lake water.

4. CONSERVATION AND MANAGEMENT MEASURES

It seems that Lake Tana fishery is under a threat from different illegal activities. Therefore, implementing all necessary management measures is vital for the sustainability of the lake and wise use of its resources. Currently, almost all fishers (both reed boat and motorized boat fishers) are mainly operating during the breeding season and in spawning grounds of each species. Tilapia fishing is carried out at littoral regions; Catfish at littoral flooded area; *Labeobarbus* is mainly targeted at river mouths and a little distance towards upstream. The most surprising fishing

activity that is shocking and will probably lead to a total collapse of Lake Tana's fishery has been the use of undersized monofilament gillnets imported from the Sudan (from Gelabat town) since 2008. During peak spawning season at the pre-rainy season, peak rainy season, and post-rainy season at all spawning grounds setting,the use of 5 up to 7 cm stretched mesh by all fishers become a common practice.

4.1. Restocking

As the aquatic habitat changes due to natural (drought, flood, habitat destruction) or human (over-harvest, pollution, habitat lost to development and dam construction) influences, the natural production of fish declines.

There has been a decline in the population of fish in Lake Tana over the past years. While all the reasons for the decline are not entirely known, it is agreed that a combination of loss of habitat, dredging of rivers, over-fishing, and various forms of pollution are all to blame. Therefore, stocking of fish should be one of the many management strategies to help replenish the populations for years to come. The need for mass production of quality fish seed can only be satisfied by artificial propagation methods. These methods permit the incubation and hatching of eggs and the rearing of seed under well protected conditions.

A fish hatchery is a facility designed to raise fish. It provides an optimum environment for fish eggs to develop and hatch by maintaining proper water temperature and oxygen levels, and providing adequate food supplies and safety from predators. The hatchery holds a captive brood stock, spawns wild fish on-station, and produces fish that could be released to water bodies when required.

It is known that some dams are planned to be constructed on the feeder rivers of Lake Tana, and these dams may hamper the migratory movement of the fish, and aggravating the already diminishing natural stock of the *Labeobarbus* spp. in Lake Tana. One of the mitigation measures for reducing this danger is restocking the lake with fingerlings of *Labeobarbus* spp. raised under controlled conditions (in hatchery and ponds).

The case of *Labeobarbus* spp. of Lake Tana may, however, be further complicated by the occurrence of several species in the rivers and the lake and it is not only a problem of one species as we see in several instances of other countries.

4.1.1. Closing the fishery during the spawning months (July-October)

Evidence shows that low recruitment is already a major problem for the *Labeobarbus* stock in Lake Tana. It is, therefore, very important to reduce the fishing pressure on the breeding population. To achieve this, fishing in the inflowing rivers of Lake Tana

and around the river mouths should be closed every year from July to October. Wetlands around Lake Tana like Wollala and Shesher should be closed from any fishing activities during the rainy season. The littoral areas of Lake Tana with a radius of 5km from the shore should be closed from any fishing activities for two months (June and July) every year.

4.1.2. Prevention of destructive fishing methods

Destructive fishing such as poisoning, explosives, as well as fishing practices that can hinder the free movement of spawning stocks, such as fencing the rivers, beach seines, and trawls should be strictly forbidden. Fish inspectors have the duty to check any of these destructive fishing methods.

Mesh size regulations should be implemented seriously and the aim is to allow immature fish to escape from being caught by gill nets. The regulation allows 8 cm and above stretched mesh size of gill nets for fishing. In order to avoid illegal mesh size and monofilament gillnet, the Bureau of Agriculture should issue licenses for gillnet making associations. Then all fishers with fishing licenses need to buy only from the registered net makers. The fish inspectors need to inspect on the ground whether or not those gill nets used are from a licensed net maker. The illegal monofilament small size gillnets imported from the Sudan need to be destroyed immediately by the Bureau of Agriculture and its use prohibited nationally.

4.1.3. Implement licensing of fishers and enforcing the control of illegal fishing

Any fishing for commercial purposes should be licensed. Motorized boats and traditional reed boats are fishing units and should be licensed for fishing. A license commits the fishers to respect the fishery regulations. The Bureau of Agriculture should approve the Directive for providing fishing licenses. Data on the fishers (legal and illegal) operating in Lake Tana are available at the Bureau of Agriculture. These data are reported by the district Office of Agriculture.

Currently, there are about 1686 fishers around the lake who are fishing for commercial purposes. First, all of them need to be licensed without considering any new ones. Then monitor the resource status for two years. The decision as to whether or not to provide new licenses will be dependent on the resource base. It is not advisable at all to give fishing licenses for River fishery. Licenses can be issued, however,for reservoir fishery.

The license will limit the number of gillnets per boat and number of fishing days per week. For a commercial motorized boat, 25 gillnets of 100 m per boat are recommended. For reed boat fishers, a maximum of 3 gillnets per boat are proposed. They should fish only three times per week during the non-restricted fishing season.

For effective implementation of licensing, fishers around the 10 districts must organize themselves in cooperatives. The cooperatives could be organized by the district Cooperative Promotion Agency and District Office of Agriculture. Then the Bureau of Agriculture with its District Office should issue individual fishing licenses for members of the cooperatives.

4.2. Enforcement of Management Measures

It is obvious that the lake fishery can play a significant role in the lives of the fishing communities and contribute to the regional economy if its sustainable yield is maintained. It is crucial, therefore, to design a management plan with clear objectives to utilize the fish resource in a sustainable way. Given that the resource is freely open to access, the lake is subjected to an influx of fishers and other illegal users.

Recognizing the dangers posed to most water bodies in the country, a National Fisheries Proclamation was ratified by the Federal Parliament in 2003. It provides broad guidelines related to resource conservation, food safety, and aquaculture. This document puts considerable emphasis on regulation, permits, and the role of the fishery inspector. It is intended that regional administrations should then use the Proclamation as a broad framework upon which they can develop their own regulations.

The Amhara Regional State was the first region to develop a Regional Fisheries Proclamation in 2003. This regional proclamation covers the same areas as the national policy, but has an additional objective relating to the creation of employment opportunities in fishing communities. It also states that information, including research findings, should be made available to the fishing communities. Like the National Proclamation, it focuses heavily on regulatory measures (command and control) and the roles of fishery inspectors.

Based on the proclamation and regulation, the Bureau of Agriculture is given the legal responsibility to issue directives necessary for the full implementation of the proclamation and regulation. In this regard, the Bureau has completed the draft of two directives and submitted it to the Bureau's management for approval.

To enforce the above management measures, fish inspectors need to be assigned in the ten districts around Lake Tana. The inspectors must be experienced/savvy fishers with good practical knowledge on the lake and its fisheries.

4.3. Participatory Management Approach

It is imperative to establish committees on fishery management in each of the bordering *kebeles*. Members of these committees should assist fish inspectors mainly during the rainy season because of many restrictions on fishing. The committee and

the inspectors, thus, could take full responsibilities to monitor the resource and bring unlawful fishers to the respective districtcourts. The committee should monitor all activity around the water bodies from July to October. Moreover, it should address any complaints from the community or any destructive fishing activities throughout the year.

4.4. Awareness Creation

The characteristics of the fishers need to be first understood to develop appropriate enforcement and awareness creation mechanisms. Knowledge, Attitude and Practice (KAP) analysis will provide insights into fishers' characteristics.

In a recent study made by the World Bank-assisted Nile Irrigation and Drainage project, it appears that the fishermen's knowledge about the fish resources is quite high. They are aware that the fish resource is depleting. They are also aware that the size of their catch is getting smaller from year to year due to overexploitation. The fishers apparently got fishery-related awareness through extension agents and this needs to be strengthened. However, only some of the fishers are aware that the government has laws, rules, and regulations with regard to fishing activities and fish resource management. The fishers have no idea about the contents of these law. It is, therefore, vital to design awareness creation programmes for fishers as well as for extension workers about the law, regulation, and directives.

The objective of creating awareness on fishing activities and fish resource management is to motivate the fishers to practise legal and environment-friendly fishing by upgrading and deepening their knowledge and understanding of the importance of preserving the fish resource. Training development agents and research workers on the laws, regulations, and directives could help them to effectively enforce the fishing rules and regulations for sustainability of the biodiversity and livelihoods of the people.

5. CONCLUSIONS

Lake Tana has unique biodiversity and it is an evolutionary laboratory. However, as a multi-purpose lake, the resource use is exposed to overexploitation and the biodiversity of the lake, the environment, and the livelihoods of the people are under threat. The threats have been identified and their mitigation strategies are proposed. Therefore, the water of the lake and its environment should be managed in an integrated participatory approach. Otherwise, this unique aquatic ecosystem may be damaged irreversibly and lost in the future. Better late than never!

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BIODIVERSITY POTENTIAL, CHALLENGES, AND OPPORTUNITIES IN THE DRYLANDS OF EASTERN ETHIOPIA: THE CASE OF BABILE ELEPHANT SANCTUARY

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ABSTRACT

Babile Elephant Sanctuary (BES), which is located in the semi-arid part of eastern Ethiopia, is one of the largest (6,982 km^2) area established to protect ecologically isolated population of the African elephant (*Loxodonta africana).* In this study, the biodiversity potential, existing challenges, and future opportunities of benefit accruing from biodiversity and eco-tourism were analysed. Diversity Index, vegetation communities, basal area, wild edible and medicinal plants, elephant population, human and livestock population pressure, and elephant poaching were investigated. A total of 75 quadrats, each with 20 x 20 m width, were laid out to make a plant species inventory. Participatory Rural Appraisal technique and field observations were employed. The extent of external pressure was assessed following a 5-point arbitrary scale of disturbance. Six plant communities having 237 plant species in 155 genera and 57 families were identified. Twenty-four woody species browsed by elephants, 43 traditional medicinal plants, and 32 edible wild plants were recorded. Total density of woody species was 19,991 individuals ha^{-1} though trees accounted for only 2.7 percent. Shannon diversity index (H') and evenness (E) were 3.55 and 0.72, respectively. The African elephant is an umbrella species of the sanctuary in which a total of 324 elephants were recorded through a direct count with a maximum estimate of 400 elephants. However, in 2011-12 about 42 elephants were killed, which was the highest mass-killing ever recorded in Ethiopia. Out of those killed, adult elephants numbered 21 and the whereabouts of tusks of 24 elephants with the dead bodies could not be known. This showed that the killing was linked to elephant poaching rather than a human-elephant conflict. In addition, charcoal making, human-elephant conflicts, human and livestock population pressure are the major challenges. Consequently, Babile Elephant Sanctuary (BES) deserves an urgent conservation priority in this changing climate before it is too late to save the elephant species and the entire biodiversity of this important sanctuary from extinction.

Keywords: Conservation, elephant poaching, *Loxodonta africana*, protected areas, species diversity

1. INTRODUCTION

The present estimated area of drylands in Ethiopia is over 75 million ha, which is about 70 percent of the total area of the country (EFAP, 1994). Of this, 25 million ha is covered with woodlands and bushlands. Most of the protected areas of Ethiopia are

located in these drylands. These enormous areas of dryland vegetation resources are facing serious problems of degradation. Protected areas cover approximately 14 percent of the country‘s surface area (Hillman, 1993). There are nine national parks, three sanctuaries, wildlife reserves and 18 controlled hunting areas covering an area of about 194,000 km^2 (IUCN, 1992). However, except a few, most of the protected areas exist only on paper. According to IUCN (1992), of the total protected areas, only 30,316 km^2 (2.5 percent) is properly managed.

Babile Elephant Sanctuary in the semi-arid part of east Ethiopia is one of the protected areas. The sanctuary was established to protect the only known population of the isolated and ecologically distinct sub-species *Loxodonta africana orleansi* (Barnest *et al*., 1999). The most recent molecular analysis indicated that this ecologically isolated relic elephant population is *Loxodonta africana africana* (Ishida *et al*., 2011). The ecology of this relic elephant population is under high human and livestock pressure. As a result of mass influx of a large number of farmers and their livestock from the east and north, the home range of elephants of Babile has shrunk by about 65.5 percent since 1976 (Yirmed *et al*., 2006). Although it has been designated as the largest sanctuary for elephants (6984 km^2) in the country, no systematic ecological study has been done until until recently.

The floristic diversity study was carried out in the Erer Valley, which is the largest part of the Babile Elephant Sanctuary. This valley is the most extensive part of the sanctuary where it is currently subject to increasing settlement pressure. Both the human and livestock populations have increased dramatically (Anteneh, 2006). The Erer Valley, including Erer ‘*Guda*’ and Erer ‘*Xiqa*’ Valleys, had the densest vegetation stand in the entire sanctuary (Stephenson, 1976). Since the Erer Valley is a borderline between the eastern Hararghe highlands to the west and the Ogaden lowlands to the south and east, conservation of such an ecosystem can prevent the current rapid desertification process in the area. Moreover, it supports the Babile Elephant Sanctuary, which is the natural home to highly endangered elephant sub-species known as *L. africana africana* (Ishida *et al*., 2011).

The objective of this study was to analyse the overall biodiversity potential, existing challenges, and opportunities for ecotourism and benefit sharing in the Babile Elephant Sanctuary. The study was aimed at elucidating the current status of biodiversity in the Babile Elephant Sanctuary and producing baseline information for its future development and conservation.

2. MATERIALS AND METHODS

2.1. Study Area

Babile Elephant Sanctuary, in the eastern lowlands of Ethiopia, is part of the Somali-Masai centre of endemism. The underlying rocks are mainly marine in origin and soils are characterized by xerosols and yermosols, which are indicative of aridity. The sanctuary is situated at about 560 km from Addis Ababa, in Oromia and Somali Regional States. The sanctuary lies between 08°22'30"-09°00'30" N latitude and 42°01'10"-43°05'50" E longitude, and the elevation ranges between 850 m and 1785 metres above sea level. The largest and currently the basic vegetation zone in the sanctuary is the Erer Valley. Four drainage river valleys (Fafem, Daketa, Erer, and Gobele) rise from Garamuleta-Gursum highlands and extend southwards through the sanctuary to join Wabi Shebelle River Basin (Figure 1). The mean annual temperature is about 19.6^{0}C, while the mean annual rainfall is 702.9 mm year^{-1}. Rainfall is bimodal, occurring from March to April (short rainy season) and June to September (long rainy season).

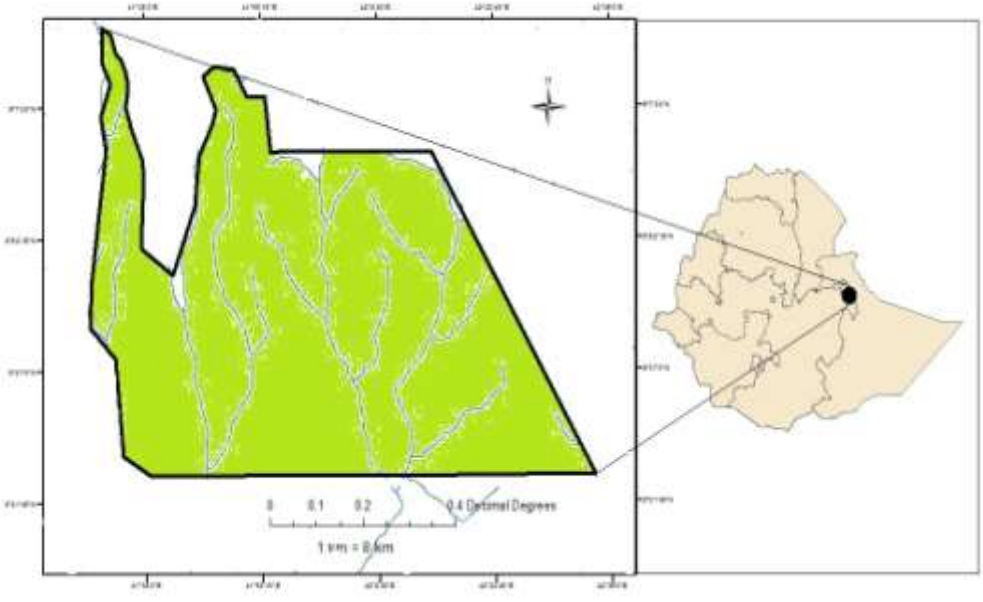

Figure 1. Map of the Babile Elephant Sanctuary (Sintayehu W. Dejene, 2014).

2.2. Faunal Diversity

The varied species that the Sanctuary holds include the African elephant (*Loxodonta africana orleansi*), Lion (*Panthera leo)*, Leopard (*Panthera pardus)*, Menelik's bushbuck *(Tragelaphus scriptus meneliki)*, Black and white colobus monkey (*Colobus guereza*), Bush pig (*Potamochoerus porcus*), Hamadryas baboon (*Papio*

hamadryas), Aardvark (*Orycteropus afer*), Lesser kudu (*Tragelaphus imberbis*), Greater kudu (*Tragelaphus strepsiceros*), Oribi (*Ourebia ourebi*), Salt's dik-dik (*Madoqua saltiana*), Common bushbuck and Spotted hyena (*Crocuta crocuta*). Salt's dik-dik was the most numerous of these (Barnest *et al*., 1999).

The area is renowned for hosting species of particular touristic interests like the African elephant, Black-maned lion, Leopard, Hamadryas baboon and Menelik's bushbuck (an endemic mammal in the Sanctuary) (Yirmed *et al*., 2006)). These animals are found mainly in the valleys and escarpments.

2.3. Data Collection

2.3.1. Vegetation data

Several and continuous vegetation data collections were carried out from September 2006 up to June 2010. Stratified sampling design was used as described by Krebs (1989) due to the different formation types prevalent in the study area. Twelve representative sites were selected by visual observation on the basis of homogeneity in floristic composition. A total of 75 sample plots were established. The size of the major plots for tree species was 20 m x 20 m, as recommended by Kent and Coker (1992). In each sample plot, all tree species with diameter at breast height (DBH) $\geq$ 2.5 cm and height $\geq$ 1.5 m were recorded and their cover estimated following the method of Mueller-Dombois and Ellenberg (1974). Within the 400 m^2, five sub-plots of 5 m x 5 m were set up, four at each corner and one at the centre, to collect data on shrubs and climbers and the mean value of these five subplots were used in the analysis. Within each 25 m^2 sub-plots, five 1 m x 1 m sub-plot was used to collect data on the species diversity and richness of herb and grass species including estimate of their percentage cover.

Plant species were recorded and voucher specimens of plant species were collected and deposited at the National Herbarium (ETH), Addis Ababa University and herbarium of Haramaya University. The nomenclature of plant names in this study follows the published volumes of Flora of Ethiopia and Eritrea (Hedberg & Edwards, 1989, 1995; Edwards *et al.*, 1995, 1997, 2000; Hedberg *et al*., 2006), and by comparing with authentic specimens at the Herbaria of these two Universities.

2.3.2. Elephant Population data collection

Population count - Data were collected seasonally on 10 days per month in both the dry (December to early March) and rainy (mid March to April and June to September) seasons (Norton-Griffiths, 1978). Surveys were made both by vehicle and on foot. Long term monitoring of elephant births and mortality rates, and

population structure were assessed from data on population dynamics over an extended period of time (Douglas-Hamilton, 1972; Moss, 1988, 2001). Information from local people was used to supplement information on observed elephants. A systematic aerial total count of elephants was conducted in April 2006 following the method described by Norton-Griffiths (1978).

2.3.3. Ethnobotanical data

Ethnobotanical data were collected using Participatory Rural Appraisal (PRA) technique as recommended by Martin (1995). Twenty sampling sites were identified from the sanctuary where settled farmers and trans-human pastoralists are found. Basic information about the wild edible plant species including their local names, uses, parts used and method of preparation were collected. Basic information about traditional medicinal plants species used for treating illnesses of humans and livestock including their local names, type of diseases treated or controlled, part used, method of preparation, part administered, dosage used, and major drawbacks were collected. Information was collected from 90 informants (65 male and 25 female) where 15 are key informants (local healers) selected with the assistance of clan leaders, peasant association leaders, and local communities. Some household's members from each village were taken randomly and appropriate numbers of informants were selected. The selection of key informant was done using the systematic sampling method and other informants by random sampling method. The informants were grouped into three age groups, i.e., 20-35, 35-50 and above 50. Semi-structured questionnaires and interview was administered in the local languages (Oromo and Somali languages). In addition, observations, group discussions, and guided field walks with key informants were employed. The extent of external pressure on the sanctuary was assessed following a 5-point arbitrary scale of disturbance with a particular focus on agricultural activities, human settlement, logging, firewood collection, charcoal making, livestock browsing, fire, and honey production. The scores 5 for the highest treat, 4 for high treat, 3 for moderate traet, 2 for less treat, and 1 for the least treat, were used. Photographs and tape recorder were used to document information from the informants as well as the number and types (age categories and sex) of elephants killed in Gobelle and Erer valleys along with the condition of tusks of the slain elephants (removed and found).

2.4. Data Analysis

Plant community types were analyzed using the program TWINSPAN (Hill *et al*., 1975; Hill, 1994). Species richness, evenness (range between 0 and 1) and Shannon-Weiner Diversity Index (that range between 1 and 3.5) were analyzed using Biodiversity professional soft ware program version 2 (Niel, 1997). Basal area (BA) is the cross-sectional area of tree stems at diameter at breast height. Data collected from interviews and direct observations on elephant population and death were

coded, computerized, and analyzed using the Statistical Package, SPSS v.16 (SPSS Inc., Chicago).

Ethnobotanical data were analyzed using both qualitative and quantitative methods (Martin, 1995: Cotton, 1996). SPSS computer programme version 16.0 was used. Simple preference ranking was used. In this analysis method, each informant was involved in thinking of some items (in this case 7) and rank them based on a given criterion, according to their personal preference or perceived degree of importance in the community. The most important or preferred items are assigned with the highest number (in this case 7 is the highest for food plants), while the least preferred or important item was given the lowest number which is "1".

Direct matrix ranking was also used for identification of major plants used by the local community. Direct matrix ranking involves asking an informant to order given items according to several criteria or attributes, one at a time. For each attribute, the most preferred item was assigned with the highest number, depending on the number of items being compared (in this case 10 items), and the least preferred one with the least number, which is "1" (Martin, 1995: Cotton, 1996). Then the informants were asked to rate their preferences and the overall number of an item chosen by each informant was added to give the preference rank of the given item (Martin, 1995: Cotton, 1996).

3. RESULTS AND DISCUSSION

3.1. Floristic Diversity

A total of 237 plant species in 155 genera and 57 families were identified (Appendix 1). Fabaceae had 36 (15.1 percent) species, Poaceae had 19 (8.0 percent) species, Asteraceae had 15 (6.3 percent) species, Acanthaceae had 14 (5.9 percent) species, Tiliaceae had 12 (5.0 percent) species, Euphorbiaceae had 10 (4.2 percent) species, Malvaceae had 10 (4.2 percent) species, Lamiaceae had 11 (4.64 percent) species, Convolvulaceae had 9 (3.8 percent) species, Asclepiadaceae had 8 (3.4 percent) species; Amaranthaceae, Boraginaceae, and Capparidaceae each has 6 species (each 2.5 percent); Rubiaceae, Sapindaceae and Solanaceae has each 4 species (each 1.7 percent); Burseraceae, Anacardiaceae, and Sterculiaceae has each 3 species (each 1.3 percent), 18 families have 2 species each (account 15.2 percent) and 22 families are represented by only 1 species each (account 9.2 percent). From the total plant species 102 (42.9 percent) are herbs, 58 (24.8 percent) shrubs, 32 (13.4 percent) trees, 20(8.4 percent) grasses, 17 (7.1 percent) climbers, 5(2.1 percent) shrub/trees, 2 (0.8 percent) ferns and 1 (0.4 percent) is epiphyte.

The overall species richness of a given vegetation type can give a general impression of their diversity (Tadesse, 2003). In this regard, the species richness in the Erer

valley of Babile Elephant Sanctuary was higher than the nearby valley, Daketa valley, which was reported to have 202 species in 54 families by Teketay (1995) and Nechsar National Park where 199 plant species in 42 families were reported by Andargie (2001).

3.2. Plant Community Types

A total of six plant communities were identified and named after one or two of the dominant species and/or characteristic species, which occur in each group using the relative magnitude of mean cover abundance. These are: I. *Tamarindus indica*; II. *Acacia robusta*; III. *Acacia seyal - Balanites aegyptiaca*; IV. *Acacia senegal - Acalypha fruticosa;* V. *Terminalia brownii - Boswellia neglecta* and VI. *Acacia bussie - Grewia tenax* community type. Each of these community types are source of plant species used as wild edible, medicinal,gum and resin, perfume, Detergents, etc.

3.3. Shannon Diversity Index, Species Richness and Evenness

The overall plant diversity (Shannon Diversity index) and evenness was 3.55 and 0.72, respectively. Species richness ranged from 31 up to 79 where the least was from community 2 and highest from community 3. Community 2 had the least species evenness value (0.59) whereas community 5 had the highest (0.83). The Shannon-Weiner index ranged from 2.10 up to 3.44 where the least was for community 2 and the highest for community 3 (Table 1).

Table 1. Species richness, evenness, and diversity in the six plant community types.

Community	Richness (N)	Evenness (E)	Diversity (H')	H'Max
1	31	0.70	2.44	3.43
2	34	0.59	2.10	3.52
3	79	0.78	3.44	4.36
4	71	0.72	3.10	4.26
5	59	0.83	3.39	4.10
6	58	0.80	3.25	4.00

The overall species diversity value showed a high value which indicated a high diversity in the study area. However, the evenness was less. Lower evenness indicates the dominance of a few species in the area (Feyera, 2006). Accordingly, species of *Opuntia stricta, O. ficus-indica, Acalypha fruticosa, Acacia senegal, A. mellifera* and *A. brevispica* are highly dominant. Diversity and evenness of species in plant communities is used to interpret the relative variation of the community indices and explain the underlying reasons for the differences among communities.

3.4. Floristic Similarity

Results from Sorensen's similarity coefficient analysis indicated that communities 1 and 2 (58 percent), 3 and 4 (57 percent), and 5 and 6 (54 percent) showed high similarity coefficient. Less similarity coefficient was obtained between communities 1 and 5 (15 percent), 1 and 6 (18 percent), 2 and 5 (23 percent), 2 and 6 (25 percent), and 1 and 4 (29 percent) (Table 2).

Table 2**.** Sorensen's similarity coefficient in species composition between the six community types.

Community	**1**	**2**	**3**	**4**	**5**	**6**
1	-					
2	0.58	-				
3	0.30	0.32	-			
4	0.29	0.31	0.57	-		
5	0.15	0.23	0.43	0.42	-	
6	**0.18**	**0.25**	**0.41**	**0.40**	**0.54**	**-**

3.5. Woody Species Density

The total density of woody species was 19,991 individuals ha^{-1}, where the total density of trees was 394 individuals ha^{-1} (2.7 percent of the total density), shrubs 17,460 individuals ha^{-1} (86.3 percent) and climbers 2,137 individuals ha^{-1} (11 percent). The densities of six species: *Opuntia stricta* (26.5 percent), *Acacia senegal* (9.77 percent), *A. brevispica* (8.76 percent), *Euphorbia burgeri* (6.44 percent), *Acacia mellifera* (4.94 percent), and *Grewia tenax* (4.19 percent) constitute about 60.6 percent of the total density of woody species. The remaining 61 species constituted 39.4 percent of the total density. The mean density of trees, shrubs and climbers was enumerated (Table 3).

Table 3. The mean density of trees, shrubs, and climbers in the study area.

Habit	**Mean ± S.E. individuals ha^{-1}**	**Minimum individuals ha^{-1}**	**Maximum individuals ha^{-1}**	**Number of species**
Trees	32 ± 9.96	3	167	22
Shrubs	619 ± 203.3	64	3843	36
Climbers	315 ± 103.4	53	835	9
Total	385 ± 114.2	3	3843	67

In each community, density was calculated for woody species. Community 4 is the highest in terms of shrubs density (14579 individuals ha^{-1}) and community 1 is the lowest (1360 individuals ha^{-1}). Inversely, community 4 was the lowest in terms of

tree density (198 individuals ha^{-1}) and community 1 was the highest (550 individuals ha^{-1}) (Figure 2).

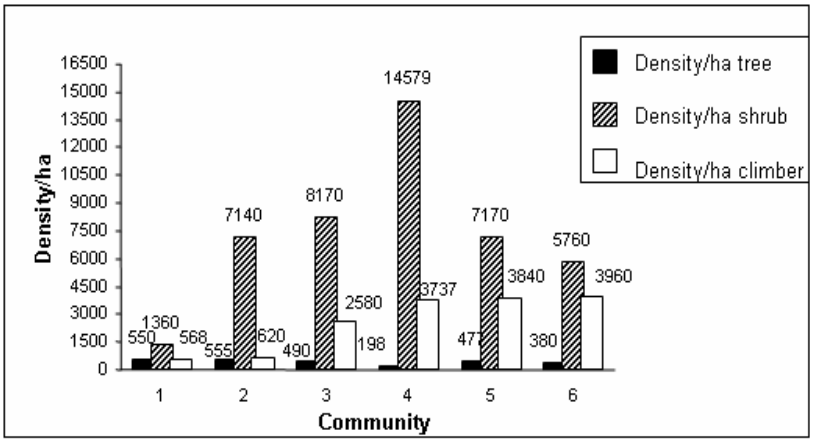

Figure 2. Density ha^{-1} of trees, shrubs and climbers in the six community types

The bushlands and thicket (community 4) were dominated by small-sized woody species that contributed to the highest density of individuals per hectare. The least density of the most important tree species like *Tamarindus indica, Balanites aegyptiaca, Berchemia discolor, Acacia albida, Acacia etbaica, Sterculia africana, Salvadora perisca, Commiphora erythraea, Acacia nilotica* and *Combretum molle* could be due to selective exploitation for their multipurpose value by the local communities. However, the highest densities of small-sized shrubs and climbers such as *Opuntia stricta, Acalypha fruticosa, Acacia brevispica* and *Acaciasenegal* could be due to the less palatable or unpalatable nature of these plant species to both livestock and resident elephants in the sanctuary.

3.6. Wild Edible Plants Species Potential

A total of 32 plant species that belong to 19 genera and 15 families are used as food in the study area. The family Fabaceae comprises of the largest number of species (8 plant species), followed by Tiliaceae (7 plant species). Apocynaceae, Balanitaceae, Boraginaceae and Rhaminaceae consists 2 species each. The rest families contain only 1 species each. Out of these 12 (37.5 percent) species are trees, 3 (9.4 percent) are shrubs/trees, 15 (46.9 percent) are shrubs, 1 (3.1 percent) is a climber and 1 (3.1 percent) is herb (Table 2). From the part used for food, fruits score the highest i.e. 77.4 percent and gum the second 13 percent.

Out of these, 20 species were documented by Bayafers Tamene (2000) and 12 species by Gemedo Dalle (2004). About 13 percent of the total plants documented in Borena Lowlands were edible (Gemedo Dalle *et al*., 2005). Zemede Asfaw and Mesfin Tadesse (2001) estimated that about 8 percent of the higher plant species of

Ethiopia are edible. The relative high percentage of wild edible plants in the study area may be due to the more intensive utilization of plants by the local communities in this semi-arid region as compared to inhabitants in the humid highlands. Cattle herders are more knowledgeable in identifying and using these wild edible plants. Even most of the young cattle herders (both male and female) spend the whole day in the forest tending their cattle and using these edible plants like *Opuntia ficus-indica, Tamarindus indica, Berchemia discolor* and *Balanites aegyptiaca* with milk. However, according to most informants as compared to the past ten or more years, this days most of the wild edible plants are not easily accessible for the local community. Similarly, Bayafers Tamene (2000) stated that many wild food plant species are not easily accessible nowadays for the local communities due to deforestation. Those plant species, which are drastically declining in abundance from the study area include *Tamarindus indica, Balanites aegyptiaca, Oncoba spinosa, Ziziphus spina-christi, Berchemia discolor* and *Salvadora perisca.*

Plate 1. The fruits of *Opuntia ficus-indica (top left), Balanites aegyptiaca (top right), Oncoba spinosa (bottom right),* and *Ziziphus spina-christi (bottom left)*

The females are collecting the fruits of *Opuntia ficus-indica, Tamarindus indica* and *Oncoba spinosa* for sale in the nearest local market places such as Bisidimo, Babile, Erer towns and get reasonable income. In the different part of the country, the fruits of *Opuntia ficus indica, Tamarindus indica* and *Oncoba spinosa* are collected and sold in the local market (Zemede Assfaw, 1997; Bayafers Tamene, 2000). In the study area the fruits of *O. ficus indica* ripen two time a year i.e., after the long rainy season and the short rainy season. Interestingly, the plant gives more fruits after the short rainy season, and famished local communities may use the fruits as asource of

food. In addition, plant species like *Acacia senegal, Acacia mellifera and Acacia seyal* are used during famine. The part used is the gum which is tasteless but satisfy an immediate need of food for any one starved. As stated by Zemede Asfaw (1997), edible wild plants often help to prevent starvation amine.

The responsdents noted that it is an enjoyable task to collect the ripen small fruits of *Carissa spinarum, Euclea racemosa ssp. schimperi, Grewia bicolor* and *Rhus natalensis* by children and young cattle herders and use it as a snack as well as to bring home for other family members. Obviously, this can be used as a supplementary food and may fill the gap in the nutrition of the local community that depends predominantly on limited cultivated crops like many part of the country. As stated by Zemede Asfaw and Mesfin Tadesse (2001), the wild edible plants are reserve foods that fill the food deficit gap and also may have future potential as food crops if domesticated.

3.7. Medicinal Plants for Livestock

A total of 20 plant species that belong to 19 genera and 14 families were recorded as having ethnoveterinary use. Out of these, 12 species were documented by Debela Hunde *et al.,* (2004). Still in the study area, many other medicinal plants were available to use for treating livestock illnesses. Shrubs accounted for 45 percent, herbs 25 percent, trees 20 percent, and climbers 10 percent. Like the human medicinal plants, trees and shrubs accounted for more than 60 percent of the ethnoveterinary medicines for the same reason.

For the plant parts used, the leaf constitutes 57.7 percent, root & fruit equal proportion i.e. 19.2 percent each and sap 3.8 percent. Therefore, harvesting medicinal plants is less destructive on the natural vegetation because the most frequently used part is the leaf. About 14 different health problems confronting livestock were documented. The most common disease of livestock in the study area is wounds/dermal infections in which 8 plant species are used for the treatment followed by infected eye which is treated using four species and lymphatic swelling treated using two species. Plant species used to treat wounds/dermal infections are *Abutilon fruticosum, Aloe pirottae Boscia minimifolia, Cissus rotundifolia, Commicarpus plumbagineus, Cucumis dipsaceus, Dodonaea angustifilia,* and *Ozoroa insignis*. The pastoralists are more knowledgeable than the settled agriculturalist in identifying medicinal plant species for treating livestock illnesses as well as in the methods of preparation and treatment.

3.8. Population Status of Elephants

The BES hosts about 324 (direct count) and 400 (estimated) African Elephants (*Loxodonta africana africana*) (Yirmed, 2007; Ishida *et al*., 2011).

3.9. Major Threats/Challenges

As a result of mass influx, the home-range of elephants of Babile has shrunk by about 65.5 percent since 1976 (Yirmed Demeke *et al.,* 2006). Currently, it is estimated that only about 34.5 percent of the original habitat is left for the existing population of African elephants in BES. In the sanctuary every year there is an increment in human settlement and in this study a total of 40 villages (permanent & temporary) were encountered with in the current boundary of the sanctuary. In addition, charcoal making, firewood collection, overgrazing, deliberate fire to clear for agriculture, and selective tree cutting for construction are the main threats to the sanctuary. Agriculture scored 5 which is the major threat to the sanctuary; human settlement and overgrazing scored 4; charcoal making and tree cutting scored 3; invasive species like *Lantana camara* and *Parthenium hystrophorus* scored 2; and medicinal plants collection scored 1, which are the second, third, fourth and fifth (the least) threats to the sanctuary, respectively. The underlying root cause of deforestation and environmental degradation in the study area is an ever-increasing human population that caused an influx of people from both highlands and lowlands of the surrounding area. As stated by Feyera Senbeta and Fekadu Tefera (2001), protected areas have hardly been managed in Ethiopia due to population pressure.

The destruction of the vegetation could be one of the reasons for the Erer River to have changed from perennial in the past to seasonal at present. This was forecasted by Demel Teketay (1996) who stated that, the rivers Erer, Daketa and Gobelle would dry up if vegetation of the area could not spared. The current condition of all the rivers flowing into the sanctuary is very bad. The rivers dry up soon after the rains (were perennial before). Undoubtedly, the loss of vegetation cover has contributed to this penomenon. This in turn will reduce drinking water supplies and disrupt irrigation schemes which are so vital in the lowlands, including the Ogaden area since these rivers are tributaries of Wabishebele River.

3.10. Mass Killing of Elephants in the 2011-2012

In the 2011 and 2012, unexpectedly higher numbers of elephants were killed the Babile Elephant Sanctuary (BES). In this study, a total of 32 dead elephants were counted in Erer and Gobele Valleys. Some reports showed that the killing exceededforty-two elephants by referring to the report of the Ethiopian Wildlife Conservation and Development Authority (EWCA). This is the highest mass-killing

of African elephants ever recorded in Ethiopia. Out of the 32 dead elephants recorded in this study, male elephants accounts for 11, adults accounted for 21, and the tusks of 21 elephants was already removed by the time the wardens reached the areas of incidences (Figure 3-5)

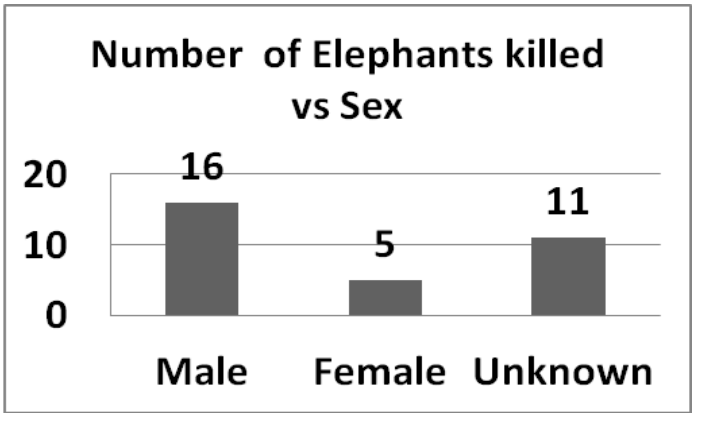

Figure 2. The sex categories of killed elephants

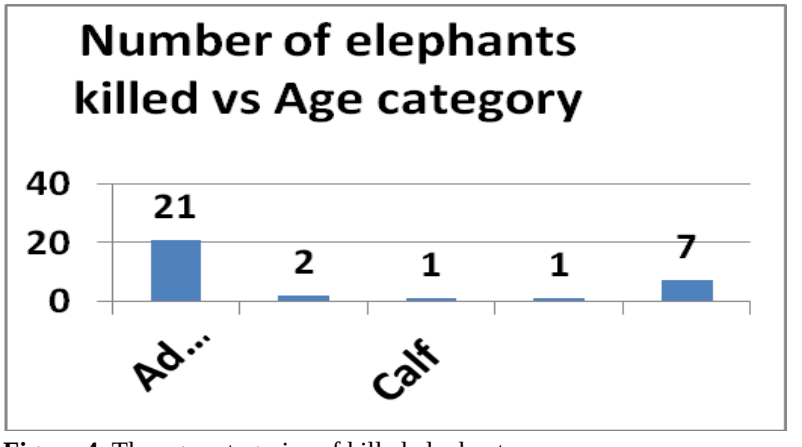

Figure 4. The age categories of killed elephants

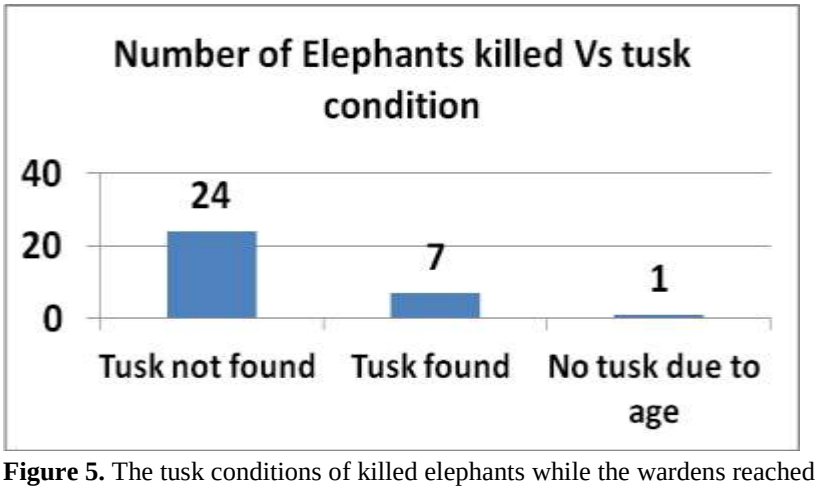

Figure 5. The tusk conditions of killed elephants while the wardens reached to the areas


Plate 2. Some of elephants found killed in the BES

In general, the overall analysis showed that the 2011-12 mass killing was linked to h elephant poaching and human-elephant conflict.

3.11. Opportunities in the BES

Due to the accessibility of this particular habitat, it can be used as an outdoor classroom and research site for the nearby institutions of hiher eraning such as Haramaya, Dire Dawa, and Jijiga Universities. Moreover, the area is able to attract eco-tourism due to its biodiversity potential and topographic features (like, the "Rock Valley" of Daketa) and historical places (ancient historic city of Harar, prison house for Prince Lij Eyasu at Gurawa town in Gara Muleta, etc). This can generate income that can be used to the benefits of the sanctuary and the local community if better management is planned for the sanctuary. There is also GPS satellite tracking of elephants and ecotourism development in the area which should be encouraged.

4. CONCLUSION

Babile Elephant Sanctuary is a reserve of natural wealth. However, currently the natural vegetation of the sanctuary is being exploited and abused destructively. The underlying root cause of deforestation and environmental degradation in the study area is an ever-increasing human population that has caused an influx of people from both highland and lowlands of the surrounding area. Management action should be developed to reverse or at least to stabilize the present trend in the sanctuary. This could be achieved by appropriate management and plans that include restoration and rehabilitation measures. There is also a need for domestication of some of the multi-purpose plant species as well as sustainable harvesting of the wild edible and medicinal plant species. Moreover, research activities covering the nutrient contents of the edible plant species will optimize their value for conservation of the natural stand in general and the target plant species in particular. The study area is also home to a number of plant specieswhich the local communities use as sources of for

fuel, construction, household utilities, market value, flavouring, cleansing, farm tools, honey collection, and other traditional herbs or medicine.

The BES which is an important sanctuary for elephants is not protected with legislation. The destructive incidents in the sanctuary are often under-reported or not reported at all. Therfore, awareness creation and management plan that should carefully consider possibilities of sustainable utilization of the area by the local people should be considered. As stated by Feyera Senbeta and Demel Teketay (2003), lack of integration of the local people living around the conservation areas in the conservation efforts, and absence of law enforcement systems are the major constraints to the overall conservation efforts in Ethiopia.

With the danger posed by climate change and rapid desertification there is a need for conservation of this natural vegetation that can be used as a buffer zone between the Ogaden desert and the mid to high altitude areas of eastern Hararghe. In general, as part of the remaining vegetation cover in the Babile Elephant Sanctuary and as part of the habitat of the only living representative individuals of the elephant (*Loxodonta africana africana*), which is a highly endangered and declining animal specis, as well as a variety of other animals, the BES should be afforded the highest protection possible as a matter of urgency before it is too late.

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MOLECULAR MARKERS: A REVIEW ON TOOLS FOR CHARACTERIZATION AND CONSERVATION OF WILD ANIMALS

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ABSTRACT

Simultaneous presence of various animal genetic resources in a given region or country is known as animal genetic diversity. Africa is rich in wild animal resources which is a major tourist attraction. Wildlife diversity (WLD) is an important asset for developing countries like Ethiopia; it can play an important role in uplifting the country's economy. Hence, characterization, conservation, and maintenance of WLD should be a priority. Preservation of the ecological niche is the most important challenge that we faced. Global climate change has resulted in the depletion of wildlife habitat and responsible for extinction of a number of wildlife species. Characterization helps us to distinguish and generate information for conservation of genetic resources, strains, species, and populations. Characterization can be based on morphological (phenotypical), biochemical (protein level), and molecular marker based (DNA level). The molecular studies based on mitochondrial DNA (mtDNA) and nuclear DNA are more popular as they save time, minimize long term investigation cost and best in information generation. Moreover, they are the most accurate method of characterization of a given populations, which help to develop appropriate conservation strategies. This review addressed the various molecular markers through Restriction Fragment Length Polymorphism (RFLP), Random Amplification of Polymorphic DNA (RAPD), Amplified Fragment Length Polymorphism (AFLP), Microsatellite (short tandem repeats), and Single Nucleotide Polymorphisms (SNPs) that are used in the characterization of wildlife.

Keywords: Animal genetic resources, DNA polymorphism, populations, species, wildlife diversity

1. INTRODUCTION

Genetic diversity refers to an intra (within) and inter (among) specific variations in genetic materials. The presence of various animal genetic resources in a given region or country is known as animal genetic diversity (Templeton, 1993). Animal genetic diversity offers multiple opportunities for development and improving human well-being. Thus, its conservation and sustainable use are of critical importance.

Ethiopia's geographical location and physical feature have resulted in the diversification of wildlife (Shibru, 1995). The large altitudinal and latitudinal ranges make Ethiopia an ecologically diverse country and home of several unique habitats. Out of the 277 mammalian species known to occur in the country, 31 are endemic

(Hillman, 1991). Many of Ethiopia's protected areas exist on records only, while others have declined in size or quality (Schloeder and Jacobs, 1993). On the other hand, tourism sector in Ethiopia is serving as a major source of foreign exchange earnings in the country claiming an average of 23.34 percent from 1995 to 2007 (World Bank, 2007). Ethiopia's great potential for tourism development is still unexploited. Therefore, conservation, characterization, and maintenance of wild animals should be a priority.

Loss of biodiversity is among the greatest problems facing the world today (Frankham *et al.*, 2002). Studies on the genetic resource of a population give a comprehensive overview of the essential concepts, and tools needed to understand how genetic information could be used to conserve species threatened with extinction, and managing ecologically and commercially important species (Anagaw, 2008). A number of species have already become extinct, and the populations of many others have remained at risk of extinction. In this respect, new molecular techniques are increasingly useful in the conservation of genetic diversity (Anagaw, 2008).

With the application of molecular techniques, studies on genetic diversity have become a distinct discipline. Undoubtedly, many conservation geneticists apply the genetic markers to make decisions on conservation of endangered wild animals. Identification and characterization are important steps towards designing sustainable conservation strategies of wild animals. Various methods have been developed over the years for charcaterizing the genetic diversity of wild animals and these methods are largely categorized into phenotypical, biochemical, and molecular markers.

Therefore, this review addresses the various molecular markers through Restriction Fragment Length Polymorphism (RFLP), Random Amplification of Polymorphic DNA (RAPD), Amplified Fragment Length Polymorphism (AFLP), Microsatellite (short tandem repeats), and Single Nucleotide Polymorphisms (SNPs) that are used in the characterization of wildlife genetic diversity.

2. MOLECULAR CHARACTERIZATION

The molecular studies based on mitochondrial DNA (mtDNA) and nuclear DNA are more popular as they save time, minimize long term investigation cost and are the best for generating information. Examining variation of appropriate genetic markers in relation with demographic and geographic parameters is used to obtain information about population and evolutionary processes (Sunnucks, 2000). Genetic markers are specific chromosomal regions that vary in the DNA sequence from a single base to longer sequence changes, such as micro and mini satellites, allow detecting genetic differences among individuals in a population. The advent of genetic tools such as

restriction enzymes and methodologies of polymerase chain reaction made the use of molecular markers easy to use and popular (Mullis *et al.*, 1986).

Molecular (DNA) markers are chosen over biochemical and phenotypical markers to characterize the genetic diversity of wild animals because they are found in a relative abundance, independent of growth and physiological state and provide a more powerful source of genetic polymorphism (Garcia, 1998; Clark *et al*., 1999; Karl and Bowen, 1999). Molecular markers can be grouped into two major classes: mtDNA markers (D-loop region, cytochrome b gene, 12S rDNA and 16S rDNA genes) and nuclear DNA markers (RFLP, RAPD, AFLP, Micro satellite, and SNPs) (Arif and Khan, 2009).

2.1. Mitochondrial DNA (mtDNA) Markers

Mitochondria are the only source of mammalian cytoplasmic genetic information. Mammalian mitochondrial DNA is a small circular DNA with a size of 15-25 kb (Wallace, 1986). Each mammalian mitochondrion DNA contains 37 genes, 13 protein-coding genes including cytochrome b, 2 ribosomal RNA (rRNA) genes, and 22 transfer RNA (tRNA) genes (Gray, 1989). Each mitochondrial DNA molecule contains a non-coding region called displacement loop (D loop) that regulates initiation of replication and transcription (Clayton, 1991). This region stretches around 1kb and it is amenable to PCR amplification before sequencing to find out molecular variability. The sequence of 12S rRNA is highly conserved and usually used in taxonomy for high category level (phyla and sub-phyla) whereas the 16S rRNA is used for mid category classification (Arif and Khan, 2009). A number of features make mtDNA a useful genetic marker in population genetics studies and phylogenetics; these include maternal inheritance, lack of recombination and fast rate of evolution (Avise, 1991). The rate of evolution of the mtDNA is different for different parts of the molecule. The rRNA genes evolve approximately 100-fold quicker than their nuclear counterparts and the D-loop evolves 5-times faster than the rest of the mtDNA (Avise, 1991). Various studies have indicated the importance of mtDNA in revealing phylogenetics of wild animal's genetic diversity (Dianne *et al*., 1995; Johnson *et al*., 2004; Malisa *et al*., 2006; Zhang *et al*., 2006).

2.2. Nuclear DNA Markers

2.2.1. Restriction Fragment Length Polymorphism (RFLP)

Restriction Fragment Length Polymorphism (RFLP) is the variation(s) in the length of DNA fragments produced by specific restriction enzymes from genomic DNAs of two or more individuals of a species (Kahl, 2001). RFLP analysis was one of the first techniques to be widely used for detection of variation at DNA level. The technique

consists of isolation of DNA, digestion of the DNA with restriction enzyme, separation of the DNA fragments with gel electrophoresis according to their size followed by hybridization using fluorescently or radioactively labelled probes (Southern, 1975; Figure 1). Botstein *et al.* (1980) stated that the difference among individuals in the length of restriction fragments is largely because of the loss of a cleavage site or formation of a new one. Insertion or deletion of certain DNA sequence can also alter the size of restriction fragments. RFLP can be used to study genetic distance, population variation, gene flow, effective population size, and analyses of parentage and relatedness. One of the advantages of RFLP is giving reproducible results within and among laboratories and produces co-dominant markers.

Polymorphic markers are described as co-dominant or dominant if they can distinguish between homozygotes and hetrozygotes (Collard *et al.*, 2005). However, the drawbacks associated with RFLP analysis are the requirement of relatively high quality and large quantity of DNA (2-10mg), labour intensive and the requirement of probes for detection. The development of PCR based RFLP analysis (PCR-RFLP) has made the technique to be less laborious with relatively small quantity of DNA and possibility of detection without use of probes. Among other DNA based markers, PCR-RFLP has been used in few studies (Malisa *et al*., 2006).

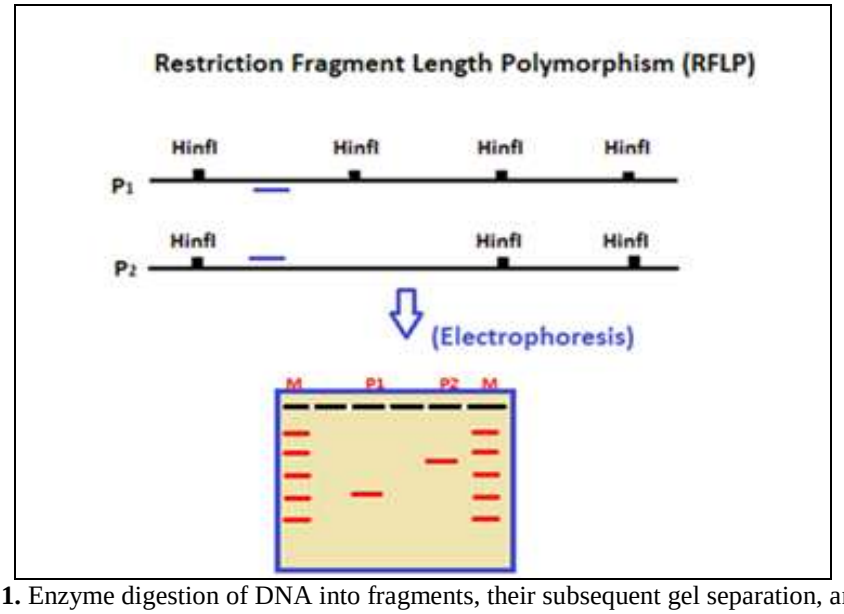

Figure 1. Enzyme digestion of DNA into fragments, their subsequent gel separation, and the detection of allelic variation in two animals from population 1 and 2.

2.2.2. Randomly Amplified Polymorphic DNA (RAPD)

RAPD is a molecular technique first developed by Williams *et al.* (1990), which uses short arbitrary primers (10-12 base pairs) that bind randomly to multiple places in the

genome and subsequently amplify these regions by PCR (Kahl, 2001). The PCR products are then separated using electrophoresis on either agarose or polyacrylamide gel. The presence or absence of bands is used for detecting polymorphism among individuals (Figure 2). RAPD lacks reproducibility within and among laboratories, but it has been used for molecular characterization of the genetic diversity of wild animals because it is cost effective, simple, and quick method as compared to other molecular techniques (Kahl, 2001). Helen *et al*. (2009) reported the existence of high genetic diversity and the occurrence of intense and constant gene flow in red fox (*Vulpes vulpes*) populations using RAPD markers. Padilla *et al*. (2010) used 45 RAPD primers to study genetic diversity of Iberian imperial eagle (*Aquila adalberti*) and found out high heterozygosity in this species. Freitas *et al*. (2007) revealed the importance of RAPD marker for conservation of fish species. Gouin *et al*. (2001) indicated the loss of genetic diversity among 21 Crayfish (*Austropotamobius pallipes*) based on four RAPD primers. Saudi Arabian Oryx (*Oryx leucoryx*) populations were characterized based on 20 RAPD primers and indicated sufficient variability within this populations (Fahim and Al-Otaibi, 2011).

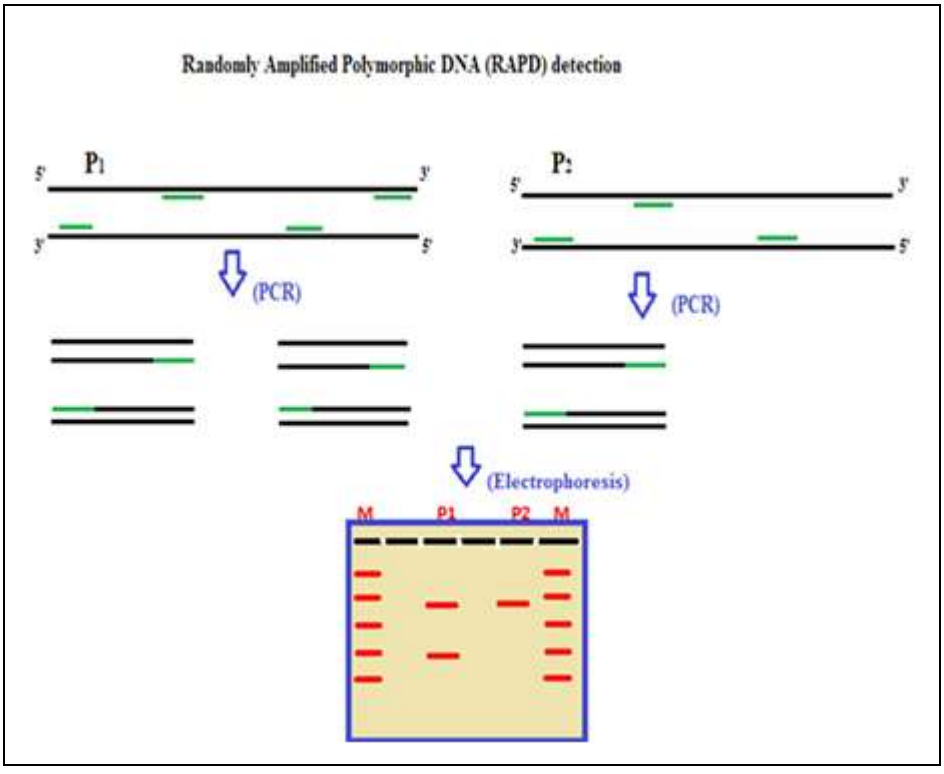

Figure 2. Examples of variation detection between two animals from population 1 and 2 using RAPD.

2.2.3. Amplified Fragment Length Polymorphism (AFLP)

AFLP is a molecular technique that combines restriction based RFLP marker and PCR based RAPD marker (Khal, 2001). The AFLP technique is based on the amplification of subsets of genomic restriction fragments using PCR. DNA is cut with restriction enzymes, and double-stranded adapters are ligated to the ends of the DNA-fragments to generate template DNA for amplification. The sequence of the adapters and the adjacent restriction site serve as primer binding sites for subsequent PCR amplification of the restriction fragments (Vos *et al.*, 1995). The amplified fragments are then separated by electrophoresis and the variations are scored based on presence or absence of bands. The principle of AFLP is indicated below (Figure 3). Even though, it is advantageous in its quick scan and detection of whole genome polymorphisms, highly reproducibility, needs no prior sequence information and probe generation, it is technically expensive, labour intensive and inherited as dominant marker. Studies have revealed the importance of AFLP markers for identification and characterization of species and populations (Zenger *et al*., 2006; Haig *et al*., 2004; Giannasi *et al*., 2001).

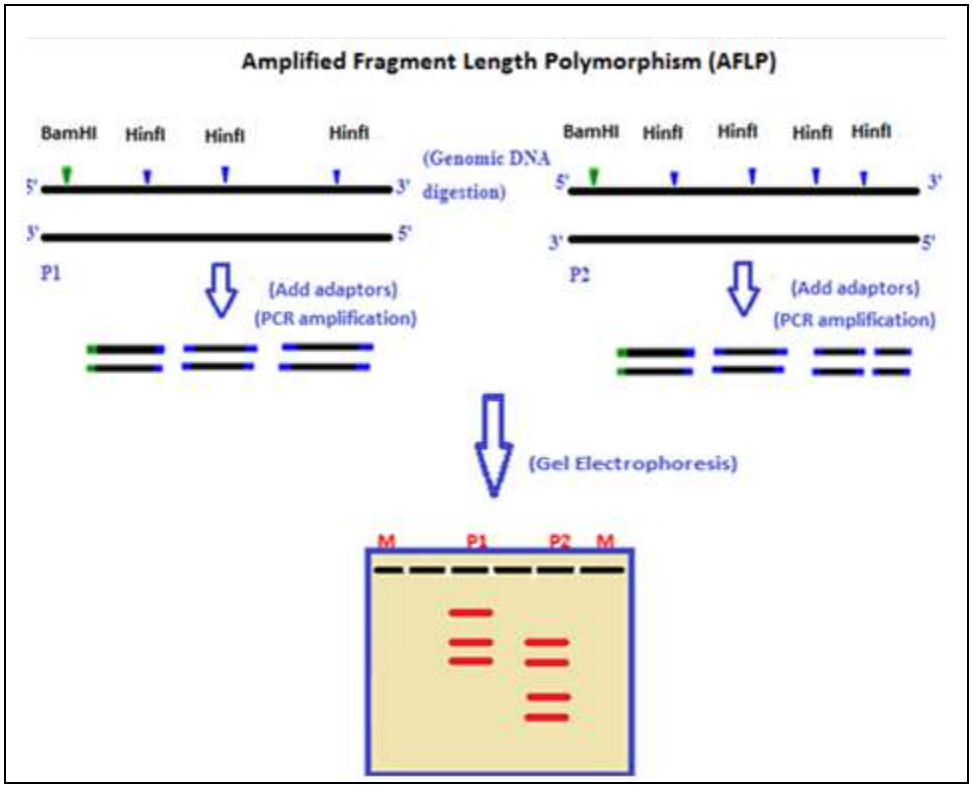

Figure 3. Schematic diagram depicting the variation of two individuals (Population 1 and 2) using Amplified Fragment Length Polymorphism.

2.2.4. Microsatellite Markers

Microsatellite is a sequence of short tandem repeated segments of 1-6 base pairs at a unique physical location in the genome. It is a class of repetitive DNA elements (Tautz and Rentz, 1984; Tautz, 1989). The di-, tri- or tetra-nucleotide repeats are arranged in tandem arrays consisting of 5 – 50 copies, such as $(AT)_{29}$, $(CAC)_{16}$ or $(GACA)_{32}$. Polymorphism among individuals occurs due to variation on the number of repeats (Figure 4). The primary mutational mechanism leading to changes in microsatellite length is DNA polymerase template slippage caused by mismatches between DNA strands while being replicated (Kruglyak *et al*., 1998). During replication of a repetitive region, DNA strands may dissociate and then re-associate incorrectly. Renewed replication in this misaligned state leads to insertion or deletion of repeat units, thus altering allele length.

Several important characters make microsatellites as informative marker to study variation within and among populations. Microsatellites are variable and exhibit a high level of allelic variation, co-dominantly inherited and thus applied to study genetic variability, population structure, and gene flow among populations. Currently, microsatellite markers are found to be suitable molecular markers to study wild animal's genetic diversity. Eblate *et al*. (2011) reported polymorphism of six microsatellite markers in African antelope species. Liukkonen *et al*. (2012) indicated the usefulness of microsatellite markers to differentiate between released and wild partridges in Finland. The purple swamphen (*Porphyrio porphyrio*) was characterized using 10 microsatellite markers (Subrata *et al*., 2012).

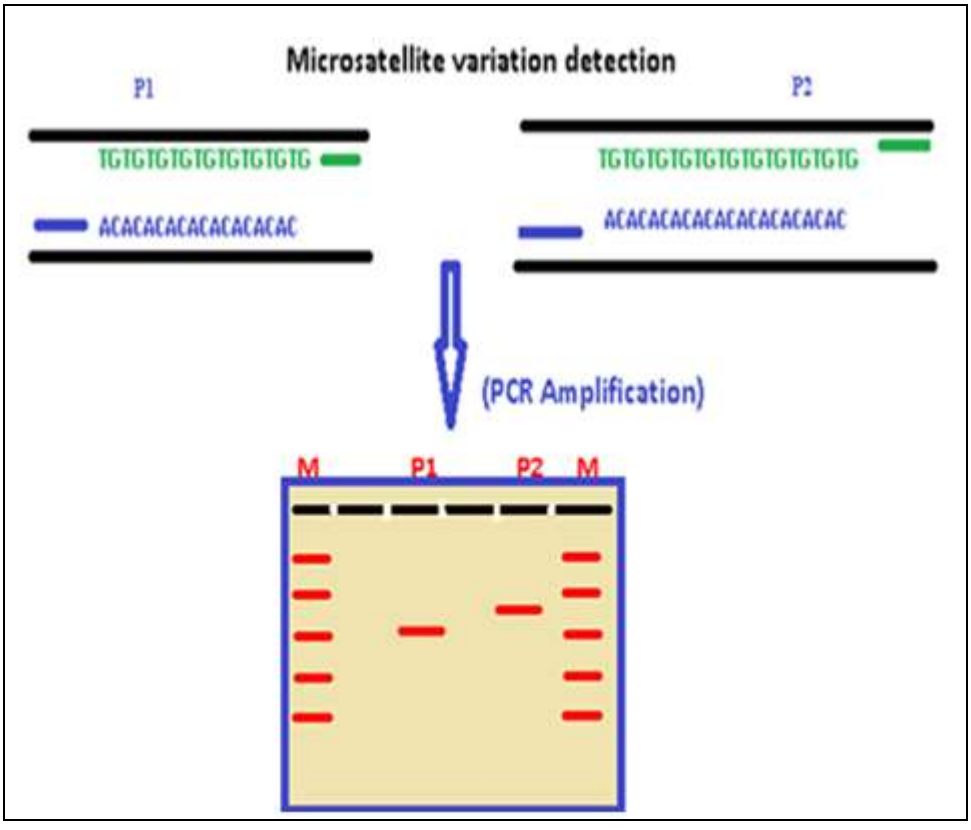

Figure 4. Schematic drawing showing how microsatellite variation (short Population 1 and long Population 2) can be detected using gel electrophoresis after PCR amplification. M: Standard DNA marker, P: population.

2.2.5. Single Nucleotide Polymorphisms (SNPs)

SNPs are variations in a DNA sequence that occur when a single nucleotide in the sequence is altered at least in one percent of the population (Kahl, 2001; Syvanen, 2001). SNPs are the most frequent type of variation found in DNA (Brookes, 1999). They are primarily detected by DNA sequencing, but RFLP and primer extension with allele specific probes are also employed for SNPs analysis (Syvanen, 2001). Variations among individuals using SNPs can also be detected by single strand conformation polymorphism (Ren, 2001; Figure 5) .They are the most abundant molecular marker systems ever known in the genome with high genetic variability (Gupta *et al.*, 2001). They are highly reproducible and very informative. However, they are relatively expensive and require prior knowledge of sequence. A large number of SNPs have already been developed in human but the limited number of SNPs for many species creates a hurdle to their application in population genetic studies (Gupta *et al*, 2001).

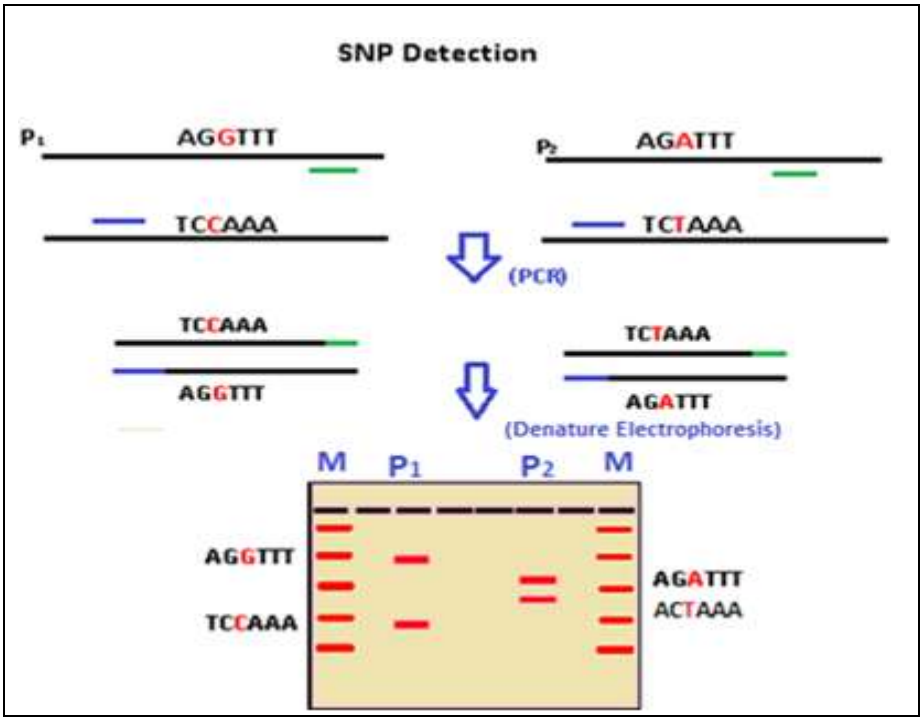

Figure 5. SNP detection by single strand conformation polymorphism in two animals from population 1 and 2.

Finally, using as many markers as possible it can be observed that endangered population or species show lower sequence diversity, which enables to develop breeding programs to reduce unnecessarily mating in order to minimize inbreeding and the loss of genetic diversity.

3. CONCLUSION

Molecular marker study tools are most accurate and more informative than phenotypic and biochemical methods of characterization. Molecular markers are important to know the genetic variability within and among animal populations thereby helping to develop appropriate conservation strategies. The most critical step in conservation genetics analysis is the choice of appropriate molecular marker tools. Inappropriate selection of molecular marker tools will result incorrect decision for animal conservation. Therefore, characterization for conservation and maintenance of WLD has to be done in careful manner. The Ethiopian wildlife conservation strategies need to address and consider molecular marker as a tool for effective conservation of endangered and endemic wildlife species.

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Theme 2

Agro-biodiversity and Food Security

THE ROLE OF HOME GARDENS FOR *IN SITU* CONSERVATION OF AGRO-BIODIVERSITY IN HOLETA TOWN, OROMIA NATIONAL REGIONAL STATE, ETHIOPIA

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ABSTRACT

This study was conducted to assess the role of home gardens for *in situ* conservation of agro-biodiversity in Holeta town. Data were collected from 75 randomly selected home gardens. Ethno-botanical data were collected using home garden observations, semi-structured interviews and market surveys. Preference ranking, direct matrix ranking, paired comparison, and descriptive statistics were used in data analysis. A total of 112 plant species belonging to 93 genera, and 43 families were identified. Out of these, 49 species (43 percent) were herbs, 32 species (29 percent) were trees, and 28 species (25 percent) were shrubs, and (3 percent) species were climbers. Further analysis of the results showed that 70 species were cultivated, 35 were wild while seven species were domesticated. Of the cultivated species, 41.07 percent were food crops and 58.93 percent were non-food crops. Family Fabaceae consisted of the highest number of species (11species), whereas *Ensete ventricosum* was the most frequently occurring species (93.75 percent) in the home gardens of the area. Gardens were managed by both men (47.93 percent) and women (38.41 percent). Medicinal plants accounted for 13 percent of the total plant species, out of which 33.33 percent were nutraceutical plants. Direct matrix analysis showed that *Juniperus procera* was the most important versatile species followed by *Cordia africana*. In conclusion, the study showed that home gardens are *in situ* conservation sites for cultivated, domesticated, and wild species and contribute substantially to household food and nutrition security.

Keywords: Household food security, home gardens, poly-cultural farming, indigenous knowledge.

1. INTRODUCTION

Biodiversity is crucial for survival, health and well-being of humans. It gives greater resilience to ecosystems and organisms. Agro-biodiversity is the most important part of biodiversity for human survival. It involves cultivated and wild plants, domestic and wild animals, insects, forests and fish genetic resources, and microorganisms (Qualset *et al*., 1995). Complex, diversified, and highly traditionally rooted part of

agro-biodiversity conservation and utilization is found in home gardens (Eyzaguirre and Linares, 2004 and Zemede Asfaw, 2004) since it has existed for millennia (Kumar and Nair, 2006).

Home gardens are variously named in the English language as agro forestry home gardens, backyard gardens, farmyard, roof top gardens, and homestead farm gardens (Talukdor *et al*., 2000; Kumar and Nair, 2004). In Ethiopia, a common Amharic vernacular name equivalent to the term home garden is '*Yeguaro-ersha*', and '*Oddo'* in Afaan Oromo which means a piece of land in the backyard of a house (Zemede Asfaw, 2001). Home garden is also known as '*Daddegoyo*'in Keficho (Feleke Woldeyes, 2000), '*Daniio'* and '*Gatte Ouduma'* in Gedeo (Solomom Tamrat, 2010).

A home garden is commonly defined as a land use system involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably livestock within the compounds of individual houses, the whole tree-crop, and animal unit being intensively managed by family labour (Fernandes and Nair, 1986; Soemarwoto, 1987; Christanty, 1990; Kumar and Nair, 2004). The high diversity of species in a home garden plays wide socio-economic and ecological roles in the production of food and other products such as firewood, fodder, spices, medicinal plants, and ornamentals (Christanty, 1985; Marten and Abdoellab, 1988). High species diversity also prevents environmental degradation commonly associated with mono-cultural production systems (Fernandes and Nair, 1990). It also contributes to income generation (Hoogerbuugge and Fresco, 1993) and *in situ* conservation of agro-biodiversity (FAO 2001; Watson and Eyzaguirre, 2002). Generally, home gardens serve as refuge to a number of plant species, particularly those not widely grown in the larger agro-ecosystem (Alexiades, 1996; Eyzaguirre and Linares, 2004).

Ethiopia is one of the eight world's centres of origin and diversity of agricultural products (Vavilov, 1951). The tremendous variety and complexity of genetic resources results from the *in situ* conservation of plants traditionally grown in home gardens (Zemede Asfaw, 2001; Kumar and Nair, 2004). However, home gardens are currently under threat of genetic erosion such as, the displacement of a great variety of landraces by a few high-yielding varieties, loss of traditional knowledge of cropping patterns and management practices, socio-economic factors and drought (Kumar and Nair, 2004; Zemede Asfaw, 2004).

In Ethiopia, inventory and documentation of home gardens are very few. It has been concentrated in the south and south-western parts of Ethiopia by some researchers (Zemede Asfaw and Zerihun Woldu, 1997; Belachew Wassihun *et al*., 2003; Tesfaye Abebe, 2005; Talemos Seta, 2007; Habtamu Hailu, 2008; Solomon Tamrat, 2010). Thus, this study was initiated to document data on home gardens and to analyse plant

species composition, management practices of local people and their contribution to agro-biodiversity conservation in Holeta town.

2. MATERIALS AND METHODS

2.1. The Study Area

Holeta town is situated at a distance of 31 km west of Addis Ababa and located at $9^0$02'N latitude and $38^0$29'E longitude in Ethiopia. The town has an area of 5550 hectares (Figure 1). Holeta town is found in Oromia National Regional State (ONRS) and is bound in the east by Berfata Tokofa and in the south, Wajitu Harbu, in the north Ilala Gojo and Nanogenet in the west kebeles of Welemera Wereda. The town is found at an average altitude of 2449 m above sea level. The soil type of the area is 60% red soil, 37% black soil and 3% mixtures of black and red soils (HTRADO, 2009).

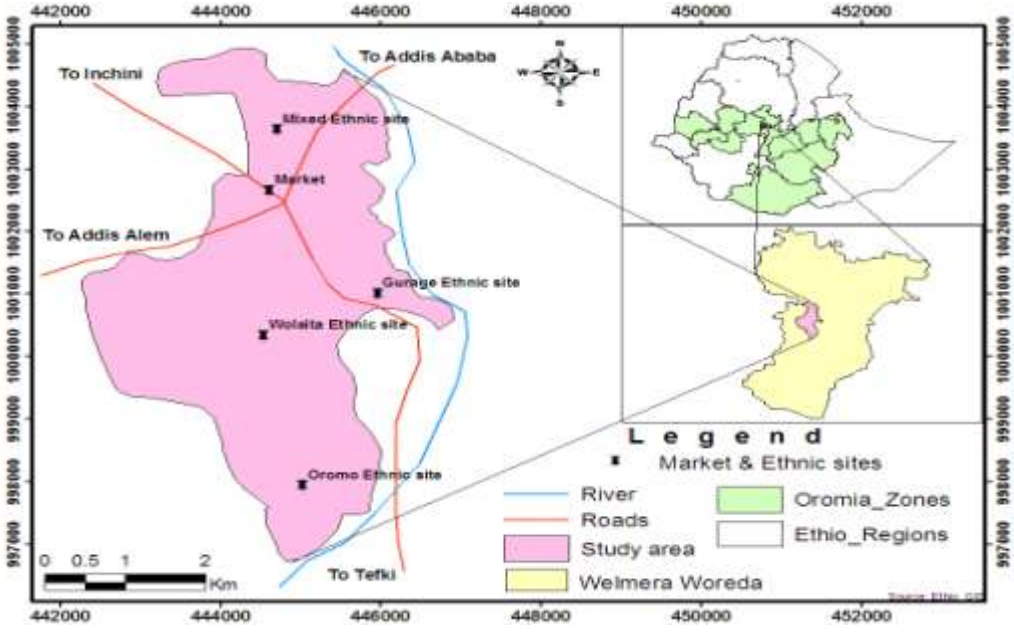

Figure 1. Map of the study area

2.2. Selection of Study Sites and Informants

During a reconnaissance survey (September, 2010) of the study area, overall information on the study area was obtained. Consequently, four study sites were identified and selected based on the presence of traditional home garden practices, and various ethnic communities (languages). They are described as Wolaita community dominated site (W.C.D.S), Gurage community dominated site (G.C.D.S),

Oromo community dominated site (O.C.D.S) and mixed community site (M.C.S). Accordingly, a total of 400 households (100 for each site) were randomly selected to determine the frequency of home gardens and to identify the types (front-yard, back-yard, side-yard or others). To conduct data collection and analysis, 75 home gardens were selected randomly from houses that practice home gardening. A total of twelve knowledgeable elders (8 men and 4 women) aged between 20-65 years were selected systematically from different sites with the assistance of community elders and local developmental agents for the ethno-botanical data collection.

2.3. Data Collection

Ethno-botanical data were collected by using semi-structured interviews, field observations, market surveys and ranking and scoring methods (Martin, 1995; Cotton, 1996). Interviews and discussions were conducted in Amharic (the local language) using a checklist of topics.

2.3.1. Direct matrix and preference ranking

Direct matrix ranking was calculated for six multipurpose tree species in order to assess their relative importance to local people and to generate a matrix that represents the views of the entire community (Martin, 1995; Cotton, 1996). Based on their relative uses, selected informants were asked to assign use values for each plant (using the following category: 5 = best, 4 = very good, 3 = good, 2 = less used, 1 = least used and 0 = not used).

Preference ranking was calculated for six food crops to determine their relative importance to local people (Martin, 1995; Cotton, 1996). Based on their personal preference of efficacy, selected informants were asked to assign use values for each plant [Highest score (10), while the one with the least effectiveness was given the lowest score (1)].

2.3.2. Floristic composition data and plant identification

Floristic composition data were collected from 75 sample plots of 10 m x 10 m (100 m^2) being delineated on 75 representative home gardens. Then, counts of each species (presence or absence) were conducted on each plot. Specimens of plants were found to be major components of the vegetation of the home gardens and they were collected and cross-checked for their local names with the help of key informants and development agents. Botanical names were established by comparing specimens with those at the National Herbarium, Science Faculty of Addis Ababa University using available Flora.

2.4. Data Analysis

Ethno-botanical data were analysed and summarised using descriptive statistics (percentage) and floristic composition data were analysed for species diversity using appropriate equations of the following parameters: frequency, density, Shannon and Wiener Index (H'), evenness and species richness, and Sorensen's Index of similarity (Kent and Coker, 1992; Shannon and Wiener, 1949 and Whittaker, 1972)

3. RESULTS AND DISCUSION

3.1. Structure of Home Gardens

The survey of 400 household in the town revealed that 342 (85.50 percent) households were practicing home gardening. The patterns of home gardens varied (Figure 2). Similar results were reported by Zemede Asfaw and Ayele Nigatu (1995), Zemede Asfaw (1997), and Talemos Seta (2007). However, the dominant home garden pattern was backyard home garden accounting for 34 percent. The size and diversity of species in the study area have positive correlations. With increase in land holding size, more variations in species composition were encountered. Tesfaye Abebe (2005) reported a similar result in his study of diversity in home garden agro-forestry of southern Ethiopia.

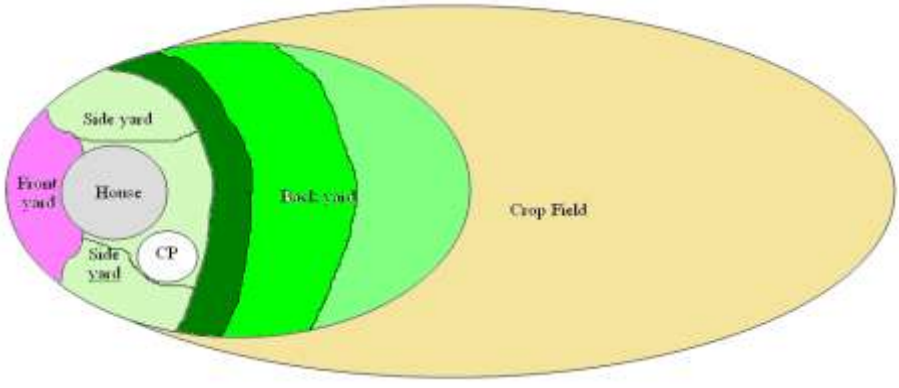

Figure 2. Sketch of common home garden pattern

Home gardens in the study area were composed of trees, shrubs, herbs, climbing plants and food crops in different strata. They consisted of trees on approximately 10 to 15 m on the upper strata (*Eucalyptus camaldulensis, Erythrina brucei, Cupressus lusitanica*), fruit crop *(Prunus persica)* and root crop (*Ensete ventricosum*), whichencompassed the middle strata, and herbaceous plants up to 1m from the ground strata (*Brassica carinata, Cymbopogon citrates, Beta vulgaris, Brassica oleracea, Daucus carota, Lycopersicon esculentum,* and *Ocimum basilicum).*

However, the horizontal structure of the species declined as one went from the home garden to the outside fields. This was also reported by Tesfaye Abebe (2005) in coffee-enset based Sidama home gardens and by Talemos Seta (2007) in enset-based home gardens in Wolaita.

3.2. Plant Diversity and Composition of Home Gardens

A total of 112 plant species were identified and documented from the study area (Appendix Table I). These plant species were classified into 93 genera and 43 families. The commonly represented families were Fabaceae which contained 11 species and topped the rank of the list, followed by Rutaceae and Poaceae, which contained eight species each ranked as second, and the third rank was occupied by family Solanaceae with seven plant species. In agreement with the current result, Tefera Mekonen, (2010) reported in Sebeta-Hawas Wereda survey, 114 plant species under 45 families were found under cultivation in home gardens.

The richest home garden contained 47 species whereas the poorest home garden contained only four species and the mean was 22 species per home garden. Among the recorded species, only 34 plant species (26.79 percent) were found at all study sites and five species in only two home gardens. From 112 plants species identified, 6.25 percent species were indigenous plants such as *Ensete ventricosum* and *Juniperus procera* (Appendix Table I), 35 species were wild species, and 70 species were cultivated crops.

The habits of the species were 49 (43 percent) herbal species, 32 (29 percent) tree species, 28 (25 percent) shrub species, and 3 percent were climber plants. *Eucalyptus camaldulensis*, *Cupressus lusitanica*, and *Prunus persica* were the top tree species. However; *Rhamnus prinoides*, *Catha edulis*, and *Dovyalis caffra* were the most prominent shrub species in the study area.

The home garden flora was composed of both food and non-food plants, accounting for 41.07 percent and 58.93 percent of the total of species in that order. Among the food crops, 19 species(17%) were fruit producing species, 15 species (13 percent) were vegetables and 6 percent pulses and cereals and ranked 1 to 3 in that order. On the other hand, from non-food components of the garden grown species, medicinal plants were 13 percent and construction and building plants were 12 percent and miscellaneous plants consisted of 5 percent, ranking 1st to 3rd, respectively.

From the total number of species recorded in the study area, *Ensete ventricosum* (93.75 percent) was the most frequent species, followed by *Eucalyptus camaldulensis* (90.63 percent) of the total sampled home gardens. The species distributed in the frequency classes indicated 6.22 percent of high frequency value species occurring in higher frequency classes A and B. These classes included *Ensete ventricosum,*

Eucalyptus camaldulensis, *Justicia shimperiana*, *Catha edulis*, *Solanum tuberosum* and *Rhamnus prinoides* and the remaining species were distributed in frequency classes C, D, and E in an ascending order containing 13.39 percent, 20.54 percent and 59.85 percent, respectively, totalling 93.78 percent. Thus, the results verify the existence of a high degree of species heterogeneity in the study area. This indicates that home gardens play vital roles in *in situ* conservation of agro-biodiversity (Lamprecht, 1989).

The value of Shannon-Wiener diversity index of sites ranged from 3.02 to 3.28 (Table 1). Diversity index with the value of H'= 3.283, was highest for the Gurage C.D.S followed by the Wolaita C.D.S (H'= 3.260) and the lowest diversity index (H'= 3.016) was recorded for the Oromo C.D.S study sites. As confirmed by owners of the home garden, diversity of plant species are affected by different factors like lack of access to water, size of home gardens, food culture, pests and weeds in the study area. This indicated that there was high species diversity at the study sites, which naturally varied from 1.5 to 3.5 and rarely exceeded 4.5 (Kent and Coker, 1992).

Table 1. Species numbers, Shannon Wiener diversity index, and species evenness

Study site	Number of species (richness)	Shannon's index (H')	Evenness (J) (H'/H'max)
Wolaita C.D.S	81	3.260	0.74
Oromo C.D.S	57	3.016	0.76
Gurage C.D.S	65	3.283	0.79
Mixed C.S	87	3.161	0.72

Sorenson similarity index of the study area ranged from 0.206 - 0.346 or below 0.5 (Table 2), indicating the existence of low similarities/high species diversity among the recognized sites. This may be related to the existence of inhabitants of the town with different ethnic backgrounds, which reflects dissimilar habits for growing plants and preference for food crops (Table 4). Hence, all the sites are important in terms of floristic diversity, and need attention from a conservation point of view (Kent and Coker, 1992).

Table 2. Sorenson similarity index of the home gardens

Clustered HGs	Oromo C.D.S	Wolaita C.D.S	Gurage C.D.S	Mixed C. S
Oromo C.D.S	1.00			
Wolaita C.D.S	0.346	1.00		
Gurage C.D.S	0.212	0.217	1.00	
Mixed C. S	0.206	0.226	0.214	1.00

3.3. Factors Affecting Home Garden Plant Diversity

According to the results of semi-structured interviews, the diversity and productivity of home gardens in the study area were mainly affected by lack of agricultural support (81.25%). This finding is consistent with the results of Podach and Jong (1991). Disease and pests are the main biological factors of the Wolaita and Gurage community dominated sites, which damaged crops grown for market as well as those grown for home consumption like *Brassica oleracea, Prunus persica,* and *Solanum tuberosum*. Small garden size (59.38%) hampered the diversity and richness of plants due to population growth and the resultant need to divide the land to share with the grown-up children as a means of livelihood as well as urbanization and development project like flower farming. The same trend of garden size reduction in urban area was reported by Zemede Asfaw (1997).

Table 3. Frequency distributional factors affecting diversity of home gardens

Factors	Study site and frequency of factors					
	Wolaita	**Oromo**	**Gurage**	**Mixed**	**Total**	**Percentage**
Lack of water	2	8	-	7	17	53.13%
Garden size	5	1	7	6	19	59.38%
Disease and pests	8	3	8	5	24	75.00%
Lack of awareness	4	7	3	2	16	50.00%
Lack of agricultural support	7	3	8	8	26	81.25%
Market access	1	2	-	1	4	12.50%
Other			3	2	5	15.63%

3.4. Food Plants in Home Gardens for Nutrition and Food Security

Out of 112 plant species identified in the study area, 43 species distributed among 36 genera and 17 families were documented as food plants and accounted for 41.07 percent of the total floral composition. Among these, 45.50 percent fruits, 30.23 percent vegetables, 13.95 percent pulses and cereals, 10.32 percent tubers and roots, and 4 percent were spices. The fruits were the most usable parts (39.96 percent) but the roots were the least usable parts (4.35 percent) of the food plants. The diversity of food crops of the study area plays a significant role in increasing the nutritional and income status of the local people. Consequently, *Prunus persica* was ranked first and *Allium sativum* was the least preferred food crop (Table 4).

Table 4. Simple preference ranking for widely used food crops in home gardens (1-10): 10- for most valuable, 1- for least valuable

	Respondent													
Botanical name	1	2	3	4	5	6	7	8	9	10	11	12	Total score	Rank
Allium sativum	4	1	6	6	7	4	1	2	2	9	8	5	55	6
Prunus persica	10	7	8	5	10	9	5	6	7	10	1	3	81	1
Malus sylvestris	1	6	10	2	4	5	10	10	5	8	9	9	79	2
Lycopersicon esculentum	6	2	7	10	6	10	3	4	8	5	2	6	69	5
Ensete ventricosum	2	9	8	8	9	8	4	3	9	8	4	3	75	4
Solanum tuberosum	7	10	1	4	8	6	9	5	8	6	9	5	78	3

3.5. Important Home Garden Tree Species with Multiple Uses

Home garden owners and other peoples in Holeta town have the tradition of using various tree species found in their home gardens for different purposes. The results of 12 key informants through direct matrix ranking for four study sites showed tree species with versatile uses based on six use criteria (Table 5). The tree species were chosen depending on the informants' consensus. Thus, *Juniperus procera* with a total score of 239 (79.67 percent) was ranked first. this was closely followed by *Cordia africana* and *Olea europaea* with totals of 227 (75.33 percent) and 219 (73 percent) in second and third positions, respectively.

Table 5. Direct matrix ranking by respondents for five home garden tree species and six major uses.

Botanical name	**Attribute and score**								
	Construction & crafts	Fuel wood	Medicine	Live fence	Soil fertility	Shade	Total score	Rank	**%**
Cordia africana	47	34	-	44	57	45	227	2	**75.33**
Juniperus procera	55	32	-	54	54	44	239	1	**79.67**
Eucalyptus globulus	40	56	55	32	10	23	216	4	**71.33**
Olea europaea	44	28	23	31	44	49	219	3	**73.00**
Acacia Sesbania	43	55	-	33	42	22	195	5	**65.00**

3.6. Home Garden Plant Species with Medicinal Values

The tradition of planting nutraceutical plants and wild plant species in home gardens for medicinal purposes plays vital roles in the *in situ* conservation of agro-biodiversity. From a total of 112 plant species identified in the present study, 13 percent were used as traditional medicinal plants and distributed among 15 genera in 9 families (Appendix Table II). Among these, 33.33 percent were nutraceutical plants (Table 6) and 60 percent were wild plants. These findings are similar to those obtained by Belachew Wassihun *et al*. (2003) who reported 133 plant species were grown in the 'Gamo' home gardens, out of which 18 were used as medicinal plants.

Table 6. Medicinal and food (nutraceutical) plant species

Species name	Part used as medicine	Health problems	Method of preparation and use
Allium sativum	Bulb	Headache, abdominal crump and flue	The bulb is eaten alone or with Zingiber officinale
Ensete ventricosum	Corm, leaf	Broken limbs	The underground corm is boiled and eaten to cure injured limbs
Punica granatum	Leaf	Expel tape worm	Decoction of the leaf is reported to be used against tape worm infestation
Lepidium sativum	Seed	Constipation, evil eye, diarrhoea, skin rash	The seeds are ground, mixed with lemon and water to be taken orally to cure constipation and diarrhoea, and rubbed on the skin to treat skin rash

3.7. Indigenous Knowledge and Home Garden Management Practice

For maintenance of the diversity of home garden species in the town, gardeners employ various indigenous management practices. Soil fertility is increased and maintained by using animal manure, kitchen wastes, and crop residues. Seed selection criteria were based on maturity, yield, quality, colour and disease and drought resistances. Zemede Asfaw (1997); Belachew Wassihun *et al.* (2003) and Talemos Seta (2007) confirmed similar results.

Home garden owners dominated by Wolaita and Gurage community members have indigenous knowledge to prepare, classify, and cultivate *Ensete ventricosum*, which is a versatile crop that is used for food, fodder, medicinal, and other uses (Table 6). Zemede Asfaw and Zerihun Woldu (1997) in Wolaita and Gurage Zones and Habtamu Hailu (2008) in Sebeta Awas Wereda reported similar observations with regard to the functions of this valuable crop.

Table7. Landraces of *Ensete ventricosum* recorded in Gurage community dominated site

Vernacular name (Gurage language)	Use
Kancho	Food, Fodder, Fibre
Key enset	Medicinal, Food, Fibre, Fodder
Guariye	Medicinal, Food, Fibre, Fodder
K'ebbena	Medicinal, Food, Fibre, Fodder
Deriye	Food, Fibre, Fodder
Ankefe	Food, Fibre, Fodder
Demret	Medicinal, Food, Fibre, Fodder
Safar	Medicinal, Food, Fibre, Fodder

One of the best aspects of indigenous knowledge in the study area is work division in managing home gardens. Women (38.41 percent) participated in managing vegetables, spices, and medicinal plants by planting, weeding, watering (plate 2b) and selling (Christianity, 1990). However, men (47.93 percent) participated in cultivating cash crop plants and digging, designing, finding seed and seedlings. Zemede Asfaw (2002) remarked that the male family head is often accountable for designing home garden structure, identifying suitable places for positioning the major crops, and monitoring and strongly impacting the structure and direction of home garden development. It was confirmed by UNICEF (1982) that home gardens are useful for the maintenance of good health in developing countries. This indigenous knowledge is also important in the development of modern medicines (Dawit Abebe *et al.*, 2003; Fisseha Mesfin, 2007).

4. CONCLUSION

The results of the study have demonstrated that the home gardens at Holeta town have high species diversity and rich floristic composition that are worth for *in situ* conservation of agro-biodiversity and domestication of wild species, trial sites of new varieties of vegetables and other species. In addition, home gardens in the area contribute significantly to the gardeners' livelihoods and the society as a source of supplementary food, aesthetic values, socio-cultural, medicinal functions, and income. However, insufficient agricultural supports, smallness of the gardens, and the shifting of poly-cultural farming to a few income generating food crops have negatively affected the diversity of species. Therefore, it is vital that agricultural supports be provided for the home gardeners by concerned institutions to maintain the existing biodiversity and the traditional management systems on a sustainable basis in the future.

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Appendix Table I. Plants species found in Holeta home gardens, Ethiopia

Botanical name	Local name	Family name	Habit
Acacia abyssinica Hochst.ex Benth	Grar	Fabaceae	tree
Acacia melanoxylon R.Br	Omedla	Fabaceae	tree
Acacia Sesbania (vahl) Benth	Chaca	Fabaceae	tree
**Ajuga integrifolia* Buch-Ham ex-D.Don	Armagusa	Lamiaceae	herb
Allium cepa L.	Key shinkurt	Alliaceae	herb
Allium porrum L.	Baro shinkurt	Alliaceae	herb
**Allium sativum* L.	Netch shinkurt	Alliaceae	herb
Allophylus abyssinicus (Hochest) Radlkofer	Embuse	Sapnidaceae	tree
**Anethum graveolens* L.	Iensilal	Apiaceae	herb
Apium graveolens L.	Yeshorba kitel	Apiaceae	herb
**Artemisia absinthium* L.	Arrity	Asteraceae	herb
Arundo donax L.	Shenbeko	Poaceae	herb
Asparagus africanus L am	Serity	Asparagaceae	climber
Asplenium aethiopicum (Burm.f.)Bech	Fern (E)	Aspleniaceae	herb
Beta vulgaris L.	Keyisir	Chenopodiaceae	herb
Beta vulgaris L.	Kosta	Chenopodiaceae	herb
Brassica carinata A.Br.	Yeguragie gomen	Brassicaceae	herb
Brassica integrifolia L.	Tikel gomen	Brassicaceae	herb
Brassica oleracea L. var. capitata	Yewer gomen	Brassicaceae	herb
Brassica oleracea L.	Gomen	Brassicaceae	herb
Buddleja davidii Franch.	Amfar	Loganiaceae	shrub
Callistemon citrinus (Curtis) Skeels	Bottle brush (E)	Myrtaceae	tree
Canavalia africana L.	Adenguara	Fabaceae	herb
Citrus paradisi L.	Gripe fruit	Rutaceae	shrub
Canna indica L.	Setakuri	Cannaceae	herb
Capsicum annuum L.	Yeferenj karia	Solanaceae	herb
Carica papaya L.	Papaya	Caricaceae	herb
Capsicum frutescens L.	Yabish karia	Solanaceae	herb
Carissa spinarum L.	Agam	Apocynaceae	shrub
Casimiroa edulis La Llave	Casimer	Rutaceae	tree
*Catha edulis (*Vahl.) Forssk.ex Endl	Khat (E)	Celastraceae	shrub
Citrus aurantium L.	Komtate	Rutaceae	shrub
Citrus aurantifolia (Christm.) Swingle	Lomi	Rutaceae	shrub

Citrus medica L.	Tiringo	Rutaceae	shrub
Citrus sinesis L. Osb	Birtukan	Rutaceae	shrub
Coccinia abyssinica (Lam) Cogn	Anchote	Cucurbitaceae	herb
Coffea arabica L.	Buna	Rubiaceae	shrub
Cordia africana Lam.	Wanza	Boraginaceae	tree
**Croton macrostachyus* Del.	Bisana	Euphorbiaceae	tree
Cucumis sativus L.	Kiar	Cucurbitaceae	herb
Cucurbita pepo L.	Duba	Cucurbitaceae	herb
Cupressus lusitanica Mill.	Yefirenj tid	Cupressaceae	tree
**Cymbopogon citralus* (DC) Stapf	Tej-sar	Poaceae	herb
Daucus carota L.	Karot	Apiaceae	herb
Dovyalis caffra (Hook.f.Harv.)Hook.f.	Koshim	Flacourtiaceae	shrub
**Ensete ventricosum (Welw) Cheesman*	Enset	Musaceae	herb
Eragrostis tef (Zucc.)	Teff	Poaceae	herb
Erythrina brucei Schweinf	Korch	Fabaceae	tree
Eucalyptus camaldulensis Dehnh	Netch bahrzaf	Myrtaceae	tree
**Eucalyptus globulus* Labill	Key bahrzaf	Myrtaceae	tree
Ficus elastica Roxb.	Yegoma zaf	Moraceae	tree
Ficus sur Forsk.	Sholla	Moraceae	tree
**Hagenia abyssinica (*Bruce) J. F. Gmel.	Koso	Rosaceae	tree
Hordeum vulgare L.	Gebs	Poaceae	herb
Juniperus procera Hochst,ex.Endl	Yabesha tid	Cupresaceae	tree
Justicia shimperiana L.	Sensel	Acanthceae	shrub
Lactuca sativa L.	Selata	Asteraceae	herb
**Lepidium sativum* L.	Fetto	Brassicaceae	herb
Ligustrum vulgare L.	Yeferenj mefakya (A)	Oleaceae	tree
Lippia adoensis var adoensis	Kessie	Verbenaceae	shrub
Lippia adoensis var koseret Sebsebe	Koseret	Verbenaceae	shrub
Lycopersicon esculentum Mill	Timatim	Solanaceae	herb
Malus sylvestris Miller	Pom, apple (E)	Rosaceae	shrub
**Mentha spicata* L.	Nana	Lamiaceae	herb
Millettia ferruginea (Hochst.) Bak	Birbira	Fabaceae	tree
Morus alba L.	Yeferenj enjory (A)	Rosaceae	tree
Musa x *paradisiaca* L.	Muz	Musaceae	herb
Myrtus communis L.	Ades	Myrtaceae	shrub
Nicotiana tabacum L.	Timbaho	Solanaceae	herb
Ocimum basilicum L.	Besobila	Lamiaceae	herb
**Ocimum lamiifolium* Hochst ex Benth	Damakese	Lamiaceae	shrub
Olea europaea L. sub sp cuspidata Wall ex G.Don.)Cif	Weyra	Oleaceae	tree
Osyris quadripartita Dec.	Kert	Santslaceae	shrub
Otostegia integrifolia Benth	Tinjuit	Lamiaceae	shrub
Pennisetum puprureum Schumach	Elephant grass (E)	Poaceae	herb

**Pentas schimperiana* (A.Rich.)	Weynagifte	Rubiaceae	herb
Persea americana Mill	Abokado	Lauraceae	tree
Phoenix reclinata Jacq	Zenbaba	Areaceae	tree
Phaseolus vulgaris L.	Fossolia	Fabaceae	herb
Physalis peruviana L.	Yefiranj awt	Solanaceae	herb
**Phytolacca dodecandra* L' Herit	Endod	Phytolaccaceaeeae	shrub/climber
Pinus patulla Schiede ex Schltdl.& Cham	Arzelibanos	Pinaceae	tree
Pisum sativum L.	Ater	Fabaceae	herb
Plectranthus edulis L.	Yewolaita dinich (A)	Lamiaceae	herb
Podocarpus falcatus (Thunbr.)R.B.ex.Mirb	Zigba	Podocarpaceae	tree
Prunus africana L.	Tikur enchet	Rosaceae	tree
Prunus x domestica L.	Prim (E)	Rosaceae	tree
Prunus persica (L.) Batsch	Kok	Rosaceae	tree
Psidium guajava L.	Zitun	Myrtaceae	tree
**Punica granatum*L.	Roman	Punicaceae	shrub
Rhamnus prinoides L' Herit.	Gesho	Rhamanceae	shrub
Ricinus communis L.	Gulo	Euphorbiaceaeae	shrub
Rosa hybrida Hort.	Tsigereda	Rosaceae	shrub
Rosmarinus officinalis L.	Sigametibesha	Lamiaceae	shrub
**Ruta chalepensis* L.	Tenadam	Rutaceae	shrub
Saccharum officinarum L.	Shenkorageda	Poaceae	herb
Salix subserrata Willd	Aleltu	Salicaceae	tree
Schinus molle L.	Kundoberberie (A)	Ancardiaceae	tree
Sesbania sesban L. Merr	Sesbania	Fabaceae	shrub
Solanum nigrum L.	Yabish awt	Solanaceae	herb
Solanum tuberosum L.	Dinch	Solanaceae	herb
Sorghum bicolor L.	Tinqish	Poaceae	herb
Trigonella foenum graecum	Abish	Fabaceae	herb
**Verbena officinlis* L.	Atuse	Verbenaceae	shrub
**Vernonia amygdalina Del.*	Grawa	Asteraceae	tree
Vica faba L.	Bakela	Fabaceae	herb
Vitis vinifera L.	Weyn	Vitaceae	climber
Washingtonia filifera L.	Zenbaba	Areaceae	tree
Zantedeschia aethiopica (L.) K.P.J Sprengel	Tirumba-abeba	Areaceae	herb
Zea mays L.	Bekolo	Poaceae	herb

E- English name; * Medicinal plants

PROFITABILITY OF COFFEE-ENSET BASED AGRO-FORESTRY PRACTICES IN YIRGACHEFE DISTRICT OF ETHIOPIA

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ABSTRACT

Coffee-enset based agro-forestry is an important agricultural practice in southern Ethiopia. However, empirical evidence is lacking concerning the profitability and management of the system. Therefore, this study was conducted in Yirgachefe district of Ethiopia to assess the plant composition, management activities, and associated costs and benefits of Coffee-Enset-Based Agro-forestry (CEBAF) and Parkland Agro-forestry (PLAF) practices. Data were collected from 101 randomly selected households through structured interviews. Additionally, focus group discussion, key informant interviews, field observations, and market assessment were conducted. Cost-benefit of the system was analysed. In the cost-benefit analysis, returns to land and labour were calculated. The results indicated that coffee-enset-based agro-forestry practice consisted of diverse components of perennial and annual plant species, which involve intensive management activities as compared to the parkland agro-forestry practice. The results of the cost-benefit analysis showed that the total production cost of coffee-enset-based agro-forestry practice was 1.33 times higher than that of parkland agro-forestry practice. However, the total benefit obtained from coffee-enset-based agro-forestry practice was 9.76 times higher than the total benefits obtained from parkland agro-forestry practice. The return to land of coffee-enset-based agro-forestry practice was 33.63 times higher than that of parkland agro-forestry practice. Similarly, the returns to labour of coffee-enset-based agro-forestry were 7.6 times higher than that of parkland agro-forestry practice. It can, therefore, be concluded that coffee-enset-based agro-forestry practice is markedly more profitable and less risky than parkland agro-forestry practice.

Keywords: Cost-benefit analysis, parkland agro-forestry, returns to labour, returns to land

1. INTRODUCTION

Agro-forestry is one of the most commonly proposed strategies for tackling problems associated with deforestation, land degradation, biodiversity loss, crop failure, and climate change. It is an integrated means for solving land-use problems by allowing farmers to produce diversified products like food, fibre, fodder, and fuel

simultaneously from the same unit of land. Such types of integrated approach include home gardens, parklands, alley cropping, woodlots, and boundary planting (Nair, 1993).

For farmers in the tropics, home gardens are of vital importance (High and Shackleton, 2000). In Ethiopia, home gardens constitute an ancient food production means and the agro-biodiversity, and ensure food self-sufficiency and security in time of scarcity (Zemede Asfaw, 1997). The agro-forestry practices of southern Ethiopia (coffee-enset based and enset-coffee based agro forestry practices) are a good example of home gardens that have sustained livelihoods in the area for centuries (Tadesse Kippie, 2002). Coffee-enset based agro-forestry (CEBAF) or enset-coffee based agro-forestry (ECBAF) practice refers to growing coffee and enset as two major components of a cropping system (Tesfaye Abebe, 2005), where coffee is the more dominate component than enset in the first case and enset is the more dominant component than coffee in the second case. CEBAF is a traditional agro-forestry practice in Yirgachefe district of Gedeo zone, southern Ethiopia. In some district of the zone, parkland agro-forestry (PLAF) is also widely practised (SNNPR BoARD, 2007).

PLAF was introduced by farmers through conservation of selected tree species preferred for multiple products that are economically useful for farmers' livelihoods (Kamara and Haque, 1992). This practice is found throughout the semi-arid and sub-humid zones of Africa in varying structure and composition of indigenous species, in pure stands or mixtures depending on farmers' preferences and zone of occurrence. The system is also common across the highlands of Ethiopia (Poschen, 1986; Motuma *et al*., 2008). For example, Poschen (1986) noted a PLAF practice in the Hararghe highlands of eastern Ethiopia where farmers grow *Faidherbia albida* as a permanent tree crop on farmlands with cereals, vegetables, and coffee underneath or in between.

CEBAF and PLAF practised in Yirgachefe district help to sustain the livelihood of the people of the area. Nevertheless, different land uses practised by individual households involve different levels of production costs and benefits. Thus, it is vital for policy makers to identify which land use practice would better serve to improve the livelihood of rural households (Rasul and Thapa, 2006). However, no scientific study has been done on the practices. Hence, this study was conducted to assess CEBAF and PLAF in terms of plant composition, management practices; associated production costs and benefits and the tangible benefits obtained by households from each of the two types of agro-forestry practices; and to compare the profitability of the two practices in Yirgachefe district.

2. MATERIALSANDMETHODS

2.1. The study area

Yirgachefe district is located in Gedeo administrative zone of the Southern Nations, Nationalities, and Peoples' Regional (SNNPR) State of Ethiopia. The district covers approximately 304.07 km^2. With an average population density of about 652 persons per km^2, the district is one of the densely populated areas in the country (FDREPCC, 2008). The district is characterized by a humid tropical climate. About 92% of the district lies in the *weynadega* (mid- altitude between 1500 and 2500 m above sea level) and 8% of this district lies in the *dega* (high altitude above 2500 m above sea level) agro-climatic zone (SNNPR BoARD, 2007). The average annual rainfall of the area ranges from 1500- 1700 mm with considerable inter-annual and inter-seasonal variation. The rainfall pattern is bi-modal with a short rainy season that extends from March to June and a long rainy season extending from August to October. The dominate soil types of the area are clay loam, sandy loam, sandy, loamy, and clayey. The farming system of the district is agro-forestry. Crop production both for subsistence and for cash generation is the major activity of the farming system.

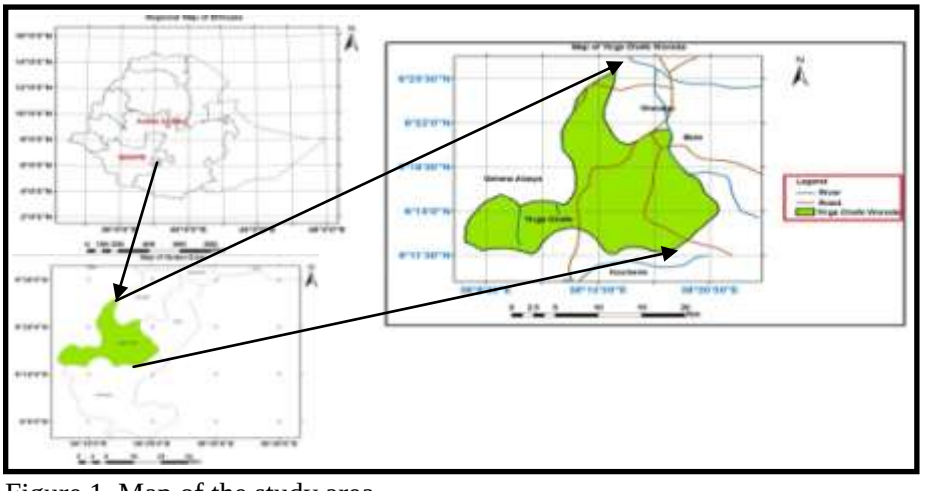

Figure 1. Map of the study area

2.2. Methods of Data Collection and Analysis

Primary and secondary data were used in this study. The primary data were collected through household surveys, focus group discussions, field observations, market surveys, and key informant interviews. The survey data were collected through structured questionnaires from 101 (5% of the total households). Accordingly, 29 households who practised PLAF and 72 households who practised CEBAF were randomly selected. Two focus group (one men and one women group in each agro-forestry practice) discussions and field observations were conducted to assess the two agro-forestry practices in terms of their components (combinations of crop types) and

management activities. Major management costs and benefits of plants constituting both types of agro-forestry practices were also discussed in the focus group discussions. Key informant interviews were conducted to get general information about the study site and the agro-forestry practices before conducting the actual survey. The data were collected from January to April 2011. Secondary data were obtained from the Agricultural and Rural Development Office of the district.

Qualitative data were collected through focus group discussions, key informant interviews and field observations and qualitatively interpreted. The quantitative data (cost and benefit) obtained from the household survey were analysed by employing Cost Benefit Analysis. In the Cost Benefit Analysis, economic performance indicators such as the Returns to Land and Returns to labour (RL) from the two agro-forestry practices were calculated and compared.

2.3. Returns to Land (Net Present Value)

The Net Present Value (NPV) determines the net returns by discounting the streams of benefits and costs back to the beginning of the base year using appropriate discount rate over the life time (analysis period) of the production system. The agro-forestry practice with higher NPV is taken as an economically better option than with lower NPV (Chandra, 1998).

Smallholder households seek to maximize Return to household Labour (RL) as it is their main asset. Hence, following Fagerstroem *et al*. (2001), RL was calculated by subtracting the material costs from the gross benefit and dividing the proceeds by the total person-days. An agro-forestry practice is attractive if RL is greater than the opportunity cost of the family labour; in the case of the two practices the one with a higher RL would be selected.

Current prices of inputs and outputs were used to calculate the values of both practices and the prices were set constant throughout the life cycle of the practices. The life cycle of the coffee (25 years) were considered in the analysis because coffee is the main crop in the CEBAF practice of the study area. A discount rate of 10% which is recommended for the evaluation of projects by the Ministry of Finance and Economic Development of Ethiopia (MoFED, 1998) was used in the study.

Due to lack of reliable data, it was difficult to predict the future yield and output prices. Hence, sensitivity analysis was carried out to show the effect of the change in these key variables on the NPV. Additionally, in the adoption of new agro-forestry practices, farmers are not only concerned about costs and benefits, but also consider risks associated with them. At the study site, most farm households are deriving their livelihood primarily from agriculture, with which varieties of risks and uncertainties (tenure insecurity, recurrent drought, diseases) are involved. As a result, five

assumptions were made in the sensitivity analysis. These included: if yield increases/decreases by10 percent, keeping other key variables constant; if wage increases by 10 percent, keeping other key variables constant; if discount rate increases by 10 percent, keeping other key variables constant; if yield increases by 10 percent and discount rate and wage decrease by 10 percent; and if yield decreases by 10 percent and discount rate and wage increases by 10 percent.

3. RESULTS AND DISCUSSION

3.1. Coffee-enset-based Agro-forestry Practice

3.1.1. Plant species composition

Three gardens, namely, home garden, village forest garden, and coffee-enset farm were identified in the CEBAF practice, following Fernandes and Nair (1986) classification of extended home gardens. In the home gardens of this study area, ensetis the dominantly grown perennial crop mostly in association with trees such as *Erythrina abyssinica* and *Vernonia amygdalina* as well as with annual root crops such as taro (*Colocasia esculenta*) and yam (*Dioscorea villosa*) (Table 1). Likewise, in coffee-enset farm/plot, coffee (*Coffea arabica*), enset and shade trees are grown together. Village forest gardens are also composed of coffee and shade trees such as *Millettia ferruginea* and *Croton macrostachyus*. In addition, wood lots of *Eucalyptus camaldulensis* and boundary planting were commonly observed in the area.

Table 1. Plant species most commonly constituting the CEBAF practice

Local name	English name	Botanical name	Place of observation
Bune	Coffee	*Coffea arabica*	Village forest garden and coffee-enset farm
Wese	Enset	*Ensete ventricosum*	Home garden and coffee-enset farm
Godarree	Taro	*Colocasia esculenta*	Home garden
Boyina	Yam	*Dioscorea villosa*	Home garden and Village forest garden
Boloke	Common bean	*Phaseolus vulgaris*	Village forest garden
Dedatu		*Millettia ferruginea*	Village forest garden
Weleenna		*Erythrina abyssinica*	Home garden
Mokkonssa		*Croton macrostachyus*	Village forest garden
Aebicha		*Vernonia amygdalina*	Home garden
		Eucalyptus camaldulensis	Woodlot

The results showed that various plant components (ranging from annuals to perennials) were grown in combination in the CEBAF practice; however, the perennials dominate the practice as compared to annuals. Different researchers also reported that diverse plants were grown in similar agro-forests; Murdiyarso *et al.* (2002) described that agro-forests contained complex number of plant and animal species. Likewise, Fikrey Tesfaye (2011) revealed that *Millettia ferruginea, Vernonia amygdalina, Croton macrostachyus,* and *Eucalyptus camaldulensis* were dominantly

grown woody species in the multi-strata agro-forests of Yirgachefe district. Tadesse Kippie (2002) also stated that agro-forests in the Gedeo zone are commonly managed in association with perennials like shade trees, food crops, fruits and timber trees. It is also composed of diverse and complex vegetation arrangements including perennial multipurpose shade trees/shrub species (in the upper storey), coffee, enset (in the middle storey) and numerous kinds of annual vegetables (in the under storey) and animals (SLUF, 2006).

3.1.2. Management activities

The results of the study revealed that different shade tree and crop management activities were incorporated in the CEBAF practice. Households pruned the lower and old branches of *Millettia ferruginea*, practised lopping of *Croton macrostachyus* and *Erythrina abyssinica* and thinning, pruning and lopping of *Vernonia amygdolina*. The farmers also practised coppicing of *Eucalyptus camaldulensis* at the age of four years and above; they also cut off *Eucalyptus camaldulensis* (boundary planting) when it reached the age of four years after planting, then after every three years. These management activities were done to reduce competition from shading and to get additional benefits such as fodder and firewood from living trees. In line with this, Fikrey Tesfaye (2011) noted that pruning, thinning, pollarding and coppicing were the dominant shade tree management activities that are usually practised in the agro forests of Yirgachefe district of Ethiopia.

In the same way, different crop management activities are practised in the CEBAF. Planting, hoeing, slashing the under storey, fertilizing, capping the tip of the coffee plant, replacement planting, pruning and harvesting were the dominant crop management activities. Planting of all components of the practice is done at the time of establishment. It is also carried out when it is necessary. Hoeing was found to be carried out twice a year starting from the establishment time and it continued until the coffee and/or enset starts bearing yield (at the fourth year after planting). Then, it would be conducted once in two years until the end of the life cycle (25 years). Replacement planting for failed seedlings was conducted for coffee and shade trees at the first and second years after planting. Slashing to retard weed growth was carried out three times per year until the fourth year after establishment, then after twice per year until 25 years. Capping, to facilitate more coffee fruit development, was done only once (at year three after planting) in the life cycle of the coffee plant. Pruning of older coffee branches, to facilitate fruiting and reduce competition, was carried out once a year starting from year five after planting. Fertilization with coffee pulp was conducted during the time of establishment. At the time of enset harvesting, another enset seedling was planted to replace the harvested enset. Fresh coffee fruit harvesting was started at year fourth year after planting and the tree stayed productive for quite a number of years until its yield decreased considerably after 25 years. First

harvest of ensetalso started at year four after planting and was sustained until year seven (enset matures between 4-7 years after planting in this practice). Root crops were harvested annually. First harvest of most of the shade trees (through pruning and lopping) started at year five after planting. The edge plant (*Eucalyptus camaldulensis)* started producing firewood and wood for construction beginning from year four after planting and stayed productive for about 25 years.

Similar studies showed that farmers in Gedeo agro-forests slash the weeds found under enset twice a year (after the age of four years, once a year) to suppress weed growth underneath and cultivate the soil and adding up organic matter twice for the first two years (Tadesse Kippie, 2002). A study conducted in Wonago district also indicated that farmers cultivate and slash coffee stands 2-3 times per year and they also prune lower old branches of coffee to stimulate fruiting and to reduce stiff competition among the trees for resources (SLUF, 2006).

3.2. The Parkland Agroforestry (PLAF) Practice

3.2.1. Plant species composition

The PLAF practice of the study site, *Syzygium guineense* trees were deliberately preserved and managed on crop fields grown with annual crops such as *teff*, maize, barley, common bean and sweet potato. PLAF like the one in the study site is common across the highlands of Ethiopia (Poschen, 1986; Motuma *et al.*, 2008; Abera Worku, 2009). Most farming systems in the highlands are composed of different large-stemmed tree species that are deliberately let to grow and are managed by the farmers. For instance, Abera Worku (2009) also noted a PLAF practice where *Croton macrostachyus* followed by *Warburgia ugandensis*, *Syzygium guineense*, *Cordia Africana*, *Pygeum africanum*, *Ficus vasta*, *Faurrea rochetiana*, *Strychnos mitis*, *Podocarpus falcauts*, and *Olea africana* were grown in association with annual crops such as *teff*, maize, sorghum, and common bean by the farmers of Burkitu Peasant Association in the Oromia region of Ethiopia.

3.2.2. Management activities

Assisted regeneration and lopping were the two main parkland tree management activities conducted in PLAF practice of the study area. The farm households manage naturally regenerating *Syzygium guineense* tree on their farmlands. In a similar observation, Okia *et al*. (2005) recorded naturally regenerated parkland trees (*Vitellaria paradoxa)* from seedlings in northern and eastern Uganda.

Lopping of branches of *Syzygium guineense* tree was conducted every year starting from year six after planting of the trees. It was mainly practised to avoid shading effect on the under storey annual crops as well as to get additional outputs such as

firewood from the standing tree. Biruk Asfaw (2006) also reported that farmers in south east Langano of Ethiopia practised lopping of branches mostly on PLAF.

Different management activities were also practised for the under storey annual crops. Cultivation, planting/sowing, weeding and/or weed control through herbicide application and harvesting were the most common management activities. Farmers of the study area also practised mixed cropping particularly maize with common bean, and other beans. Moreover, crop rotation was also dominantly practised by the farmers in the district.

3.3. Production Cost Estimation

The results showed that the total production cost of CEBAF practice was 1.33 times higher than the production cost of PLAF practice (Table 2). The production cost involved costs of establishment and management of the agro-forestry practices.

3.3.1. Establishment costs

Results of the analysis showed that the establishment cost of CEBAF practice was 4.67 times higher than the establishment cost of PLAF practice. This is because CEBAF involved intensive establishment activities and needed buying seed and seedlings of various plant species. The establishment cost included labour and non-labour costs. The labour cost of CEBAF practice was 2.22 times higher than the labour cost of PLAF practice. Similarly, the non-labour cost of CEBAF practice was 19.28 times higher than the non-labour cost of PLAF practice.

Table 2. Production costs (Birr/ha) of the CEBAF and PLAF practices

Operation	Year	PLAFP	CEBAFS	Relative (PLAFP=100%)
Establishment	0			
Labour cost		3510	7785	222%
Non-labour cost		590	11375.50	1928%
Total establishment cost		4100	19160.50	467%
Management cost				
Labour cost	1-25	244,500	325815	133%
Non-labour cost	1-25	32,956	30151.35	91.5%
Total management cost	1-25	277456	355966.35	128%
Total production cost		281556	375114.35	133%

Similarly, Rahman *et al.* (2007) found that the establishment cost of multi-strata agro-forestry system was 1.33 times higher than the establishment cost of traditional mono-cropping.

3.3.2. Management costs

The results showed that the total management cost of CEBAF practice was 1.28 times higher than that of PLAF practice (Table 2). The total labour cost incurred in management of components of CEBAF practice was 1.33 times higher than the total labour cost of PLAF practice. In line with this result, Rahman *et al.* (2007) estimated the labour cost of multi-strata agro-forestry system at three times higher than the labour cost of traditional monoculture since agro-forestry system requires intensive management activities. However, the non-labour costs of the PLAF practice was 8.5% higher than the non-labour cost of CEBAF practice because most of the seedlings/seeds planted/sown in the CEBAF practice are perennial, which do not require regular purchasing.

3.4. Benefits of CEBAF Practice

The CEBAF practice provides diversified benefits to farm households of the study area. The benefits included firewood, fodder, construction material, honey, coffee and *kocho*[1]. Coffee is primarily used as a source of income (cash crop) for households. *Kocho* is mainly used for household consumption (main staple food). Enset leaf is used as fodder and a source of income by selling it as a wrapping material for khat leaves for sale. Root crops (taro and yam) are commonly used for household consumption (food). Common bean is used for home consumption. The shade trees (pruned branches) are used at home for fodder, firewood and building materials, and to generate income through sale as poles and timber. *Eucalyptus camaldulensis* is mostly used as a source of firewood, for construction and to generate income. Honey is used for home consumption.

The CEBAF provided farmers with diverse products/outputs which are reported to be available all-year round. Similar studies conducted by Williams *et al*. (1997) showed that agro-forestry focuses strongly on increasing income through involving diverse components and conservation of natural resources.

3.5. Benefits of PLAF Practice

The benefits obtained from PLAF practices included firewood, fodder, building materials and food. Crops such as maize, *teff*, bean, barley and common bean are used for home consumption whereas sweet potato is used to generate income (main cash crop). *Syzygium guineense* tree was used as a source of firewood (lopped branches), building materials, for making farm equipment and to generate income through timber sale. In line with this result, Bayala *et al*. (2002) indicated that

farmers retained trees on their farmlands primarily because of the benefits derived from their fruits. In addition, Biruk Asfaw (2006) reported that farmers maintained trees/shrubs on their farms for different socio-economic purposes including medicinal products, provision of shade and shelter, fodder, firewood, etc.

3.6. Estimation of Financial Benefits

The financial benefits obtained from the different products of the two agro-forestry practices are shown in Table 3. The gross benefit of CEBAF practice was 9.76 times higher than the gross benefits of the PLAF. This could be attributed to the fact that the CEBAF practice provided diversified outputs which altogether increased the total benefits gained.

Table 3. Financial benefits of CEBAF and PLAF practices (Birr)

Product	Year	PLAF	CEBAF	Relative PLAF=100%)
Maize	1-25	35000	-	
Teff	1-25	56250	-	
Barley	1-25	70000	-	
Bean	1-25	37500	-	
Haricot bean	1-25	131250	11250	
Sweet potato	1-25	33250	-	
Coffee berries	4-25	-	2245580	
Kocho	4-25	-	1132950	
Enset leaf	4-25	-	21439	
Forage	1-25	7500	-	
Pole/timber	5-25	6000	93104	
Boundary plant	4-25	-	81600	
Fuelwood	5- 25	570	2270	
Honey	5-25	-	5880	
Taro	1-25	-	31250	
Yam	1-25	-	58680	
Gross benefit		377320	3684003	976%

PLAF=Parkland Agro-forestry; CEBAF=Coffee-Enset-Based Agro-forestry

In a case study of the degraded agricultural lands, Rasul and Thapa (2006) reported that the gross benefit obtained from agro-forestry practice was 25% greater than the gross benefit obtained from shifting cultivation. The average annual income/benefit for CEBAF practice was much higher (9.76 times) than the PLAF practice. Consistent with this result, Rahman *et al.* (2007) reported that a multi-strata agro-forestry system was more beneficial than the traditional mono-cropping system where the gross benefit from the multi-strata agro-forestry system was 14.2 times higher than the gross benefit from a traditional monoculture.

3.6.1. Profitability analysis

Results of the cost-benefit analysis revealed that the returns to labour (NPV) of CEBAF practice was 33.63 times higher than that of the NPV of the PLAF practice (Table 4). Returns to labour (RL) of CEBAF practice was also 7.63 times higher than RL of the PLAF practice.

Table 4. Profitability evaluation of CEBAF and PLAF practices

Criteria	PLAF	CEBAF	Relative (PLAF = 100 %)
NPV (Birr/ha)	29817.90	1002867	3363%
RL(Birr/person-day)	21.46	163.78	763%

PLAF=Parkland Agro-forestry; CEBAF=Coffee-Enset-Based Agro-forestry

Likewise, in a case study of the degraded agricultural lands, Rasul and Thapa (2006) reported that economic returns from agro-forestry were greater than shifting cultivation. They also described that the higher cash incomes provide greater "buying power" with respect to food, especially when agriculture is not practised, or when the crops fail. A study by Rahman *et al.* (2007) also showed that the NPV of a multi-strata agro-forestry system was five times higher than the NPV of a traditional monoculture.

3.6.2. Sensitivity analysis

The sensitivity analysis showed that the NPV was highly sensitive to the worst case scenario (10 % increases in discount rate, wage increase as well as 10% decreases in yield). It was 20.77% and 79.30% less than the base NPV of CEBAF and PLAF practices, respectively (Table 5).The NPV was more sensitive to yield increase/decrease and was 17.39% and 45.38% less than the base NPV of CEBAF practice and PLAF practices, respectively. Hence, the household has to intensively manage the plants constituting the CEBAF and PLAF practices to avoid decreases in yield. In the same way, the NPV was more sensitive to wage increase. It was 11.16% and 30.95% less than the base NPV of CEBAF practice and PLAF practice, respectively.

Table 5. Sensitivity analysis with change in the key variables

Change of key variable	NPV of PLAF (%)	NPV of CEBAF (%)
Yield increase (10%)	145.38	117.39
Yield decrease (10%)	54.62	82.61
Discount rate increase (10%)	91.60	89.66
Wage increase (10%)	69.05	88.84
Best case scenario	192.20	224.50
Worst case scenario	20.70	79.23

NPV= Net Present Value; PLAF=Parkland Agro-forestry; CEBAF=Coffee-Enset-Based Agro-forestry

Results of the sensitivity analysis showed that high rate of discounting affects CEBAF practice negatively; this is because the main benefits obtained from the plant constituting the CEBAF practice accrues from the fourth year onwards after planting through the twenty-five year period in contrast to PLAF practice, where the main benefits obtained from plant components accrues from the first year onwards after planting/sowing up to a twenty-five year period. Similar results were reported by different researchers. For instance, Ajayi *et al*. (2009) reported that increases in discounting rate negatively affected net profit for all practices (continuous maize cropping without fertilizer, continuous maize cropping with fertilizer, *Gliricidia*-maize intercrop, *Sesbania*-maize rotation and *Tephrosia*-maize rotation). The different effects may have resulted from the variations in time at which the benefits were obtained, *i.e*. the main benefits from agro-forestry practices were obtained from in the third through the fifth year only in contrast to the conventional practices where benefits (maize yield) accrued throughout the five-year period.

4. CONCLUSION

The result of the profitably analysis showed that both CEBAF and PLAF practices were economically profitable (NPV > 0 and RL > opportunity cost of household labour). Nevertheless, the CEBAF practice was economically more profitable than the PLAF practice. The results of the sensitivity analysis indicated that the NPVs of both agro-forestry practices were highly reduced with reasonable increases in discount rate and labour wage, and a decrease in crop yield. Even though the NPVs from both practices were still positive under the worst case scenario analysis (i.e. simultaneous increases in discount rate and labour wage as well as reduction in crop yield), the CEBAF practice showed better economic performance and less risks than the PLAF practice. Therefore, to maximize profits from their land and resource inputs, it is recommended that smallholder farmers in the district adopt the coffee-enset based agro-forestry (CEBAF) practice.

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SELECTION OF TREE SPECIES FOR AGRO-FORESTRY AND PLANTATION DEVELOPMENT WITH PARTICULAR EMPHASIS ON DOMESTICATION AND CONSERVATION

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ABSTRACT

Scarcity of firewood and other biomass energy supply, the need for conservation of genetic resources, and ease of adaptability calls for managing, conserving and utilizing remnant indigenous tree species in high forests and woodlands. Accordingly, selection of indigenous tree species for domestication for agro-forestry and plantation was carried out at Yayu and Harenna high forests as well as at Delomena and Moyale woodlands of Ethiopia. Transect walk and interviewes with key informants drawn from agricultural and pastoral households were conducted to explore preferences for tree species. The respondents revealled that 90, 88, 99, and 100% of the households in Harena, Delomena, Yayu and Moyale areas , respectively, gathered and used forest products. Similarly, 56, 39, 35 and 46 potential tree species in Moyale, Yayu, Harena and Delomena, respectively, were identified as suitable for plantation or agro-forestry purpose.The indigenous trees species most prefered foragro-forestrywere *Grewia villosa*, *Albizia schimperiana*, *Combretum molle*, and *Cordia africana*with scores 1.2 to 2.5, while the tree species most preferred for plantation were *Commiphora kua, C. africana*, and *C. erythraea* with scores 1.3 to 2.5, respectively, in Moyale, Yayu, Delomena, and Harena areas. The observed variations in storability of seeds of the selected species indicated the need for human intervention for propagation and conservation. Men in woodlands were more knowledgeable than women and woodland residents were more knowledgeable than those in the high forests about the different uses of plants. Farmers' reluctance to plant indigenous tree species was attributed to the presence of off-farm resources, lack of market and land, and poor capacity of institutions. It could be concluded that there are sizable numbers of indigenous tree species that are preferred both for agro-forestry and plantation purposes in the high forests and the woodlands of the country, which present a good opportunities for forest development, biodiversity conservation, and improved livelihoods of people living in the areas.

Keywords: Delomena, Harena, high forests, Moyale, Yayu, woodlands

1. INTRODUCTION

Local people in many parts of Ethiopia perceive that growing indigenous tree species is only nature's work and have no reputable uses. From the 320 commercial known Ethiopian timber producing tree species, only less than 1% [*Juniperus procera*

(Endl.), *Podocarpus falcatus* (Pilger), *Cordia africana* (Lam), *Hagenia abyssinica* (Bruce), *Pouteria adolfifrederici* (Rob and Gilb)], and a few more are used in plantation development (WURC, 1995).

The scarcity of firewood and other biomass energy supply experienced in the country, the need for conserving genetic resources, and ease of adaptability of tree species justify rescuing, managing, and utilizing remnant indigenous tree species in high forests and woodlands. High forests are characterised by trees that develop from seeds and vegetative propagules with tree canopies covering more than 40% and exceeding the height of five metres, including natural forests and forest plantations. Woodlands are characterised by trees with a 5-10% canopy cover and a height exceeding five metres or by a shrub or bush cover of more than 10% and a height of less than five metres (FAO, 2000).

In many parts of Ethiopia, scattered indigenous trees are commonly maintained in farm plots, roadsides, residential compounds, and mountainous areas after clearing the original dense vegetation. Trees that form components with food crops or livestock on cropland, pastureland or home garden are considered as farm trees (Leakey and Simons, 1998) (hereafter referred to as agro-forestry tree species). Trees grown in a monoculture or mixed stands are considered as out of farm or off-farm plantations (Ford-Robertson, 1971; Evans, 1992) (hereafter referred to as plantation species).

The attitude of people towards different uses of trees and the desired characteristics of trees determine the domestication of tree species for agro-forestry and plantation purposes. Agro-forestry tree species are known to improve soil fertility, provide shade, shelter, food, feed, or firewood, and improve the growth and welfare of neighbouring plants and animals (Leakey and Simons, 1998). Plantation tree crops fulfil the criteria for use as agro-forestry tree crops or woody plant species and produce quality lumber or have high calorific value for firewood in domestic or industrial uses (Evans, 1992).

Experiences of other African countries show significant impact of forest research on agro-forestry and plantation development (Kiwuso *et al*.,2002; Nshubemuki and Mugasha, 2002; Oballa, 2002). However, most of the forest research activities in Ethiopia focused mainly on introduction of exotic tree species for the purpose of industrial wood (lumber, veneer, etc). Limited studies have been conducted on selection of indigenous tree crops for domestication and conservation in the country. Therefore, the objective of this study was to select indigenous tree species from high forests and woodlands for agro-forestry and plantation purposes using indigenous knowledge of farmers.

2. MATERIAL AND METHODS

2.1. The study Area

The study was conducted in 2008 at four forest sites, in two high forests (Yayu and Harena) and two woodlands (Delomena and Moyale). Yayu is located at 8°20ˈN and 35°55ˈE and 1200-2500 m above sea level, at the distance of about 560 km from Addis Ababa in the south-westerly direction. Harenna is an Afromontane forest, which is located at 60 02'N and 39° 45ˈE and 1,300 - 3000 m above sea level, at the distance of about 530 km from Addis Ababa in the south-easterly direction. Harenna and Delomena are located in the same district. Delomena is located at the distance of 21 km south of Harena forest at the elevetion of above 1,500 m above sea level. Moyale is located at 3° 68'N and 38° 61ˈE and 1,150 to 1,350 m above sea level, at the distance of about 700 km from Addis Ababa in the southerly direction (Figure 1).

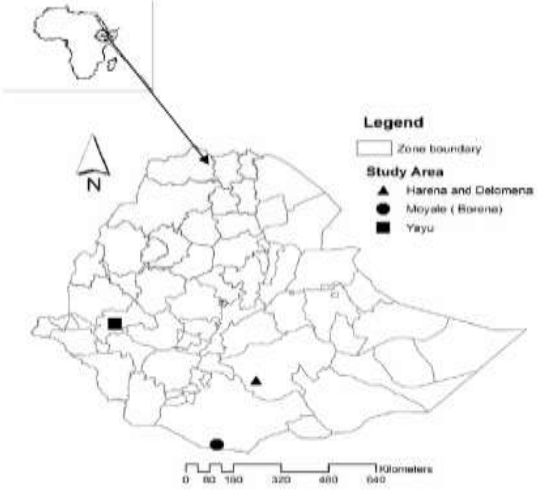

Figure 1. Map of the study area

2.2. Data Collection and Analysis

Informal and formal surveys were conducted using questionnaires and focus group discussions. In the informal survey, reconnaissance assessment and Participatory Rural Appraisal (PRA) tools were used for eliciting background information. Households were selected based on proximity to the forest for extraction of forest products. The formal survey was conducted at two stages using a purposive sampling technique. At the first stage, the survey was done systematically by selecting groups of households living around the forests. At the second stage, the structured, semi-structured, and open-ended questionnaires were pre-tested by selecting five households randomly interviewing them at each site. Transect walks were made with key informants and Natural Resources Department officials to discuss the preference

of local people for indigenous tree species. After preparing the final questionnaire, 30 households were interviewed at each site concerning their preferences for tree species aimed at domestication and conservation, and to develop agro-forestry and plantations forests (Dery *et al*., 1999).

The responses in the questionnaires were categrorized and the preferred tree species were prioritized and analysed using SPSS version 12 and excel 2003 by the methods of free listing (Bernard, 2000; Biggerlaar and Good, 1996). The frequency of mentioning by 30 interviewees and the 1-5 rank mean of each species was calculated as position or score. The prioritized tree species were validated through a workshop held with farmers, pastoralists, and experts working in natural resources management and agriculture sectors.

3. RESULTS AND DISCUSSION

90, 88, 99 and 100 percent of the respondents noted that forestry products are gathered and used by any person with no ristriction at Harena, Delomena, Yayu, and Moyale study sites, respectively. On average, 80 percent of the interviewed households in the high forest areas responded similarly that they had no knowledge about the silvicultural attributes of individual tree species. The local people reportedly use the available trees in the high forests and woodlands, but have no drive to know the silvicultural attributes of the trees. However, the respondents had good knowledge about the diversity, abundance, and regeneration status of the indigenous tree species in their vicinities. Furthermore, farmers have considerable knowledge about different values of native trees species. The survey results also revealed that older people are more knowladgable about plants and their uses than younger people. In addition, in comparison to men, women are less knowledgeable about the different uses of plants except those who descended from families that know and have expertise on traditional herbal medicines. The above differences in knowledge about the uses of plants between women and men could also be ascribed to the fact that the former often cut down large trees for construction of houses and the latter merely collect faggot and dried twigs for use as firewood. Farmers and agro-pastoralists revealed that they had immediate interests in domesticating and conserving tree species (Tables 1 and 2) for agro-forestry and plantation development provided that the constraints mentioned at different points in this study were removed. The ranks or position of tree species that the local people would like to domesticate and conserve (Tables 1 and 2) showed that the most prefered tree species forthe agro-forestrypurpose were *Grewia villosa* (score1.2), *Albizia schimperiana* (score2.1), *Cordia africana* (score2.0), and *Combretum molle* (score2.5)inMoyale, Yayu, Harenna, and Delomena, respectively (Table 1).

Table 1. Most preferred tree species for agro-forestry

Botanical name	Moyale		Yayu		Harenna		Delomena	
	Frequency	Position	Frequency	Position	Frequency	Position	Frequency	Position
Grewia villosa	30	1.2						
Grewia bicolor	30	2.2					24	3.4
Boswellia neglecta	27	3.5						
Delonix elata	24	4.4						
Albizia schimperiana			29	2.1	26	3.1		
Cordia africana			30	3.3	29	2.0		
Acacia spp.			28	4.0				
Albizia gummifera			26	5.1				
Millettia ferruginea			29	6.2	30	6.7		
Mimusops kummel					27	4.4		
Vepris dainelli					24	6.7		
Persea americana							28	1.5
Mangifera indica							25	1.8
Combretum molle							30	2.5

Similarly, the most preferred plantation tree species were*Commiphora kua* (score *1.3*), *Eucalyptus* spp. (score 1.9), *Commiphora erythraea* (score 1.3), and *Eucalyptus spp.* (score 1.4), respectively, in Moyale, Yayu, Delomena, and Harenna. Common fruit tree like *Persea americana* and *Mangifera indica* were listed in the top five preferred plants to be grown for agro-forestry purpose.

Table 2. Most preferred tree species for off-farm plantation development

Botanical name	Moyale		Yayu		Harenna		Delomena	
	Frequency	Position	Frequency	Position	Frequency	Position	Frequency	Position
Commiphora kua	30	1.3						
Boswellia neglecta	30	1.9						
Acacia senegal	26	2.7						
Terminalia brownii	30	3.3						
Delonix elata	27	4.9					26	4.4
Eucalyptus spp.			30	1.9	30	1.4	23	2.5
Cordia africana			30	2.6	28	2.5		
Podocarpus falcatus			27	3.5	29	4.9		
Aningeria adolfi-friederici			24	5.2				
Prunus africana			22	7.0				
Warburgia ugandensis					26	6.6		
Olea capensis					21	7.1		
Tamarindus indica								
Commiphora erythraea							30	1.3
Berchemia discolour							27	5.0

The respondents indicated that the longevity of seed of the selected tree species ranges from recalcitrant to orthodox. Getting seeds at the time when needed for planting is not easy in the areas since seed storage is not possible for some species like *Aningeria adolfi-friedericii, Combretum molle, Millettia ferruginea, Mimusops kummel, Olea capensis, Prunus africana, Warburgia ugandensis.* Therefore, *in situ* conservation is the best alternative for these species. In this connection, area closures and cut-and-carry system of livestock feeding is of vital importance to protect the trees from extinction.

The local people have a long tradition of using plant species as the main sources of medicine against both human and livestock diseases. For example, *Delonix elata* is known to cure diseases associated with helminth in Delomena area.
In Moyale, both the indigenous knowledge and some tree species have become threatened. For example, *Trichilia emetica* which is useful for making local soap and cosmetics, wood oil, and for treating skin disease (Miftah Fekadu and Temesgen Yohannes, 2004), has been threatened by over exploitation. In addition, low and unreliable rainfall and lack of sedentary life among pastoral communities has hindered the prospect of tree planting and care.

Given that shortage of livestock feed is the major challenge faced by the society, domestication and conservation of the tree sepecies identified (Tables 1 and 2) could be one strategy to allevate the problem and enhance food security in the region. The sensitization workshop confirmed that agro-pastoral communities have started domestication of some of the identified tree species.

At Yayu, a small-scale wood enterpreuner has now started using the less known tree species. However, because of the poor timber quality of the less known tree species, farmers are unenthusiastic to domesticate and conserve the prioritized tree species. We observed that exploitation of the tree species merely by waiting for the trees to regenerate naturaly is not tenable to meet the demand of society for firewood and constraction material. Similarily, lack of seedlings and knowledge of propagation, and the associated weak instititutional supports for domestication and conservation of the tree species is also the another major problems.

At Harena, many useful indigenous plant species are gradually disappearing because of the expansion of agriculture at the expense of forest resources. Migrant farmers do not manage the land as sustainably as native farmers. However, both native and migrant farmers conserve high value medicinal trees, e.g. *Warburgia ugandensis*. However, more than 95% of the respondents indicated that they do not want to plant trees on farm land since trees compete with agricultural crops. More than 80 perecent of the respondents indicated that they are not interested in plantingdifferent tree speciesbecause of freely availabe sufficient wood from the natural forest.

The results of the study have also clearly revealed the following constraints:
Constraints that hinder tree/shrub conservation

- Availability and access to off-farm resources by farmers, poor productivity and agricultural expansion
- Lack of reward for conservation of indigenous tree products and wild environment
- Lack knowledge about the value of wild resources products and ecological services
- Lack of attention to conserve wild ecosystems and consideration of wild ecosystems as free goods with no clearly defined ownership

Constraints that hinder tree planting

- Competition between trees and crops, reduction in the cropping area, and increasing damage from birds roosting on trees
- The silviculture of most indigenous tree species is unknown
- Poor extension service given to natural resource management, forestry, and related activities
- Lack of a responsive and enabling farm forestry, domestication policy, and marketing infrastructure

The contribution that domesticated indigenous wild trees make to the livelihoods of many farmers is often not acknowledged by Bureaus of Agriculture (BoA). Reduction of the pressure from the remaining forest and improvement in the livelihood of subsistence of farmers could be achieved through selection of important wild trees species and making concerted efforts towards domestication and conservation. Seed security of the tree species and, knowledge on the propagation is achievable only through participatory conservation.

For selecting the most important wild tree species, a long-term ethno-botanical programme is required. The domestication and conservation of indigenous trees for the production of different products within the agro-forestry practices, for example, has been suggested as a sustainable means of promoting the reduction of poverty in tropical countries (Leakey and Simons, 1998). Domestication and conservation of wild plants is the most viable factor that can substantially protect the erosion of genetic diversity (Shrama 2004; Persley, 1992). All extension staff felt that insufficient attention has been given to the development and management of the tree crops. The natural resources development agents need to look imaginatively at the needs of the farmers and provide them with planting materials and technical knowledge to develop the forest sector. The training that most extension staff have so far acquired excludes skills required in tree and forest management. Therefore, there is a vital need for farmer-to-farmer extension and knowledge and capacity exchange in the domestication, management, and conservation of the untapped underutilized tree species. Industrial development of forest products in Ethiopia could be realized

by domestication and conservation of high value but new timber, oil and cosmetic producing wild plant species (Henry and Grindley, 1994; Miftah Fekadu and Temesgen Yohannes, 2004).

The BoA should promote, through further training and field exercises, a more interactive form of extension whereby extension officers become facilitators to encourage farmers to plant economically and ecologically suitable trees. Such related experience has been successful in Ha Bac Province in Northern Vietnam (Neave and Quang, 1994). Domestication should be looks at not only from farmers' points of view but also from the point of view of the need to rehabilitate and increase the forest cover of the country. There is increasing evidence that smallholders are key for the success of reforestation efforts in the tropics (Garrity, 1994; Pasicolan, 1996).

4. CONCLUSIONS

The results of the study have demonstrated that farmers and pastoralists inhabiting the areas of Yayu, Harena, Delomena, and Moyale forests use the tree species for different purposes. However, the result signify that the farmers and pastoralists need specific training and capacity building to acquire skills for domestication, conservation, and sustainable utilization of indigenous trees and shrubs. Therefore, efforts should be exerted to make the agricultural and agro-pastoral communities aware of the environmental and economic values of indigenous tree species that provide wood and non-wood products to create new market opprtunities and income for the inhabitants. It is also necessary that policy makers design participatory and comprehensivestrategies for promoting domestication and plantation of indigenous trees. This process should be backed by scientific evidence generated through research for verifying the use values of the tree species intended for domestication, plantation, and conservation. These efforts need to be backed by adequate and detailed silvicultural and ethno-botanical data.

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Appendix Table 1. Major tree species of the study area

No.	Scientific name	Vernacular name	Family	Study area			
				Moyale	Yayu	Harena	Delomena
1	*Acacia abyssinica*	Ambo	Mimosoideae	x			
2	*Acacia albida*	Gerbi	Mimosoideae			x	x
3	*Acacia brevispica*	Hamaresa	Mimosoideae	x			x
4	*Acacia busie*	Hallo	Mimosoideae	x			
5	*Acacia lahai*	Burquqe	Mimosoideae	x	x		x
6	*Acacia seyal*	Wacho	Mimosoideae	x			
7	*Acacia sieberiana*	Bura (Gurcha)	Mimosoideae	x			
8	*Acacia tortilis*	Tedecha	Mimosoideae	x			
9	*Acacia xiphocarpa*	Dadetcha	Mimosoideae	x			
10	*Acokanthera schimperiana*	Karachu	Apocynaceae	x	x		
11	*Albizia grandibracteata*	Alele	Mimosoideae		x		
12	*Albizia gummifera*	Sasa	Mimosoideae	x			
13	*Albizia shimperiana*	Ambobesa	Mimosoideae		x		
14	*Aningeria adolfi-friederici*	Guduba	Sapotaceae	x	x	x	x
15	*Aningeria altisma*	Keraro	Sapotaceae	x			
16	*Apodyte dimidiata*	Mewa	Icacinaceae		x		x
17	*Balanites aegyptiaca*	Bedana	Balanitaceae	x			
18	*Berchemia discolour*	*Jejeba*	Rhamnaceae		x		x
19	*Bridelia micrantha*	Rigaraba	Euphobiaceae		x		
20	*Calpurina sp.*	Cheketa	Papilionaceae	x			
21	*Canthium oligocarpum*	Metekoma	Rubiaceae			x	
22	*Capparis cartilaginea*	Gora	Capparidaceae			x	
23	*Carisa edulis*	Agamsa	Apocynaceae			x	x
24	*Combretum guenzii*	Bika	Combretaceae	x			x
25	*Combretum molle*	Rukesa(Didisa)	Combretaceae	x			x
26	*Commiphora confusa*	Hamesa	Burseraceae	x			x
27	*Commiphora erythraea*	Hagarsu(Hagar)	Burseraceae	x			
28	*Commiphora habessinica*	Chalenga(qa)	Burseraceae	x			
29	*Cordia africana*	Wodesa	Boraginaceae	x	x	x	x
30	*Croton macrostachyus*	Mekenisa	Euphorbiaceae	x	x	x	x
31	*Dalbergia lactea*	Sarte	Papilionoideae		x		
32	*Delonix elata*	*Sukela*	Caesalpiniaceae		x		x
33	*Diospyros abyssinica*	Loko	Ebenaceae	x	x	x	x
34	*Diospyros mespliformis*	Tile	Ebenaceae	x			
35	*Dodonea angustifolia*	Etecha	Sapindaceae	x			
36	*Ehretia cymosa*	Hulaga (Ulaga)	Boraginaceae	x	x	x	x
37	*Ekebergia capensis*	Sombo/Uma	Meliaceae		x	x	x

		a					
38	*Embelia schimperi*	Hanqu	Myrsinaceae			x	x
39	*Erythrina abyssinica*	Wolensu	Papilionoideae	x	x		x
40	*Euclea schimperi*	Meisa	Ebenaceae				
41	*Euphorbia candelabrum*	Adami	Euphorbiaceae		x		
42	*Fagaropsis angolensis*	Dhero (Ero)	Rutaceae	x			
43	*Ficus sur*	Arbu (shola)	Moraceae		x	x	x
44	*Ficus ovata*	Dembi	Moraceae	x			
45	*Ficus sycomorous*	Oda	Moraceae	x	x	x	x
46	*Ficus vasta*	Kilta/ Dembi (warka)	Moraceae	x	x		
47	*Filicium decipiens*	Chenea	Sapindaceae			x	x
48	*Flacourtia indica*	Akoku	Flacourtiaceae	x		x	
49	*Galiniera saxifraga*	Adama	Rubiaceae	x			
50	*Gardenia lutea*	Gamela	Rubiaceae	x			
51	*Grewia bicolour*	Haroresa	Tiliaceae	x			x
52	*Grewia fallax*	Ogomdi	Tiliaceae	x			
53	*Grewia ferruginea*	Bruri/ Dokenu	Tiliaceae	x	x		x
54	*Grewia tenax*	Eka (Dheka)	Tiliaceae	x			
55	*Hyphaene thebaica*	Meti	Palmae				x
56	*Juniperus procera/ excelsa*	Hinesa	Cupressaceae		x	x	x
57	*Justicia schimperiana*	Dumuqa	Acanthaceae		x		
58	*Maerua sp.*	Kelkalcha	Capparidaceae	x			
59	*Maesa lanceolata*	Abeyi	Myrsinaceae		x		
60	*Millettia ferruginea*	Dadtu/ sotelo	Papilionoideae		x	x	x
61	*Mimosopus kummel*	Kolati	Sapotaceae	x	x	x	x
62	*Morus mesozyga*	Sacho	Moraceae		x		
63	*Ocotea kenyensis*	Deressa (Danisa)	Lauraceae	x			
64	*Olea capensis sub sp. capensis*	Onema	Oleaceae			x	x
65	*Olea capensis sub sp. hochesteteri*	*Egersa*	Oleaceae				x
66	*Olea capensis sub.sp. welwistchii*	*Gegema/Sigida*	Oleaceae		x	x	x
67	*Olea europea sub species africana*	Ejersa	Oleaceae	x	x	x	
68	*Oncoba spinosa*	Jilbo	Flacourtiaceae	x			
69	*Phytolaca dodecandera*	Indod	Phytolacaceae		x		
70	*Piliostigma thonningii*	Kora	Caesalpinioideae	x			
71	*Pittosporum abyssinincum*	Geda(Gedal)/ Ch'eka	Pittosporaceae	x			
72	*Pittosporum viridiflorum*	Bacho	Pittosporaceae				x
73	*Podocarpus falcatus*	Birbirsa	Podocarpaceae		x	x	x
74	*Polyscias fulva*	Koriba	Araliaceae			x	x
75	*Protea gauguedi*	Alo(Alkebesa)	Proteaceae	x			
76	*Prunus africana*	Omi/ Suke	Rosaceae		x	x	x
77	*Psydrax*	Gale	Rubiaceae			x	x

	schimperiana						
78	*Rhus glutinosa*	Tatessa	Anacardiaceae	x	x		
79	*Rhus natalensis*	Debobesa	Anacardiaceae	x		x	x
80	*Rhus vulgaris*	Marero/Mandhera/ Tatisa	Anacardiaceae	x		x	x
81	*Ricinus communis*	Qobo	Euphorbiaceae		x		x
82	*Sapium ellipticum*	Bosoqa (Bokosa)	Euphorbiaceae	x			
83	*Schefflera abyssinica*	Getema	Araliaceae		x		
84	*Schrebera alata*	Dhame (Temey)	Oleaceae	x			
85	*Strychnos mitis*	Mulka	Loganiaceae				x
86	*Syzgium guineense*	Bedesa	Myrtaceae		x	x	x
87	*Syzgium guineense sub.sp. macrocarpa*	Gootu	Myrtaceae		x	x	x
88	*Tamarindus indica*	Roqa	Caesalpinioideae	x			
89	*Teclea nobilis*	Hadhesa/ Hirqe/ Chedea	Rutaceae	x	x	x	x
90	*Trichilia dregeana*	Luya	Meliaceae		x		
91	*Trichilia emetica*	Anona	Meliaceae	x			
92	*Vepris dainellii*	Arabe	Rutaceae			x	x
93	*Vernonia amygdalina*	Ebicha	Asteraceae		x	x	x
94	*Vernonia auriculifera*	Reji	Asteraceae		x		
95	*Vigna unguiculata*	Katetisa (kotate)	Papilionaceae				x
96	*Viola eminii*	Shilafu	Violaceae		x		
97	*W.ugandensis*	Beftii	Canellaceae			x	x
98	*Ximenia americana*	Huda (Udha)	Olacaceae	x		x	x
99	*Ziziphus mauritiana*	Kukura	Rhamnaceae	x		x	x
100	*Ziziphus mucronata*	Qurkura	Rhamnaceae				x

CATTLE AND CAMEL POPULATION DYNAMICS AND LIVELIHOOD DIVERSIFICATION AS A RESPONSE TO CLIMATE CHANGE IN BORANA ZONE, ETHIOPIA: ITS IMPLICATION FOR THE CONSERVATION OF THE BORANA CATTLE

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ABSTRACT

The objective of this study was to assess cattle and camel population dynamics and its implication on species conservation, and livelihood diversification of pastoralists. Cattle and camel population dynamics, and household incomes were quantified using herd histories and interviews of 51 households in three districts. The result indicated that 27 (52.9 percent) of the respondents didn't have any camel 20 years-ago, whereas at present, 12 (22.9 percent), 24 (47.7 percent) 10 (19.6 percent) and 5 (9.8 percent) possess more-than 30, 20-30,5-20 and 2-5 camels, respectively in their herd. Before 20 years 80.4 percent of the households had more that 40 cattle in their herd. At the moment, 30 (58.8 percent), 17 (33.7 percent), and 4 (7.8 percent) of the households possess 20-40, less than 15, and 0 cattle in their herd, respectively. All interviewed pastoralists reported that they would like to increase camel population and reduce the number of cattle in their herd in the future. This change in population dynamics might be a result of the climate change due to change in vegetation struction of pastureland. Therefore, the effect of climate change may place the Borana cattle breed at risk in the near future. Therefore, appropriate restocking, quick identification, and implementation of conservation strategies of Borana cattle is urgently needed.

Keywords: Herd, livelihood diversification, pastoralists, restocking, threat

1. INTRODUCTION

The Borana people are pastoral communities, their livelihood mainly depend on livestock production. Cattle are the dominant livestock species in their herd. The Borana region is known for producing high quality cattle and other livestock species. However, the sustainability of this pastoral production system and people's livelihood has been questioned during the last few decades. Climate variability is considered as a major threat to the pastoral economy (Cossins and Upton, 1988). The trend in climate changes in the past 50 years, and projection for the next 20 years in East and South Eastern pastoral zones of Ethiopia showed a north-west ward retreat

in *Belg* rain with about 250 mm decline in the rain (FEWSNET, 2012). The anticipated drop in rainfall will cause a reduction in the quantity and quality of viable pasturelands. Moreover, the frequent droughts in these areas are making it difficult for livestock to recover during the poor rainy seasons.

Earlier evidence from the 1980s and 1990s estimated that 37 percent and 42 percent of the cattle population in Borana were lost due to the impact of drought (Desta and Coppock, 2002). Studies conducted in southern Ethiopia indicated that cattle holdings fell from an average of 92 to 58 cattle per household in 1980 and 1997, respectively showing an overall net drop of 37 percent in cattle population during these period (Solomon and Coppock, 2002). The change in livestock dynamics is mainly attributed to climate change (Hoffmann, 2010; Thornton and Gerber, 2010). Cossins and Upton (1988) and Ayana and Oba (2007) revealed that cattle herd dynamics in Southern Ethiopia is strongly determined by rainfall variability rather than the stocking rate used by pastoralists. Many studies have been undertaken and variable conclusions have been made regarding the loss and disaster that occurred on the Borana pastoralists and their animals during the past 20 to 30 years. However, no concrete measures were taken to conserve the Borana cattle breed, which is at risk because of the dynamics in livestock population to cope with change in the environment. Even though, there is an initiative to have a Boran cattle improvement ranch at Yabelo by Oromia agricultural Research Institute, some ranch such as Adami Tulu-Abernosa, which have been used as an *ex-situ* site to conserve the Borana cattle breed.

For indigenous breeds, it is appropriate to assess and model the likelihood, speed, and impact of the various aspects of climate against genetic evolution of livestock and use the results to guide the need for interventions. Absence of scientific studies, lack of selection for breeds with effective thermoregulatory control, failure to include relevant traits in relation to climate change in breeding indices, and the failure to consider genotype by environment interaction to identify animals most adapted to specific conditions will lead to the reduction of variations that exist within the breeds. Lack of appropriate indigenous cattle ecotypes conservation effort will contribute to the decline of Ethiopian cattle diversity. Solomon *et al*. (2011) also revealed the presence of low level of genetic differentiation between Abigar, Borana, Horro, Sheko, and Guraghe breeds. The loss of genetic resources of the indigenous cattle population might be due to drought (lack of grazing land), disease, and introduction of exotic breed. The Borana, Arsi, Ambo, Adwa, Ogaden, Horro, Fogera, Raya-Azebo, Danakil, and Sheko, are at risk of becoming genetically homogenous unless effective and appropriate breeding management practices are implemented (Dadi *et al*., 2008).

Though efforts made by pastoralists were not sufficiently supported by scientific methods to reduce the impact of climate change and other disturbances, they have

taken different mitigation strategies. Different studies (Kaufmann and Binder, 2002; Jones and Thornton, 2008) indicated that raising camels may replace crops and other livestock in the hardest-hit arid areas of the African continent. The potential of camels in arid and semi-arid areas, such as for generating milk or providing income from their sale was initially dismissed by communities, being considered as uneconomical (Sperling, 1987). However, at the present as a result of climate change their value is becoming increasingly acknowledged (Care Ethiopia, 2009). A typical example of this is an increasing number of camel population in Borana pastoral community in response to changing ecology and feed availability. It seems logical to rely more on browsing animals as the rangeland is often covered by bushes and trees and make economic use of them feasible (Kejela *et al*., 2005). This has therefore, triggered changes in livestock composition.

Diversification of income is a long practiced strategy by many livelihoods in order to reduce risk of external shocks, since different sources of income are likely to be affected differently by external shocks. Income diversification is key for risk management and will help vulnerable pastoral households to meet and smoothen consumption, social and labour needs and develop incomes. Therefore, the objectives of this paper were to assess cattle and camel population dynamics in response to climate change and its implication on species conservation, and livelihood diversification of pastoralists.

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted in Moyale, Mega, and Yabelo districts of Borana Zone of the Oromia Regional State. Two Pastoral *kebeles* from each district were selected purposely. The study districts are geographically found at 3° 30'N-5° 30'N Latitude and 39° 00'E-41° 00'E Longitude.

2.2. Methods of Data Collection and Analysis

Cattle and camel population dynamics, and household incomes were quantified using herd histories and interviews of 51 households. Data collection was conducted using semi-structured questionnaire based on the wealth strata with trained enumerators who speak the local language. Wealth classification was done based on the number of cattle and camel in a household. Rapid Rural Appraisal technique was used to collect information on the perception of pastoralists and historical perspectives of cattle and camel rearing. Group discussion with elders per site was undertaken. The data were analyzed using SAS (2008).

3. RESULTS AND DISCUSSION

3.1. Results

The contribution of cattle was higher in Yabello than Moyale districts whereas the contribution of camel is slightly higher in Moyale (Table 1). Both districts earned income from livestock mainly from camel, goat, and cattle. Livestock contributed about 65-70 percent of the household income (Table 2). The contribution of crop and trade to the household income in Moyale district was a little bit higher than Yabelo district.

Table 1. Contribution of livestock species to pastoralist households' income in Borena zone.

Districts	Household frequency	Percent	Livestock species	Rank	Livestock species	Rank
Yabelo	20	76.92	Camel	1	Goat and cattle	2
	6	23.08	Cattle	1	goat and camel	2
Moyale	22	88.00	Camel	1	Goat and cattle	2
	3	12.00	Cattle	1	Goat and camel	2

Table 2. Sources of pastoralist households' income in Borena zone.

Districts	Household frequency	Percent	Primary household income	Secondary household income
Yabelo	5	19.23	Livestock	Trade (15%) and crop (15%)
	21	80.77	Livestock (70%)	
Moyale	7	28.00	Livestock	Trade(30%) and crop(5%)
	18	72.00	Livestock (65%)	

Camel was the most important animal to pastoralists' households as a source of income and livelihood, prestige, adaptation to harsh environment, amount and frequency of milking per day in all the study districts (Table 3). In the two districts, the importance of camel is higher and cattle are lower in Moyale than Yabello district. Goat follows camel in importance while sheep and cattle generally seem to be the third and fourth, respectively, important animals in the pastoral areas.

Table 3. Overall importance of livestock species as perceived by pastoralist households' in Borena zone.

Districts	House hold frequency	Percent	Livestock species
Yabelo	20	76.92	Camel
	6	23.08	Cattle
Moyale	22	88.00	Camel
	3	12.00	Cattle

Perception of pastoralists regarding trend of camel populations and camel number showed that the number of camel in the herd was increased, and will increase in the future (Table 4). Borana pastoralists did not rear camel before 20 years, whereas the number of camel at present was higher. This indicated that camels are becoming important livestock species.

Table 4. Trends of camel population dynamics in the past 20 years and the future projection in Borena zone.

Districts	Current camel number	No. of respondent	Percent	Camel no. before 20 years	No. of respondent	Percent	Future projection	No. of respondents	Percent
Yabelo	5-10	7	26.92	<10	12		Increase		
	10-15	18	69.23	Absent	14	46.15		26	100
	>15	1	3.85						
						53.85			
Moyale	<10	9	36.00	<15	11	44.00		25	100
	10-20	12	8.00	Absent	14	56.00	Increase		
	>20	4	16.00						

The study showed that the population of cattle per household were reduced, compared to the report before 20 years ago (Table 5). It is expected that the number of cattle intend to decrease for the next 10 years.

The number of camels to classify in wealth category in Yabelo districts was lower than Moyale district. In the contrary, the number of cattle to classify wealth category in Yabelo district is higher than Moyale district. From the two districts more number of cattle and camel were owned by Yabelo and Moyale communities, respectively (Table 5 and 6).

Table 5. Relationship of wealth status with number of camel owned in Borena zone

Districts	Camel number	Wealth	Frequency	Percent
Yabelo	>10	Rich	5	19.2
	3-10	Medium	12	46.2
	<3	Poor	7	26.9
	None	destitute	2	7.7
Moyale	>15	Rich	4	16.7
	5-10	Medium	14	58.3
	<5	Poor	4	16.7
	None	destitute	2	8.3

Table 6. Relationship of wealth status with number of cattle owned in Borena zone

Districts	No. of cattle	Wealth	Frequency	Percent
Yabelo	30-40	Rich	7	26.9
	15-30	Medium	12	46.2
	<15	Poor	6	23.1
	None	Destitute	1	3.80
Moyale	20-30	Rich	4	16.7
	10-20	Medium	10	41.7
	<10	Poor	7	29.2
	None	Destitute	3	12.4

The Central Statistics Agency (CSA) Agricultural Sample Survey of 1997-2011 report (Table 7 and Figure 1) also showed that the cattle population in Borana was on a decreasing trend and camel population was increasing. The population of camel in 1999 was higher by 41% than the count in 1998, during which the camel population in the country showed a percentage change of -50%, indicating that the increase in camel population in Borana zone is a real regardless of the situation in other camel rearing areas of the country.

During the 2010 and 2011 Agricultural Sample Survey, the sedentary areas of Borana zone alone recorded camel population of 99,865 and 82,681, which was almost doubled as compared to previous years. These numbers are the highest as compared to any other camel rearing zones of Oromiya National Regional State. However, the 2011 National Agricultural Sample Survey showed that cattle population in Borana zone was the lowest as compared to the count since 1997.

Table 7. Cattle and camel population and percentage change of the rural sedentary areas of Borana zone (Source: Central Statistics Authority (CSA))

	Borena zone	
Years	Cattle	Camel
1997	1,418,900	49,830
1998	1,124690	62,630
1999	990,820	76,290
2000	1,042,450	117,980
2003	987,814	37,805
2004	1,087,127	61,677
2005	1,170,157	38,804
2006	1,176,620	44,306
2010	1,125,594	99,865
2011	983,466	82,681
Percentage change 2011 over 1997	-30.68	+65.92

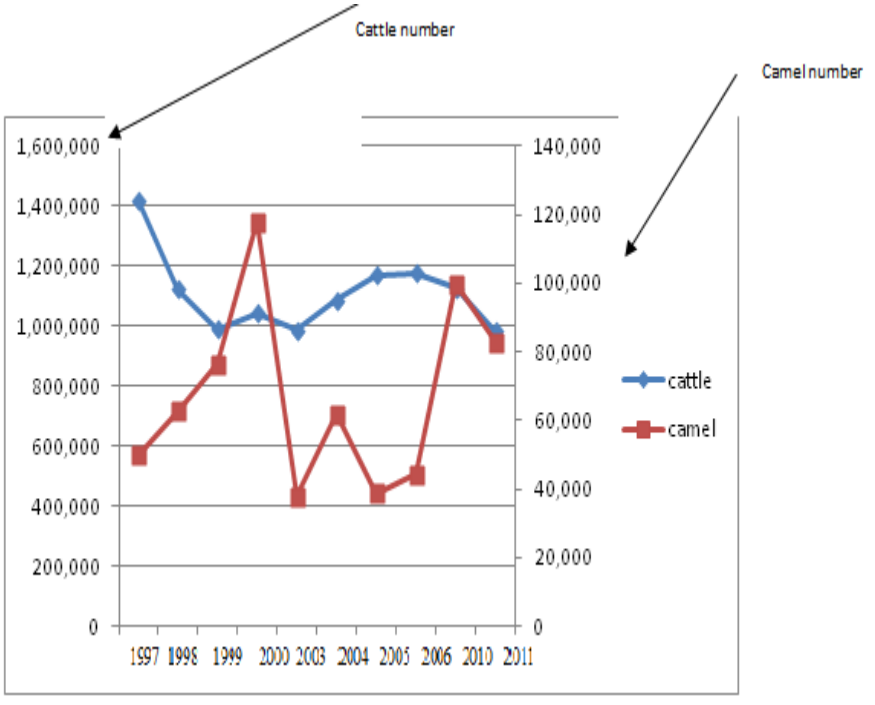

Figure 1. Cattle and camel population change of the rural sedentary areas of Borana zone

3.2. Discussion

In Borena pastoralist, the social and cultural values of households increased with increasing camel number in the recent years, indicating the increased value given by the community to camels than other livestock species. Due to this reason, the main household income generated from camel rather than cattle. This indicates the importance of camel is more in arid areas than cattle under the current scenario of climate change. This is in agreement with earlier studies (Bekele *et al.*, 2008) that noted increased aridity in Borona Zone shifted the principal stock gradually from cattle combined with small stock to camels combined with small stock. Borana pastoralists recognized camels as providing long-term security to beneficiaries in terms of milk production and improved social status (CARE, 2009).

Livelihood diversification is an indicator for the response of pastoralists to avoid risk of losing livestock due to climate change, rangeland degradation, and other factors. In addition, it indicates that productivity of livestock decreased due to the occurrence of multiple droughts in the region, which in turn made income diversification an importance venture to increase income and sustain livelihood. The result of this study was inconsistent with that reported by Little (2001) who noted that livestock herders of East Africa increasingly pursue non-pastoral income strategies to meet consumption needs and to buttress against risky shocks caused by climatic fluctuation, animal disease, market failure, and insecurity. COMESA (2009) also

suggested that income diversification would continue as a risk management strategy, especially in light of the future uncertainties in climate change and food prices.

The present study revealed that the current cattle number was 60 percent less than before twenty years ago, due to low productivity of the rangeland, erratic rainfall, and multiple droughts. Drought induced mortality affected more breeding females and immature animals than mature males in both the ranch and the communal rangeland systems (Ayana, 2007).
Borana area was one of the most affected areas in Ethiopia by the 2011 drought, where a total of about 978,197 head of animals (729,685 cattle, 85,920 sheep and 162,592 goats) were died (OCHA, 2011). The report showed that cattle population has been nearly reduced to the population that cannot be built up easily, since the total cattle population of the Borana zone was estimated at only 1,216,143 before the 2011 draught (CARE, 2009). In describing the lost cattle number, Solomon and Coppock (2002) noted that during the 17 years (1980-97) of study period, the target population of 7,000 pastoral households residing within 35n km radius of the towns of Arero, Mega, Negelle, and Yabello in the north-central region of the plateau lost 700,000 cattle. Similarly, during the 2002-2003 droughts, Ethiopia lost more than 1.4 million animals (ICRC, 2005).

Droughts of the 1980s and 1990s caused 49% herd losses under the communal land use, while 57% of the cattle mortality under ranch management was attributed to droughts of the 1990s (Ayana, 2011). In this regard, Ayana and Oba (2007) concluded that cattle herd dynamics is strongly determined by rainfall variability in southern Ethiopia in both communal and ranch management. It all shows that climate change in Borana zone affected both cattle in communal grazing land and ranch management.

According to FEWS NET (2012) the causes for such huge lose was climate changes observed in the pastoral zones of the country. The climate change occurred for the past 50 (1960–2009) years showed a northwestward retreat of the 250 mm *Belg* season rain (March–June), and projected forward for 2010–2039. The observed rainfall declines during the *Belg* season are reducing the quantity and quality of viable pasturelands. Funk *et al.* (2012) also noted that between the mid-1970s and late 2000s, *Belg* and *Kiremt* rainfall decreased by 15–20 percent across parts of southern, south western, and south eastern Ethiopia. Whatever the case may be, it is evident that more and more pastoralist households, especially the poorer households, are increasingly affected by severe drought, which occurs approximately every 3 to 5 years (Aklilu and Catley, 2010). As a consequence of high loses of cattle due to climate change, respondent pastoralists in the present study area lost interest to raise cattle in the future. Biffa and Chaka (2002) got similar response among pastoralists in Borana zone, and reported that pastoralists started animal species diversification, especially increased camel number to avert uncertainties, as strategy for drought

mitigation and coping up with changing rangeland ecology. The study by Coppock *et al.* (2008) also suggested the importance of motivating pastoralists to consider diversifying assets and incomes to overcome impact of rainfall variability and stocking rate density.

Camel number during the past 20-30 years in the study area was increased. According to Central Statistical Authority (CSA) livestock survey from 1997 to 2011, the increment of camel population in Borana zone was clearly observed. This may show the importance of camel for the present and future climate change mitigation. This is because of the fact that camel is physiologically and physically adaptable animal to the expanding bush encroachment of arid areas. Biffa and Chaka (2002) reported that ecological changes, socio-cultural conditions, and increased frequencies of drought recurrences have been the main driving force behind the expansion of camels into the Borana plateau. Similarly, Solomon *et al.* (2007) reported that camel holdings among Boranas have shown an increasing trend over time, while other livestock holdings were declining. Solomon *et al.* (2007) has revealed the existence of keeping more species diversity by the Borana households as climate change mitigation strategy. The importance and number of camel is also increasing in other Sub-Sharan African countries. In this regard, among Wodaabe pastoralists in Niger, who are usually attached to cattle breeding, camel now represents a security tool for their livestock systems during hard times (Kratli, 2007). A study conducted by Zander (2006) warned that replacement of Borana cattle by small stock and camels that is taking place to the largest degree is a serious problem and alarming Ethiopia in comparison with the status of the same breed in Kenya. The camel is a more reliable milk provider than other classes of livestock in arid areas, during both dry seasons and drought years. There is also an increasing demand for camel milk and meat. A traditional camel milk market chain has already been established along Yabello – Moyale- Kenya milk shade showing the opportunity for camel product marketing, which may trigger further shift of pastoralists towards camel rearing at the expense of cattle, which are less tolerant to the shifting ecology from grass to browsing plant species. This may raise a question about the importance of ex-situ conservation for Borana cattle in ranches out of its breeding tract.

4. CONCLUSION

The result of our study and the existing literature in the area clearly revealed that the mutual effect of pastoralist need and the impact of climate change placed the Borana cattle breed at risk in the near future. In this regards selection for animals with effective thermoregulatory control may be needed. Breeding indices should include traits associated with thermal tolerance, low quality feed and disease resistance, and to give more consideration of genotype-by-environment interactions (GxE) to identify animals most adapted to specific conditions. If *in situ* conservation is

unfavourable due to the devastating effects of climate, ex situ conservation programmes need to be developed to cater for habitat destruction and allow for emergency response. We suggest that the Borana cattle breed population is at risk. Thus, conservation status of Borana cattle should be assessed, quick identification and appropriate conservation strategies should be implemented, and appropriate breeding management practices of the breed has to be followed.

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Theme 3

Green Infrastructure and Sustainable Development

GREEN INFRASTRUCTURE AND CLIMATE CHANGE: THE CASE OF ADDIS ABABA

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ABSTRACT

Green infrastructure is defined as an urban area with a mix of street trees, parks, cultivated land, wetlands, lakes, and streams that are interconnected. The economic, social, and environmental benefit of green infrastructure is well documented. Green infrastracture contributes to cleaning air pollutants, food security, enhancingthe economy, storing and sequestering carbon dioxide, biomass fuel, and reducing noise pollution. It also supports biodiversity and acts as a *de facto* sanctuary, reduces urban heat with its general cooling effect, and reduces water pollution and flood incidences. It has also social, psychological, health, and recreational benefits. Therefore, green infrastructure ensures social, economical, and environmental sustainability in urban areas.

Keywords: Air pollutants, biodiversity, carbon sequestration, noise pollution, urban parks

1. INTRODUCTION

Green infrastructure is an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations (Benedict and McMahon, 2002). More recently Davis *et al.* (2012) defined green infrastructure as a part of an urban area with a mix of street trees, parks, cultivated land, wetlands, lakes, and streams. The latter definition is synonymous with the definition of urban forests, which describes trees, forests, green spaces and related biotic, abiotic, and cultural components in and around cities (Carter, 1995). Therefore, green infrastructure and urban forest are regarded as being similar land use types.

Green infrastructure provides the environmental, social, and economic benefits not only for present communities but also, with little management cost, to the future communities. Therefore, green infrastructure ensures the sustainability of cities and urban areas (Forest Research Centre, 2010).

This paper presents the status of green infrastructure and its importance in environmental, social, and economic sustainability and benefits in Addis Ababa. The impact of climate change in Addis Ababa and the possible roles that green infrastructure plays in combating it is also highlighted.

2. GREEN INFRASTRUCTURE AND ITS ENVIRONMENTAL BENEFITS

Green infrastructure is known to provide quantifiable or measurable environmental benefits. Trees, for example, are an important cost-effective solution to the problem of pollution and poor air quality **(**Bell and Wheeler, 2006). Consequrently, integrated trees and other vegetation are part of urban environmental improvement programs, policies/starategies, and measures **in** Mexico and South American cities **(**Escobedo *et al*., 2008**)**.

2.1 Green Infrastructure and Microclimate Amelioration

In urban areas, there is higher temperature compared to the surrounding sub-urban or rural areas. This phenomenon is called urban heat island**.** The phenomenon occurs because urban development results in large amounts of paved and dark coloured surfaces that absorb solar energy and radiate it in the form of heat causing surface and ambient air temperatures to rise. Trees can lower the rising temperature by providing shade and through the transpiration of water vapour from leaves. When trees transpire, energy is absorbed by the evaporating water, thus lowering local air temperatures **(**Bell and Wheeler, 2006**)**.

2.2. Green Infrastructure and Carbondioxide

Studies suggest that forest stands in urban environments have the potential to sequester and store more carbon than rural stands of the same canopy species composition (McNeil and Vava, 2006). Similarly, urban soils can sequester large amounts of CO_2than rural soils of equal voloumes. Thus, green infrastructure is important in counteracting anthropogenic CO_2 emissions because they store and trap CO_2 in their biomass (Richard *et al*., 2006).

2.3. Green Infrastructure and Air Pollution Reduction

The most troublesome pollutants in our atmosphere are *ozone* (O_3), *nitrogen oxides* (NOx), *sulfuric oxides* (SOx) and *particulate pollution*. Trees reduce pollution by actively removing CO, NOx, SOx, and $O_3$from the atmosphere. Leaf stomata take in polluting gases which are then absorbed by water inside the leaf. Some species of trees are more susceptible to the uptake of pollutants, which can negatively affect plant growth. Ideally, trees should be selected that take in higher quantities of polluting gases and are resistant to the negative effects they can cause. A study in Chicago region in 1991 determined that trees removed approximately 17 tons of carbon-monoxide (CO), 93 tons of sulfur dioxide (SO_2), 98 tons of nitrogen dioxide (NO_2), and 210 tons of ozone (O_3) **(**Bell and Wheeler, 2006).

Particulate matterpollution or particulate pollution matter (PM10 and PM2.5) is made up of microscopic solids or liquid droplets that can be inhaled and retained in lung tissues causing serious health problems. Most particulate pollution begins as smoke or diesel soot and can cause serious health risk to people with heart and lung diseases and irritation to healthy citizens **(**Bell and Wheeler, 2006**).**

Table 1: Urban forest management strategies to help improve air quality include (Nowak and Stevens, 2006)

Strategy	**Reason**
Increase the number of healthy trees	Enhance removal of pollutants
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	and enhance long term removal of pollutants
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Large evergreen broad-leaved trees with dense foliage collect the most particulate matter. The study conducted in Chicago in 1991 determined that trees removed approximately 234 tons of particulate matter of less than 10 microns (PM10).Large healthy trees greater than 30 inches in diameter remove approximately 70 times more air pollution annually (1.4 kg/yr) than small healthy trees less than four inches in diameter (0.02 kg/yr)**(**Bell and Wheeler, 2006).

2.4 Green Infrastructure and Water Quality

Another very important role of the urban forest is its ability to reduce water runoff and improvewater quality. High percentages of impervious surfaces in urban areas increase the amount and rate of storm water runoff.

2.5. Green Infrastructure and Sound Pollution

Noise pollution is an environmental problem of cities. Using the different barriers between noise source and the receiver, noise can be reduced trough reflection, refraction, scattering and absorption effects on noise waves. These barriers due to conditions can be either physical or biological barriers or a combination of them. Mounds, hedges and walls are of applicable noise obstructions (Maliki *et al.,* 2010).

Therefore, urban forests are biological barriers that could notably reduce noise pollution when they are planted with adequate width and density. It was estimated that a 4-5 m width tree belt with dense vegetation structure could trim sound level by 5 dBA (Jim *et al.*, 2008).

2.6. Green Infrastructure and Biodiversity Conservation

Urban forests are important not only for forest genetic conservation but also as a habitat for insects and wild animals. Therfore, they are helpful for conservation of biodivesity. Kerwa forest area in Bhopal, India, which supports several threatened and endangered plant, animal, and bird species, is a good example (Singh *et al*., 2010). Cultivating *Ficus* spp. in Bangalore parks to provide food for birds is important (Carter, 1995). Insect diversity in natural forest patches is much higher than in monoculture forest patches within urban forests in Addis Ababa (Girma Negussie, 2009; Fasil Adugna, 2010).

Urban forest also increases habitat connectivity. Therefore, it helps species migrate and survive hazards which may be caused by climate variability. A recent ElNiño resulted in die-off of mammals in the Kumbhalgarh Wildlife Sanctuary in Rajasthan, India. This die-off coincided with the LaNiña-induced drought of 2000, and two consecutive monsoon failures. Indeed, Hanuman langurs (*Semnopithecus entellus*) suffered a population crash of nearly 50% from 1999 to 2001 in the sanctuary. But, langurs in Jodhpur city were buffered against drought because of the availability of urban green habitat and food (Singh *et al*., 2010).

3. GREEN INFRASTRUCTURE AND SOCIAL BENEFITS

Trees have been shown to have noticeable and lasting effects on people's sense of community in their neighbourhoods. They play a key role in making meeting places attractive. Resident participation in tree planting projects promotes a sense of ownership and stewardship, which promotes capacity building. Studies show that communities that have a high level of resident interaction have higher levels of safety, regardless of economic conditions, because residents are willing to look out for one another. The ability of urban trees to relieve extreme heat and reduce noise pollution has been linked to a decrease in violent behaviour. Studies suggest that tree-filled areas have relatively low rates of crime and domestic violence because trees relieve stress and promote a sense of safety among residents **(**UEI, 2008).

Road side trees also reduce traffic accidents. This is because the trees' view and heat reduction will calm drivers. Individual driving speeds were significantly reduced in the suburban settings. The presence of trees at road sides makes drivers conscious of their driving speed (Dixon and Wolf, 2007).

4. GREEN INFRASTRUCTURE AND ECONOMIC BENEFITS

The more obvious economic benefits of urban forests are fuelwood, food, feed for livestock,timber and poles, spices, fibre, medicines and other non-timber products (Carter, 1999).Other benefits such asbeautification, privacy, wildlife habitat, sense of place, and well-being are attributed to higher values of urban trees, which, are difficult to price. But the fact that trees reduce building energy costs and environmental services such as reduced pollution and carbon storage can be valued in money (McPherson *et al.*, 2005).

Trees also improve local business activities and increase property values. Shoppers are willing to make more frequent and longer shopping trips to tree-lined commercial districts. Consumers have also been shown to spend up to 12% more when shopping in tree-lined districts. The sale prices of residential properties have been shown to increase at least 1% for each large front yard tree and up to 10% for large specimen trees (UEI, 2008**).**

5. GREEN INFRASTRUCTURE, SUSTAINABILITY, AND CLIMATE CHANGE IN ADDIS ABABA

5.1. Green Infrastructure and Sustainability

Addis Ababa is one of the top diplomatic centres in the world (Gebre Yntiso *et al*., 2009) and it is the city where one-third of Ethiopian urban population dwells (Alebel Bayrau and Genanew Bekele, 2007).Therefore, when talking of green infrastructure in Ethiopia, the case of Addis Ababa comes to the spot light. The fact that Addis Ababa is the capital of Ethiopia and Africa is attributed to urban forests (Horst, 2006).

Supply of fuel wood was a determinant factor for establishment of Addis Ababa back in the days of introduction of eucalyptus with its fast growth and coppicing nature. Eucalyptus provided a sustainable fuelwood supply for the city for a long time. However, the supply of fuelwood from this tree is no longer sustainable. As a result, 69% of domestic cooking is nowadays done by kerosene (Dubbale Daniel *et al.*, 2010). In addition to energy source biomass energy source, whathas now become a more pressingchallenge for Addis Ababa is fulfilling environmental, social, and economic services for its inhabitants. Thus, green infrastructure development and management is becoming very important.

However, the green infrastructure of Addis Ababa is not developed and managed well to fulfil the environmental, social, and economic services. For example, the urban forest in Addis Ababa has been transformed from once dense indigenous forest to degraded eucalyptus plantations(Horst, 2006).Meanwhile, Addis Ababa is facing

tremendous environmental and social problems associated with lack of appropriate green infrastructure development and management.

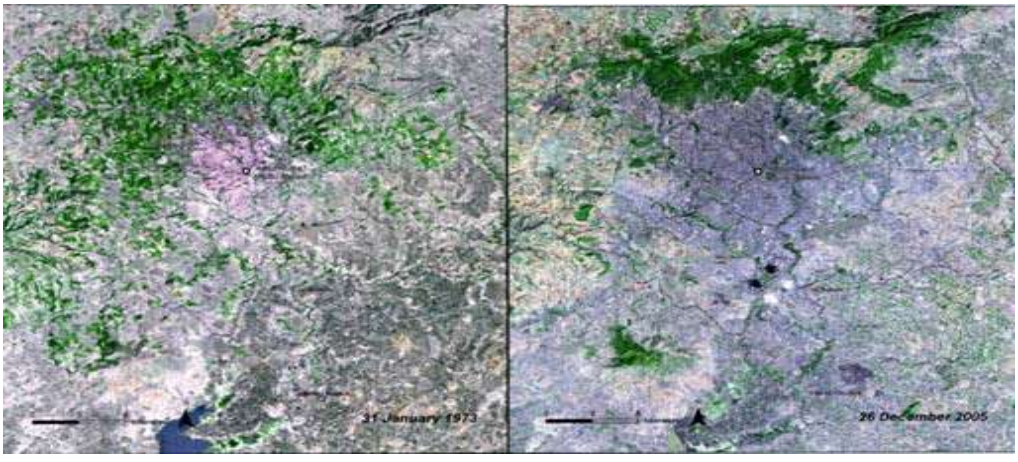

Figure 1. Satellite imagery of Addis Ababa city and its surrounding in 1973 (left) and 2005 (right). Considerable size of green cover has vanished since 1973. The 2005 imagery also shows a drying polluted lake along the southern periphery (Dubbale Daniel *et al.,* 2010)

Figure 2. River bank slum (left) and Garage wastes dumped to rivers (right)

Pollution of streams in Addis Ababa today has reached alarming levels at industrial and non- industrial point sources. The industrial point source Bio-Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of the city's streams stand at 4,475 and 14,702 mg/L respectively, while acceptable levels are 80 mg/L for BOD and 250 mg/L for COD. The Suspended solids in the city's streams, at 1563 mg/L, is also higher than the acceptable level of about 100 mg/L. Non-point source water BOD and COD in Addis Ababa stream water are found to be too high. The level of contamination by germs such as *E. coli* is in the range of 30-100,000,000 mpn (mpn: most probable number)/100ml, but the acceptable margin for clean water is 1 to 2 mpn/100 ml (Dubbale *et al.,* 2010). The ground water of Addis Ababa is also

becoming polluted. The Addis Ababa Water Bureau is now challenged with the fact that ground water quarry is not always possible due to pollution. Now most of the quarries are within the forests so that pure ground water can be obtained (Dubbale *et al.*, 2010).

Insects and most importantly butterflies are used as biodiversity indicators since they are highly sensitive to environmental instability (Girma Negussie, 2009). The butterflies that we used to see in Addis Ababa quite frequently years back are now absent from our surroundings. A study conducted in Sheger park and Ankorcha forest showed that from the recorded Lepidoptera family Noctuidae, Psychidae, Gracillariidae, Sesiidae,and Tortricidae were found while none of butterfly families was recorded(Girma Negussie, 2009).

The consequence of the environmental degradation will definitely have social and economic repercussion which will make Addis Ababa less favourable for its inhabitants. For example, national figures show that these problems are leading causes of acute respiratory infections, skin and parasitic diseases, resulting in mortality and morbidity (Alebel Bayrau and Genanew Bekele, 2007).

5.2. Green infrastructure and climate change

In Addis Ababa, the temperature has been increasing and frequent floodshave occurred in recent years (Figure 3). This could be due to climate change. According to UNDP Climate Change Country Profiles, there has been evidence of an already ongoing climate change in Ethiopia. Based on the recorded data, the mean annual temperature has risen 1.3°C per year between 1960 and 2006 and the number of hot days and hot nights has increased by 20% and 37.5% between 1960 and 2003, respectively. “Hot” is defined as 10% higher than average temperature for that area and period (Daniel Elala, 2011). There is no empirical evidence in historical data of any change in annual rainfall in Ethiopia, even with long term rainfall data at hand. However, a higher rain fall increase is predicted in Addis Ababa region compared to the country’s mean rainfall increase prediction (Daniel Elala, 2011).

However, it can be seen from the figures that the country has experienced both dry and wet years over the last fifty-five years. Years like 1952, 1959, 1965, 1972, 1973, 1978, 1984, 1991, 1994, 1999 and 2002 were dry while 1958, 1961, 1964, 1967, 1968, 1977, 1993, 1996, 1998 and 2006 were wet. Studies made by National Meteorological Agency (NMA) have shown that there is a link between ElNiño and LaNiño phenomena and Ethiopian rainfall (NMA, 2007). Therefore, the recent floods can be attributed to climate change and the consequent fluctuation in rainfall.

Figure 3. Flood caused damage in Addis Ababa in 2010

5.3. Opportunities, Challenges and Limitations

The Ethiopian Constitution Article 44 (the right to live in clean environment) and Article 92 (development should not damage environment), the 1997 forest policy, forest law 542/2007,the climate resilient green economy, and carbon trade are good opportunities for developing and managing green infrastructure in Addis Ababa and other urban centres in Ethiopia. The revised 2002 master plan is the main opportunity as it allocates 41% of Addis Ababa for green infrastructure.

However, the gigantic nature of socio-economic problems in Addis Ababa is a major obstacle to the development and management of green infrastructure. About 82% of the population in Addis Ababa lives in unplanned, high density, and low standard housings. Almost all places designated as green areas are occupied by settlements (Alebel and Genanew, 2007).

6. CONCLUSION

Addis Ababa has poor green infrastructure and has been facing enormous environmental, social, and economic problems. For resilience to climate change and to reap the benefits of sustainable environment and urban ecosystem, it is vital to re-think new strategies for developing and managing Addis Ababa's green infrastructure.

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Theme 4

Environmental and Socio-economic Consequences of Climate Change

THE ECONOMIC IMPACT OF *Prosopis juliflora* INVASION ON AGRO-PASTORAL HOUSEHOLDS AND THEIR COPING MECHANISM

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ABSTRACT

Invasive plant species pose a growing threat to the biodiversity of Ethiopia and socio-economic welfare of its people. *Prosopis juliflora* is one of the top 100 bio-invaders identified today and it is the country's number one invasive weed species. This study was undertaken to evaluate the impact of the invasive weed on the economy of people living in the invaded areas. The data were collected using cross-sectional surveys. A total of 155 household respondents were drawn from both invaded and non-invaded areas of Dire Dawa Administration. To address the impact of invasion by the plant, the data were analysed using a propensity score matching technique. After controlling for differences in demographic and socio-economic characteristics of the invaded and non-invaded households, it was found that, on average, the invasion reduced annual income from livestock production by 780.74 Birr (28.82 percent) and increased average annual crop production by 839.31 Birr (25.85 percent). Among the coping strategies used by households in the invaded areas, using prosopis either as a source of income or for domestic consumption took the lion's share (76.06 percent). It could be concluded that the invasion by the plant species has both negative and positive consequences on the economy of rural households, and alternative policy measures should be sought to reverse the adverse effects of the plant on agro-pastoral communities and to utilize it in imaginative ways.

Keywords: Crop production, firewood, invasive alien species, livestock production, propensity score matching

1. INTRODUCTION

The environmental policy of Ethiopia, the Forest Resource Strategy, and the National Biodiversity Strategy and Action Plan recognise invasive plant species to be the growing threats to the biodiversity of country and the socio-economic welfare of its people (Anagae *et al.*, 2004).

Prosopis juliflora is one of the top 100 bio invaders or Invasive Alien Species (IAS) identified today (ISSG, 2010). Once introduced to an ecosystem, the species has the ability to establish itself with immense potential to invade and out-compete native plant species and eventually take over the new environment.

Though the socio-economic and environmental impacts caused by *Prosopis juliflora* is not well known in Ethiopia, it is believed that the plant is the country's number one invasive plant species becoming a serious threat to the rural livelihood in general and to the pastoralists and agro-pastoralists in particular (EARO and HADRA, 2005), which is also true for the Dire Dawa Administration. In Dire Dawa Administration more than 12,000 hectares of grassland, rangeland, water points, croplands, settlement areas, etc are estimated to be invaded by the plant (BoARD, 2009).

Though *Prosopis juliflora* is believed to be both beneficial and harmful to the local communities, its economic impact on the agro-pastoral households in the administration has not yet been empirically evaluated. Thus, this study was initiated to fill this research gap.

The major objective of the study was to measure the impacts of prosopis invasion on the rural livelihoods of Dire Dawa Administration, through a comparative assessment of household income generated from livestock and crop production in invaded and non-invaded areas. Furthermore, the study aimed at investigating the coping mechanisms of the agro-pastoral communities against the invasion by the weed.

2. Materials and Methods

2.1. The study area

The study was conducted in Dire Dawa Administration, the most prosopis-infested area in Ethiopia next to the Afar National Regional State.

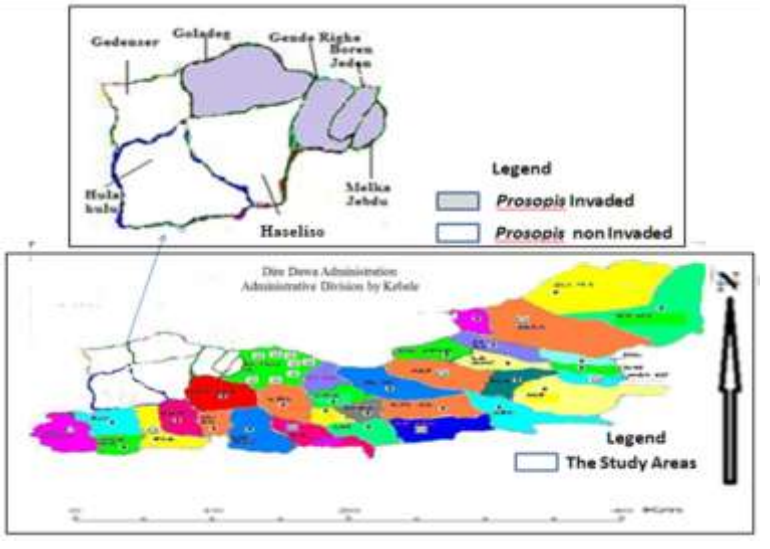

Figure 1. Map map of the study area

The study area is located to the west of the town of Dire Dawa and it covers a total area of 26,437 hectares which is nearly 20 percent of the area of the administration (Figure 1). It has an estimated total population of 17,800, nearly 16.5 percent of the rural population (BoARD, 2009).

Agriculture (both crop and livestock production) is the main stay of the economy in the study area. Subsistence mixed farming is practised by 93% of the total farm households. Selling of firewood in the town is the most important off-farm income generating activity practised by most of the households.

2.2. Sampling Design and Sample Size

Out of the 38 rural *kebeles* in the administration, census type selection method was employed to select all the four prosopis-invaded *kebeles* and a purposive sampling method was used to select three non-invaded *kebeles* based on their demographic, socio-economic, and geographic similarity with the invaded *kebeles*.

Accordingly, the *kebeles* were grouped into two strata. Stratum one, which represented the treatment group, consisting of four *kebeles*, namely, Ganda Righe, Borenjeden, Melka Jebdu, and Goladeg, which are severely invaded by prosopis. The other three *kebeles* (Hulahulul, Haselisso, and Gedenser), which are not invaded by prosopis, were categorized under stratum two representing the control group.

The probability proportion to sample size (PPS) technique was applied to determine the sample size. Accordingly, 8% of the households in each village or Ganda were selected using a systematic random sampling technique. As a result, a total of 155 households (71 households from the prosopis invaded *kebeles* and 84 households from the non-invaded *kebeles*) were identified to form the treatment and control groups, respectively.

2.3. Data Source and Type

Both primary and secondary data were used to generate the necessary information to meet the objectives of the study. Quantitative data were collected through semi-structured questionnaires. To complement the quantitative data, qualitative data were also collected through focus group discussions, story tells; transact walks with elders, development agents and key informant interviews. Secondary data were collected from relevant sources.

2.4. Data Analysis

To examine the causal effect of *Prosopis juliflora* on households' income, the Propensity Score Matching (PSM) approach was employed (Rosenbaum and Rubin, 1983). Coping strategies of the agro-pastoral households against the invasion were

assessed using descriptive statistics. Moreover, the study applied inferential statistics such as chi-square test and t-test to compare and contrast different categories of sample units with respect to the desired characters so as to draw some important conclusions.

Sensitivity analysis was also undertaken to check if the influence of an unmeasured variable on the selection process is strong enough to undermine the matching procedure.

3. RESULTS AND DISCUSSION

3.1. Perception of Households about Prosopis

Nearly 30.99 percent of the respondents in the prosopis-invaded *kebeles* responded that they came to know the bush within the previous 11-15 years whereas 67.61 percent had become aware of the invasion in the previous five to ten years. However, almost all of the respondents (98.59 percent) mentioned that they felt the severity of the invasion in the previous five to seven years.

Around 59.15 percent of the surveyed agro-pastoral households in the invaded areas perceived *P. juliflora* as undesirable species while only 5.63 percent considered it a beneficial species. The remaining 35.22 percent stated it as both beneficial and harmful.

3.2. Benefits of P. juliflora to the Local People

For agro-pastoralists in the study area, utilization of prosopis was found to be abundance-driven. The largest portion of the respondents (77.42 percent) use prosopis as a source of firewood and charcoal. About 16.13 percent use it for live fencing, 3.23 percent as feed for livestock, and the remaining 3.22 percent use it either for the combination of the above uses or for different other purposes. This implies that prosopisis widely used as a source of firewood or charcoal either for domestic consumption or as a source of income to buffer the declining income resulting from crop failure or decline in livestock production. Furthermore, some of the respondents in the group discussion mentioned that prosopis is good forage for bees to produce honey with some medicinal values even though the taste of the honey is somewhat bitter.

3.3. Adverse Effects of *P. juliflora*

The survey results on the negative impact of prosopis indicated that the largest proportion (nearly 60.56 percent) of the respondents attributed its adverse impact to the decrease in grazing land and forage availability, followed by a decline in ground water potential (9.86 percent), loss of biodiversity (7.04 percent), and others (9.86

percent). This implies prosopis invasion has adversely affects grazing land and forage availability and consequently livestock production.

Although variability was observed among the invaded *kebeles* on the proportion of grazing areas assumed to be invaded by prosopis, all the surveyed households reflected that pasture areas shrunk after the invasion by the plant species. Most of the surveyed households assumed that they lost half to three-fourth of their grazing lands due to prosopis invasion. All of the respondents interviewed during the survey claimed that forage/fodder cover of grazing areas has reduced in the past ten to fifteen years.

The most important factors often mentioned to have caused the decline in forage/fodder cover in the study area were recurrent drought and prosopis invasion. Most of the respondents and some elders in the group discussion stressed that the invasion threatened some grass species which are the major source of feed for their cattle. Accordingly, nearly 30 different grass species were perceived to be threatened by prosopis in the four invaded *kebeles*. These included grass species known by their vernacular/local names as *Serdu, Balbalessa Hadhawa, Hollagabis, Metasedi, Buran, Daremo, Cawismacaan, Nafriy, Kundi, Agar, Gumer, Deberduli, Cashcade, Andekis, Shakume, Maddhbur, Dunfure,* and *Wechere.* This situation has put heavy stress on the remaining pasture, which according to Esther and Brent (2005), leads the pastoral and agro-pastoral communities to frequent conflicts over the use of grazing lands.

3.4. Coping Mechanisms against Prosopis Invasion

Among the coping strategies, using prosopis either as a source of income from sale as firewood or for domestic consumption took the lion's share (76.06 percent) followed by eradication (9.86 percent), no action (8.45 percent), and diversification of livelihood or engaging in different off/non-farm income generating activities (5.63 percent).

The most important coping mechanism practised by the agro-pastoral households in the invaded areas was selling it as firewood/charcoal. The average annual household income generated from firewood/charcoal sale in prosopis-invaded areas was 2881 Birr. It was also estimated that 92.96 percent of the sampled households use prosopis as a source of firewood/charcoal. This constitutes around 26 percent of the average annual income of the households in the invaded areas.

About 9.86 percent of the respondents in the invaded areas tried to control the invasion by cutting down the shrub either in groups or individually. However, the fast regeneration or coppicing potential of the species to cover a large area in a short period of time discouraged them from continuing their effort to control it. Some of the respondents bitterly stated that no other aid is worthwhile than eradicating

prosopis from the area since it regenerates "in the afternoon after being cut down in the morning".

The respondents in prosopis-invaded areas said that they were not ignorant about the adverse effects of the species. However, some (8.45 percent) of them just sat back hopelessly, and took no action to control the weed. This is because they are apprehensive of the thorns of the plant. Furthermore, a few of the respondents reportedly suffered inferiority complex in selling the firewood obtained from the plant.

3.5. Propensity Score Matching (PSM) Estimation

3.5.1. Propensity score

Logistic regression model was used to estimate propensity scores of invaded and non-invaded households. The pseudo R^2 value of 0.25 (Table 1) indicates that the estimated model performs well for the intended matching exercise. In other words, the low R^2 value shows that the explanatory variables are not influenced by prosopis invasion and hence, selection into treatment was close to random.

Looking into the estimated coefficients, the variables, namely, access to irrigation, sex, off-farm employment, and farm experience had negative relationships with the households' probability of being invaded by prosopiswhile the remaining variables (Table 1) were found to have positive relationships with the dependent variable.

Table 1. Logit regression analysis of invasion by prosopis

Variable	Coefficient	Standard Error	Z- value
Age	0.013917	0.0205455	0.68
Sex	-0.1885923	0.3661125	-0.52
Education	4.356062	1.371559	2.18**
Irrigation	-2.176176	0.9807687	-2.22**
Off-farm employment	-1.862294	0.4221589	-4.41***
Distance to market	-0.1076688	0.0248297	-4.34***
Credit	0.6066343	0.351203	1.73*
Farm experience	-0.2456357	0.3607795	-0.68
Safty-net	0.6083294	0 .4395035	1.38
Drought	1.083111	0.6288512	1.72*
Constant	-5.693731	1.902717	-2.99**
Number of observation	155		
Pseudo R^2	0.32		
LR $\chi 2$ (10)	51.3		

Prob> $\chi 2$	0.024
Log likelihood	-82.2426

***, ** and * indicate significance at the 1 percent, 5 percent and 10 percent probability levels, respectively.

Moreover, the results demonstrated that proximity of households to market centre and off-farm employment were significant at 1 percent level of significance. Access to irrigation and education were significant at 5 percent level of significance while access to rural credit service and effect of drought were significant at 10 percent level of significance.

3.5.2. Imposing a common support condition

The estimated propensity scores varied between 0.26 and 0.83 (mean = 0.49) for prosopis-invaded or treatment households and between 0.18 and 0.74 (mean = 0.43) for non-invaded (control) households (Table 2). The common support region would then lie between 0.26 and 0.74. In other words, households whose estimated propensity scores are less than 0.26 and larger than 0.74 were not considered for the matching exercise.

Table 2. Distribution of estimated propensity scores

Group	No. of observation	Mean	Standard deviation	Minimum	Maximum
Total HHs.	155	0.46	0.132	0 .18	0 .83
Treatment HHs.	71	0.49	0.13	0.26	0 .83
Control HHs.	84	0.43	0.126	0.18	0.74

3.5.3. Choosing the best matching estimator

Alternative matching estimators were tried in matching the treatment and control households in the common support region (Table 3). The final choice of a matching estimator was guided by different criteria such as equal means test, low pseudo-R^2 and large matched sample size.

Table 3. Performance of matching estimators

Matching estimator	Performance criterion	
	Pseudo-R^2	**Matched sample size**
Nearest Neighbour Matching (NNM)		
Neighbour with replacement	0.0131	146
Neighbour without replacement	0.0183	142
Caliper Matching (CM)		
Radius 0.01	0.0183	142
Radius 0.25	0.0216	144
Radius 0.5	0.0216	144
Kernel Matching (KM)		
With no band width	0.0183	142
Band width of 0.1	0.0131	146

Based on these criteria, the results indicated that nearest neighbour matching with replacement and kernel matching with 0.1 band width are the two better estimators for the data we have. In order to select the best one from these two estimators, a balancing test of covariates, before and after matching, was implemented.

3.5.4. Balancing test

The Hotelling's t-squared test suggested that the differences in household characteristics between the treatment and control groups were jointly insignificant both before and after matching. In the individual covariates balancing tests (Table 4), the number of variables with no statistically significant mean difference was ten in case of nearest neighbour matching while it was only six in kernel matching. Hence, nearest neighbour matching could be preferred as the best estimator of average treatment effect because it satisfied all the three matching performance criteria (lower pseudo R^2 value, higher number of covariates with insignificant mean difference between the two groups, and larger number of matched sample size). Consequently, only the outcomes from this estimator were used to meet the study objectives of estimating the impacts of prosopisinvasion on households' income generation from livestock and crop production in the study area.

Table 4. Balancing test

Variable	Sample before matching	Sample after nearest neighbour matching	Sample after Kernel matching
1. AGE			
Mean (treatment)	42.91	41.41	41.62
Mean (control)	40.79	40.79	40.79
t-test (p value)	0.57	0.68	0.68
2. SEX			
Mean (treatment)	33.77	0.36	0.32
Mean (control)	32.14	0.33	0.33
t-test (p value)	0.90	0.72	0.89
3. FARM EXPERIENCE			
Mean (treatment)	88.73	0.77	0.81
Mean (control)	73.49	0.73	0.74
t-test (p value)	0.019*	0.23	0.04*
4. OFF-FARM EMPLOYMENT			
Mean (treatment)	81.69	0.76	0.78
Mean (control)	58.33	0.68	0.62
t-test (p value)	0.01**	0.12	0.05*
5. EDUCATION			
Mean (treatment)	81.7	0.82	0.8
Mean (control)	73.81	0.79	0.79
t test (p value)	0.03*	0.65	0.89
6. DROUGHT			
Mean (treatment)	69.48	0.74	0.69
Mean (control)	86.1	0.76	0.84
t-test (p value)	0.02*	0.19	0.08
7. SAFTY-NET			
Mean (treatment)	83.1	0.81	0.82
Mean (control)	76.19	0.76	0.76
t-test (p value)	0.29	0.49	0.37
8. IRRIGATION ACCESS			
Mean (treatment)	12.68	0.15	0.14
Mean (control)	32.14	0.19	0.19
t-test (p value)	0.004**	0.59	0.47
9. CREDIT ACCESS			
Mean (treatment)	56.34	0.48	0.50
Mean (control)	40.48	0.4	0 .40
t test (p value)	0.04*	0.36	0.09

Hotelling's test (p value)	0	0	0
Pseudo R^2	0.32	0.013	0.013
N (treatment)	71	69	69
N (control)	84	77	79

* and ** indicate significance at 5 percent and 1 percent probability levels, respectively

3.5.5. Treatment effect on the treated (ATT) group

The results (Table 5) show statistically significant negative effects of the invasion on households' average annual income from livestock sale at 5 percent level of significance. However, the effect of the invasion on households' average annual income from crop production was not statistically significant even though the effect was shown to be positive.

After controlling for differences in demographic and socio-economic characteristics of the invaded and non-invaded households, it was found that, on average, the invasion decreased annual income from livestock production (AAILP) by 780.74 Birr (28.82 percent) and increased average annual crop production (AAICP) by 839.31 Birr (25.85 percent).

The estimated difference on average annual income from livestock production in invaded households could be attributed mainly to loss of palatable grass species due to prosopis invasion. In addition, heavy dependency of livestock on prosopis pod for survival, as observed even during drought periods, resulted in prosopis-borne health hazards and adversely affected livestock production and productivity. This result is corroborated by the findings of Al-Humaid and Warrag (1998), Mugasi *et al.* (2000), Gavali *et al.* (2003), Pasiecznik *et al.* (2004), and Esther and Brent (2005).

Table 5. Average treatment effect on the treated (ATT) group

Variable	Treated	Control	ATT	t-value
AAILS	515.55	1045.96	-530.41	-2.04**
AAIMP	1411.94	1662.27	-250.32	-0.71
AAILP	1927.5	2708.24	-780.74	-1.6
AAICP	3246.55	2407.24	839.31	1.2

In contrast, the estimated positive difference in average annual income from crop production in the invaded households could be attributed to the effect of prosopis on improving soil fertility and soil and water conservation, which were mentioned by some of the respondents in the group discussions held in the invaded *kebeles*.

3.5.6. Testing sensitivity to the specification of the propensity score

The sensitivity analysis is conceptually related to the practice of assessing sensitivity of estimates by comparisons with results obtained by discarding one or more of the observed covariates (Heckman and Hotz, 1989; Dehejia and Wahba, 1999).

The result revealed that the estimates are not particularly sensitive, when compared to the estimates in the full specification of covariates (Table 6).

Table 6. Sensitivity of matching with replacement to the specification of the estimated propensity score

Specification	Obs.	Outcome Variables							
		AAILS		AAIMP		AAILP		AAICP	
		ATT	St. Err.	ATT	St. Err.	ATT	St. Err.	ATT	St. Err.
Full specification	146	-530	260.02	-250	354.4	-781	489.4	839.3	698.7
Dropping irrigation	149	-527	284.61	-263	456.7	-790	741.8	945,71	874.34
Dropping drought	153	-573	271.97	-290	381.2	-864	661.4	1008	778.06

AAILS = ; AAIMP = ; AAILP =Average annual incrome from livestock production ; AAICP = Average annual incrome from crop production.

4. CONCLUSION

The results of this study have demonstrated that prosopi*s* is still a controversial plant species. The interviews and focus group discussions revealed that a number of households do not want this plant species whereas others said that they would need the plant as a resource to make a living. The latter have demanded that efforts should be made to develop prosopis as a valuable resource, by improving the tree and stand management and adding value to the products of the plant. The former have called for eradication of the plant from their villages. However, past experiences from around the world have shown that eradication is an ineffective, costly, and futile management option. Although the agro-pastoralists in the study area are not ignorant about the benefits derived from prosopis, they are reserved to acknowledge them and blame those who introduced the alien tree species to their locality, urging its eradication. It could be concluded that *Prosopis juliflora* by itself is not a problem or a threat as such. The major problem lies in the lack of imaginatively appropriate management practices for its sustainable use. Therefore, the study implies the need to design comprehensive management and utilization strategies of invasive alien weed species (IAS) in general and *Prosopis juliflora* in particular at both national and regional levels.

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CLIMATE CHANGE: A NEW CHALLENGE FOR COMMUNITY-BASED PROTECTED AREA MANAGEMENT IN THE DEMOCRATIC REPUBLIC OF CONGO

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ABSTRACT

Climate change will potentially alter the abundance and distribution of species and composition of terrestrial ecosystems. Sufficient knowledge on the geographic range of species, location of species' habitats, species' lifecycles, population dynamics, the structure and composition of ecosystem and communities is needed to plan strategies. The significant gaps in such information pertaining to all community-based reserves are a significant obstacle to predicting the impact climate change has on biodiversity. This is also important for designing appropriate adaptation strategies and decision-making tools. There is an urgent need in the region is to improve the understanding of the potential impact of climate change on biodiversity, to improve knowledge and understanding on the interaction of climate and biodiversity, and to create more capacity to monitor impacts on biodiversity and evaluate the effectiveness of adaptation strategies. Communications are required among stakeholders to monitor and address problems caused by activities that lead to climate change.

Keywords: Adaptation strategies, climate change impacts, livelihoods, population dynamics, species' habitat

1. INTRODUCTION

The United Nations Convention on Biological Diversity has identified climate change as one of the five main threats to biodiversity, along with invasive alien species, nutrient loading and pollution, habitat change, and overexploitation (Walling, 2008). The Intergovernmental Panel on Climate Change 4th (IPCCAR4) Assessment Report concluded that climate change will have significant impacts on many aspects of biological diversity; on ecosystems, species, genetic diversity within species, and on ecological interactions. Scientists estimate that climate change could contribute to one-third of extinctions by 2050, including many species long thought "immune" to extinction risk (The Environmental Law Institute, 2011).

The range of current and potential impacts of climate change on biodiversity means that adaptation strategies are needed in the biodiversity conservation sector to address and minimise the impacts. Such strategies are needed not only to help achieve conservation goals, but also to ensure that biodiversity can continue contributing to societal adaptation to climate change and to climate change mitigation (Campbell, *et al*., 2009).

The conservation sector is only recently beginning to develop adaptation measures, but strategies such as improved protected area design, maintaining habitat connectivity in the wider landscape, and reducing other anthropogenic pressures are likely to increase the resilience of biodiversity to climate change (Campbell, *et al*., 2009). The most challenge of adapting to climate change is that the effective responses must be location-specific, and yet be contextualized to wider landscapes or ecosystems.

Protected areas have long been used as an important tool to secure sites that are perceived as important in biodiversity conservation. The IPCCAR4 outlined a number of potential adaptation strategies to reduce climate impacts on ecosystems, including the reduction of anthropogenic pressures, development of appropriate protected area networks, landscape management, controlled fire management, habitat restoration, captive breeding and assisted migration(Campbell *et al*., 2009).

There is still relatively little concrete scientific evidence on the effectiveness of different management strategies in relation to climate change so that much adaptation work is still based on ecological reasoning rather than on extensive research and case studies (Heller . and Zavaleta, 2009). In the face of these uncertainties, there is a need for proactive management strategies that can quickly be adapted to new circumstances and changing conservation priorities (Heinz, 2008; Lawler *et al*., 2009 as cited by Campbell *et al*., 2009). These will require institutional coordination, incorporation of climate change scenarios into planning, and efforts to address multiple threats simultaneously (Heller and Zavaleta, 2009).

Therefore, considerable efforts will be required to expand and redesign protected area systems to ensure that they include sufficient area to accommodate management practices that both facilitate change and maintain large populations of species of concern (Huntley, 2007).

Ensuring the continued survival of ecosystems and species under changing climatic conditions requires not only adjustments to the extent and location of protected areas, but also changes in the ways of managing them. Changes in the way that protected areas are managed have been one of the innovations in different protected areas in DR Congo. Local population is more involved in the management of protected areas and others are created by local population and managed by them. Since 2003, new protected areas have been created and others are in the process of being created. The main characteristic of these new protected areas is that all of them are community-based conservation protected areas. Berkes (2004) mentioned also that community-based conservation relies on the idea that conservation and development could be simultaneously achieved (Kanna *et al*., 2011). How to achieve conservation and development in a changing climatic situation?

2. COMMUNITY-BASED CONSERVATION

In recent decades, several community-based protected areas have emerged in eastern DR Congo whose management goes directly to local communities that created them. In the East of DR Congo, nine community-based protected areas have been created and are grouped under a platform whose mission is to strengthen the capacity of member organizations to carry out activities of nature conservation and to promote the socio-economic and cultural development in various protected areas. However, current protected areas as the case of community-based protected areas in DR Congo were established to conserve species and ecosystems in a stable climate. The conservation priorities are focused on some species in particular great apes than the protection of all ecosystem or landscape level.

The management is led by the local people and is called community management in which the population is actively involved in the management of the protected areas. Unlike other protected areas of the country, people live and conduct their activities within the protected areas. These activities generally include agriculture, hunting, harvesting of forest products, and small businesses. In all protected areas, logging and hunting for big mammals and endangered species are prohibited. But to control human activities inside the protected area boundaries is one of the biggest challenges for protected area managers.

The creation of protected areas has allowed reducing deforestation in advance of the expected loss of habitat for thousands of animal species as well as plant species. This is considered as a positive impact in the sense of adaptation to climate change as it has been suggested that, maintaining habitat connectivity in the wider landscape is one of the adaptation strategies for biodiversity conservation.

However, the need for agricultural land and the negative impact of agriculture continue posing a major threat to the ecosystem; there is an urgent need for the establishment of a realistic land use plan to reduce deforestation. Illegal hunting of animals is also a major threat to biodiversity in protected areas that need also a mitigation strategy.

Biodiversity remains vulnerable to anthropogenic activities as well as to people living within the protected areas compared to those living outside. It is difficult to judge on the trend of species abundance and how many species remain in the protected areas.

Thus, the major threats to biodiversity in protected areas are, among others, the destruction of habitat due to agriculture, logging, farming, and hunting. The adaptation to climate change requires reduction of these threats.

3. CHALLENGES WITH CLIMATE CHANGE

Data from the two national communications confirmed that the climate has changed in recent years and will continue to change in DR Congo and impacts have already been felt in some areas. The consultations with local communities in the different protected areas confirm the existence of changes in climate parameters. These changes are evaluated based on two climatic parameters: rainfall and temperature. Two trends are emerging for rainfall: some support that there is a decrease in the rain while others estimate that the rains are more intense. However, the results from meteorological data indicate that changes in rainfall are different in varied regions. However, any change in climate parameters will have a negative impact on livelihoods of the local people, particularly in the agricultural sector and also on biodiversity in the region.

To plan adaptation strategies will require sufficient knowledge about vulnerable species for which adaptation is needed. Unfortunately, very little is known about species regarding their distribution and variation in time, their ecology, habitat, and vulnerability.

Lack of human capacity to investigate in this area is also one of the reasons for non-implementation of activities in this sector. Issues of climate change are not included in the daily activities implemented in the community-based protected areas. Compared to other protected areas such as National parks, the context regarding climate change seems to be different. In community-based protected areas under investigation, people live inside the protected areas. So for these protected areas, threats from climate change problems are meant to be more important in the senses that, apart from the consideration of the direct impacts of climate change on biodiversity, the indirect impact caused on the local population needs to be taken into account, which may indirectly affect the species in the protected areas. Thus, the reduction of the vulnerability will take into account both the impact of climate change on biodiversity (direct Impact) and on the livelihoods of local people living in protected areas (Indirect Impacts). The task seems to be complex if we take into account the degree of uncertainty and lack of data on the possible impact of climate change on biodiversity in the region. But, also the lack of financial resources and human capacity to implement activities related to climate change issues add challenges.

Climate change will have impact on livelihood activities including agriculture. Therefore, adaptation strategies need to be implemented. However, it is difficult to determine whether the adaptation strategies will have benefits for biodiversity. Area managers will need to work on protected areas to ensure that climate change impacts are reduced by implementing sustainable strategies.

4. NEEDS AND PRIORITIES FOR CLIMATE CHANGE MITIGATION

There are needs of greater considerations for synergies and trade-offs in adaptation policy and planning, including improved understanding of the underpinning role of biodiversity, to avoid mal-adaptation and develop cost-effective responses to the impacts of climate change (Campbell, *et al*., 2009).

The particular situation in which community-based protected areas exist and are managed in the eastern DR Congo would lead one to think more than just implemented adaptation strategies for biodiversity. The current level of knowledge on biodiversity in theses protected areas, concerning threats and climate change issues, suggest that we need more actions than what can be done in protected areas where people do not live inside and where sufficient information is available for decision making.

To mainstream climate change and reduce its impact on biodiversity, several prerequisites are required, which could be grouped into three categories:

- Acquiring sufficient knowledge about the different aspects of biodiversity and the climate in the region
- Reducing threats other than that of climate change factors and the vulnerability of livelihoods of local population to climate change
- Strengthening the local capacity in implementing the adaptation strategies and climate change mitigation

Once these three elements are integrated, it is possible to consider the establishment of an effective management of protected areas in the context of climate change by implementing sustainable adaptation strategies. Thus, there is an urgent need for manager of protected areas to master and implement actions related to these three groups of elements. However, financial resources are often insufficient for the implementation of activities related to climate change in theses protected areas.

5. CONCLUSION

Two emerging approaches to adaptation have gained currency over the past few years, namely Community-based Adaptation (CBA) and Ecosystem-based Adaptation (EBA). Each has its specific emphasis, the first on empowering local communities to reduce their vulnerabilities, and the second on harnessing the management of ecosystems as a means of providing goods and services in the face of climate change. Considering the situation of community-based protected areas in the DR Congo, empowering local communities to reduce their vulnerabilities will increase their capacity to adapt and reduce the probabilities of indirect impact on biodiversity. Harnessing the management of ecosystems need to be applied given the level of uncertainty in these areas in the face of climate change. However, basic

information is needed on different components that need to be taken into account for the implementation of adaptation strategies at all levels: information on biodiversity in the protected areas, climate change, livelihoods, and vulnerability to climate change.

Data are needed on climate change and their impact on biodiversity and livelihoods to implement new conservation strategies considering challenges posed by climate change. However, awareness alone will not be sufficient in the management context of community-based protected areas in the DR Congo. Therefore, capacity building and funding are a priority.

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FARMERS' PERCEPTION OF CLIMATE CHANGE AND LOCAL ADAPTATION STRATEGIES IN THE HIGHLANDS OF ETHIOPIA: THE CASE OF MENZ GERA MIDIR DISTRICT, AMHARA REGION, ETHIOPIA

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ABSTRACT

This study examined farmers' perception of climate change/variability, impacts of climate change on indigenous/local grain seeds, and local adaptation strategies in the highlands. The study was carried out in Menz Gera Midir district located in the North Shoa Zone of the Amhara Regional State, Ethiopia. A total of 180 sample households selected through stratified random sampling procedure were interviewed using a structured survey questionnaire. In addition, 12 focus group discussions and 16 key informants were interviewed. Meteorological data that spanned 30 years (1974-2003) were used to analyse the patterns of rainfall and temperature. About 99 percent of respondents have indicated that temperature has increased over the past decade and the instrumental analysis confirmed that the rise of mean minimum temperature shows an increase by 0.25^0C over three decades (1974-2004). Ninety-nine percent perceived that the amount of rainfall has decreased in Meher season but the pattern and distribution varies over decades. Observed effects of the change include shift of the agricultural cropping pattern from *Belg* (autumn) to *Meher* (summer) season, loss of local wheat and barley varieties, and decline the discharge of rivers and springs used for various agricultural and household activities. About the causes of climate change, 39 percent indicated supernatural wrath and believed climate change as punishment from God, 25 percent attributed the cause to the clearing of forests and bush lands due to cropland expansion, and 36 percent indicated both. Local coping strategies of adverse effects include consumption adjustments, borrowing from relatives, dependence on food aid, engagement in daily labour, and seasonal migration to neighbouring districts. The results imply that the strategies households use need to be further explored and analysed to strengthen their adaptive capacity and formulate adaptation plans for other similar areas.

Keywords: adaptive capacity; adaptation strategies; cropping pattern, indigenous/local grain seeds, local perceptions

1. INTRODUCTION

The 2007 assessment of the Intergovernmental Panel on Climate Change (IPCC) drew couples of substantially new conclusions, which had a marked effect on policymakers. One of which was climate change is 'unequivocal' and is due to largely to emissions of greenhouse gases resulting from human activity and that the effects of this observed global warming can now be detected on every corner in the form of changed ecosystem (Letcher, 2009). As a result of the warming, the change

in climate is continuing at an increasing pace and it is already impacting life on the planet and it is highly likely that humankind is to be blamed. The rippling effect of global warming and the change in climate is a serious development issue at global and local scale, as it could make vulnerable the livelihoods of millions of people. The changing climate and the varying weather patterns are bringing negative impacts on food production, natural resources, and health in many developing countries and exacerbate the already pressing difficulties in all sectors of development.

Ethiopia is one of these vulnerable countries affected by the adverse effects of climate change and variability since the country's economy is highly dependent on smallholder rain-fed agriculture who manages less than a hectare of land per household on average. The high dependence of the economy on agriculture means, it is very sensitive to climate variability and expose to vulnerability. Ethiopia has been experiencing the negative impact of the change not only in the lowlands but also in highlands. Particularly, the highlands are fragile and under different stresses like population pressure and unwise utilization of resources. Recurrent drought events in the past have resulted in loss of lives and property as well as migration of people (Green Forum, 2008).

Investigating the existing perception of climate variability and climate change and the local adaptation strategies of farmers' has become the most timely and crucial affair in the development process of Ethiopia. Securing Ethiopia's economic and social well-being in the face of climate change requires that policymakers and stakeholders work together to integrate climate change adaptation into the country's development process.

Adaptation to climate change are two-step process; the household attitude towards the change in climate and variability and their response to the perceived change through adaptation (Temesgen *et al.*, 2009). However, as Lerner *et al.* (2009) discussed adaptation as the process of learning and storing knowledge so that others can use it presently and in the future. The adaptive capacity of the economy to climate change is determined by economic wealth, technology, information and skills, infrastructure, institutions, and equity (IPCC, 2007). These factors determine the effectiveness of strategies to adaptation effort. Very little attention has been given to empirically analyzed causes of development challenges posed by the threats of climate change so far (Aklilu and Alebachew, 2009). Research on the impacts of climate change in Ethiopia has been focusing more in the lowland parts of the country that is largely inhabited by pastoral communities and thus there has been limited understanding of the situation in the highlands agro-ecology. To understand and examine the local adaptation mechanisms local people employ, it needs prior understanding of the perceptions of local people. They tend to prefer the use of one option of adaptation for what they perceive. Therefore, strategies for adaptation without perception may not be effective. In such crucial thematic area, researches are

deficient and limited scope in the highland area of the country. This study was examined farmers' perception of climate change/variability, the household level impacts of climate change, and local adaptation strategies in the highlands. It also assessed the extent of adaptation strategies of the local community, and explored the short and long-term adaptation strategies carried by the community and the local government.

2. METHODOLOGY

2.1. Description of the Study Area

The study was carried out in Menz Gera Midir *woreda* (District) located in the North Shoa Zone of the Amhara Regional State, 282 km North of Addis Ababa. The *woreda* is located between 10.19^0 to 10.56^0E and 39.39^0N to 39.83^0N and covers an area of about 110,548 hectares. The elevation ranges between 1680 to 4000 meters above sea level. The topography of the *woreda* consists of 38 percent rugged terrain, 25 percent mountainous area, 23 percent flat landscape, 13 percent valley and 1 percent water body (Woreda Office of Agriculture and Rural Development unpublished report, 2009). The land use pattern of the area is cultivated land (33 percent), pasture land (34 percent), marginal land and residential area (30 percent), forest and bushes (2 percent) and water body (1 percent) (Woreda Office of Agriculture and Rural Development unpublished report, 2009. The climatic condition is humid (*wurch*) (76 percent) and sub-humid (*dega*) (24 percent). The range of mean annual rainfall is 800-1600 mm and temperature is 8-18^0C. The woreda has an estimated total population of 102,420, of which 49,956 (49 percent) are men and 52,464 (51 percent) are women. Of the total population of the Woreda, 10,516 (8 percent) live in urban centres. The remaining 111,457 (92 percent) live in rural areas.

Mixed farming (cultivation of crops and rearing of livestock) is the major source of livelihood that comprises about 93 percent. The main crops grown in the area are barley, wheat, bean, peas, lentil, and chickpeas. About 70 percent of the farmers' income is from crop production and 25 percent is from livestock production. Of the livestock population, 60 percent of the income is generated from sheep. The cropping pattern is predominately subsistence oriented. Wool spinning, weaving and petty trade are the most common local trades.

According to National Metrological Agency (NMA), the long rain season, *meher*, which covers 90 percent of the total production, lasts from June to September and the short rain season, *Belg* which covers 10 percent of the total production, lasts from February to May. The seasonality, intensity, and distribution of rainfall is unpredictable. Heavy rain results in water logging and floods, or rainfall ceases to occur. Crop failure is very common in the area whenever the rain stops at flowering

stage of crops. These factors force the farmers to change the cropping pattern as well as the type of crops grown. Frost is among the major factors responsible for low crop production in the area.

2.2 Sampling

Cross-sectional survey methods used, where samples were drawn from a predetermined population. A variety of methodologies were used in the collection of primary and secondary data. The primary data sources include household and key informant interviews, participatory assessments of focus group discussions, and field observations. Both qualitative and quantitative data were used in primary data collection to provide historical and current information on climate change and variability from 180 households in six *Kebele* (the smallest administrative unit in Ethiopia). The secondary data sources included both published and unpublished materials, records of ministerial offices, government statistical abstracts, reports, crop assessment reports, and meteorology data.

Participatory approaches were used with the participants in the discussions being drawn from all the sub-villages and representing various segments of the community (such as sex, age, education level, and wealth rank). Thirty per cent of the *Kebele* in the *woreda* were purposively chosen from two agro-ecological zones (*Dega* and *Wurch*) to represent the *woreda*. Stratified sampling was used to select the sample *kebele* from the *Woreda* and systematic sampling method was employed to determine the sample households from the recent list of revenue tax payer households.

2.3 Data Collection Instruments

Different data gathering instruments were utilized to generate the required information. Structured and semi-structured pretested questionnaire were used to gather the data from the field. A face-to-face interview was made to all sampled respondents from the selected *kebele.* Moreover, focus group discussions were carried out. The discussions unveiled enormous opportunities to tap the indigenous knowledge, skills, and experiences of farmers. Recording, photographing and transect walk were used to generate the relevant data. Data on rainfall and temperature were collected from meteorological records.

2.4 Method of Data Analysis

The primary data were analyzed using the adopted likert scale with 3-scales of measurement to which a respondent farmer agree, disagree or indifferent to the perception and local adaptation questions and the mean of each scale was calculated and compared for their choices. The highest mean value was the highest perception in a specific climate parameter (Karavas-Doukas, 1996). The results were presented in

percents and frequencies in pie charts, tables, and bar graphs. The long year (30 years) mean of annual, seasonal and monthly precipitation and temperature (minimum & maximum) were computed and rate of change of the means were obtained and the results were presented in graphs, percentages, and numbers.

3. RESULTS AND DISCUSSION

3.1. Patterns of Precipitation and Temperature

The annual mean rainfall of the Woreda was 902.1 mm (NMA, 2001). A three and half decade data from NMA indicated that there is fluctuation of rainfall. In year 1977 and 1980/81, the annual rainfall amount was above 1500 and 1460 mm, respectively, the highest in the three decades time and the lowest mean annual rainfall was registered in 1984 (352 mm) during the time of severe drought. Following this sharp drop in rainfall amount, the remaining consecutive years had rainfall amounts less than 1000 mm except 1996 (1014 mm), 1998 (1050 mm), 2001 (1132 mm) and 2006 (1027 mm). The computed long-term rainfall pattern has shown declining trend over the decades. The overall reduction of rainfall over the three decade was calculated to be 14.5 mm (Figure 1).

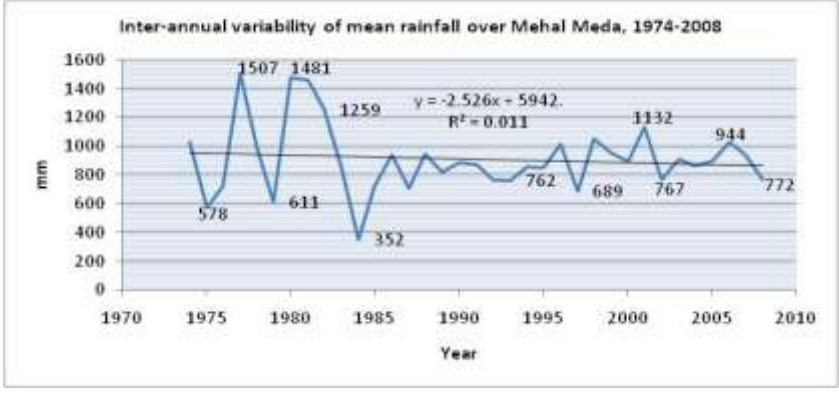
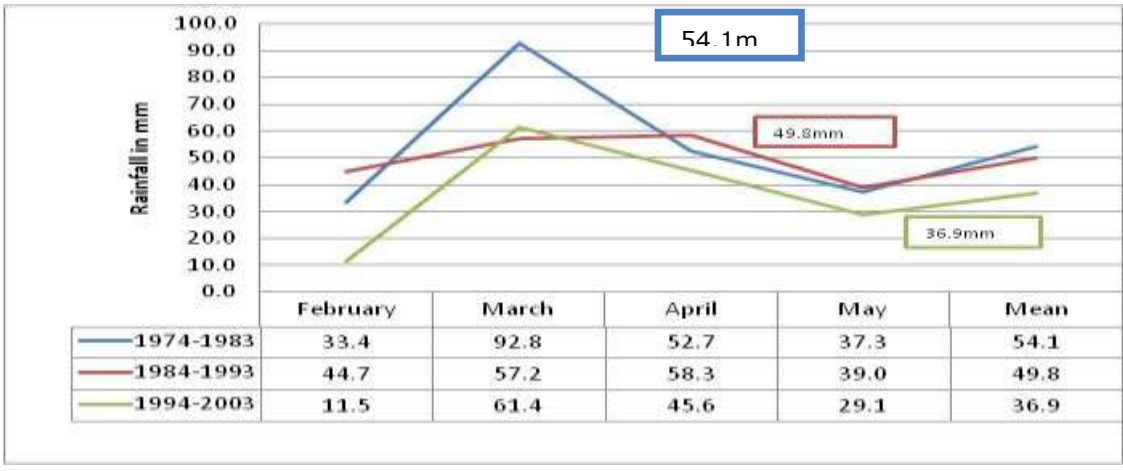


Figure 1. Mean annual rainfall in the *woreda* (NMA, 2001).

The *belg* season in 1974-1983 had the highest rainfall amount with a high mean value of 54.1 mm as compared to the mean value of the two decades. This indicates that three decades ago, *belg* season had the highest rainfall amount for *belg* production. In the second decade (1984-1993), the amount of *belg* rainfall had drastically fallen to 49.8 mm and in the third decade of observation (1994-2003) the amount significantly dropped to 36.9 mm below the amount of the other decades.



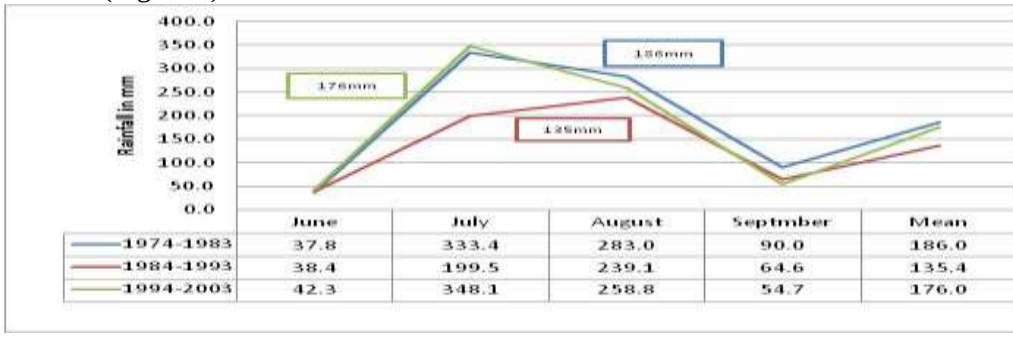
	February	March	April	May	Mean
1974-1983	33.4	92.8	52.7	37.3	54.1
1984-1993	44.7	57.2	58.3	39.0	49.8
1994-2003	11.5	61.4	45.6	29.1	36.9

Figure 2. *Belg* season rainfall variability over the woreda, 1974-2003.

The graph (Figure 2) depicts that, *belg* rain had higher mean value in the first decade. The consequent decades had shown a sharp decline. This trend had an effect on agricultural productivity, among other factors. The reduction in mean value indicates the reduction of *belg* rain, which had a negative effect on seasonal agricultural production. Farmers' perception and explanation indicate that the shift of cropping pattern had taken place as a result of decline in amount, total failure and/or erratic nature of the *belg* rain.

In the first decade of *meher* season, the rainfall amount showed higher mean value (186 mm) and the second decade had shown reduction of mean value by 27 percent (i.e.135 mm). The third decade had an increase in the mean value by 23 percent (176 mm) as compared to the second decade but reduced by 5 percent from the first decade.

The decadal mean analysis indicates that there was rainfall variability in *meher* season, which means that the pattern and distribution was varying. When *belg* and *meher* seasons were compared, the *belg* trend showed a declining trend throughout the decades (Figure 2) while the *meher* rainfall showed great variability throughout the decades (Figure 3).



	June	July	August	Septmber	Mean
1974-1983	37.8	333.4	283.0	90.0	186.0
1984-1993	38.4	199.5	239.1	64.6	135.4
1994-2003	42.3	348.1	258.8	54.7	176.0

Figure 3. *Meher* season rainfall variability status, 1974-2003.

From A1B precipitation model scenarios, the global and continental change of precipitation will be ±20 percent of the normal year, 1961-1990 (IPCC, 2007). This variability will increase by the same percent for Ethiopia. According to a mid-range emission scenario by IPCC, a modest increase in annual precipitation is expected over the country from year 2030 to 2080. The scenario shows an increase of 1.3 to 6.1 percent by year 2030, 2.4 to 11.6 percent by year 2050 and 3.9 to 18.9 percent by year 2080 (IPCC, 2007).

The instrumental records and trend of decadal temperature indicates that in the first decade (1974-1983), fluctuations were observed with the highest in 1979 (9.1°C) and the lowest in 1983 (4.8°C). Since, the data were collected long ago, the exact reasons for the highest and lowest record of temperature could not be verified by the various respondents. The recorded data of annual mean minimum temperature showed inter-annual and intra-annual fluctuations (Figure 4). The mean annual minimum temperature of the station was 7.1°C.

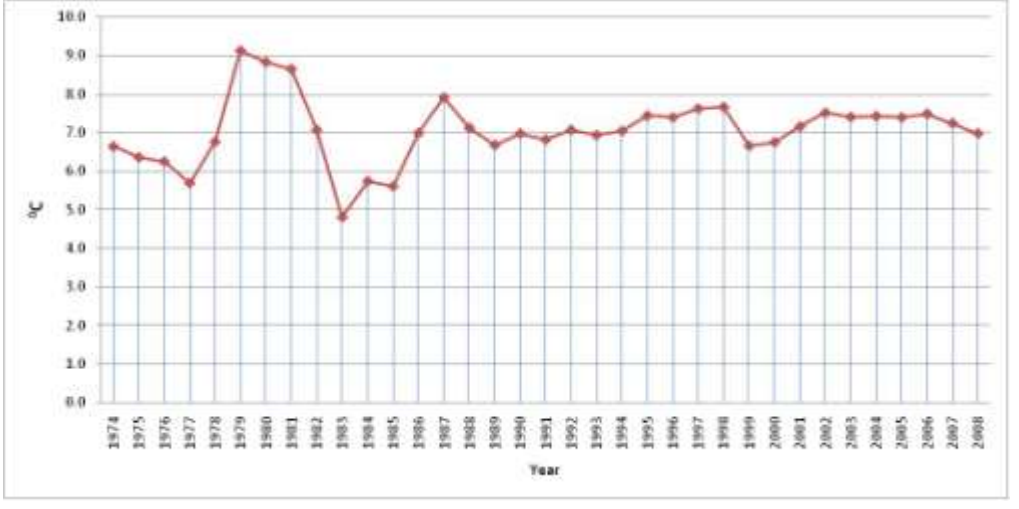


Figure 4. Annual mean minimum temperature (°C) over Mehal Meda, 1974-2008 (NMA, 2001).

However, few elderly people said that there was a rise in temperature at one time and severe frost in other time. The year 1983 was prominently remembered by these people as the severe drought year. They associate it with the 1984/5 drought even though it is two-years earlier than the so-called severe drought. They characterize the years as a time of freezing temperature and dusty dry wind were blowing from the ground. The computed rate of change of the minimum temperature for the *Woreda* over the three decades was 0.25 °C, for Gondar and Yirga Chefe was 0.1 °C to 0.4 °C, respectively (Muna, 2006). Nationally, the projection of temperature change over Ethiopia as compared to the 1961-1990 normal mean annual temperature will increase by about 0.9-1.1 °C by year 2030, 1.7-2.1 °C by year 2050; 2.7-3.4 °C by

2080 over Ethiopia from the IPCC mid-range (A1B) emission scenario (NMSA, 2007). A fifty-three years climatic data in Ethiopia has shown that temperature has been increasing at 0.37 °C per decade (NMA, 2001). The mean global surface temperature has increased by about 0.3 to 0.6 °C since the late 19th century and by about 0.2 to 0.3 °C over the last 40 years (UNEP, 2003; Muna, 2006). In the study area, in *belg* and *meher* seasons, the computed result of the recorded data has shown fluctuations. A 0.23 °C and 0.77 °C rise in annual mean minimum temperature of *belg* and *meher* seasons were observed, respectively, in the observation period (1974-2003). This rise has coincided with the qualitative response of respondents.

5.2 Farmers Perceptions of Rainfall and Temperature Situation

Of the total respondents, seventy-seven percent of respondents received climate related information through extension agents and 61 percent of the respondents heard through the medium of radios (Table 1). Respondents in *Dega kebeles* have higher probability to hear about climate from these means than *Wurch kebeles*. This is due to the fact that most of the *Wurch kebeles* are located far from main town. Focus group discussion revealed that dissemination of information for farmers would help to increase the awareness and make them ready for appropriate actions.

Table 1. Means of information communication about climate change and climate variability

Means of communication	Agro-ecology		Total
	Dega	*Wurch*	
Extension agent	109	30	139 (77%)
Radio	91	18	109 (61%)
Relatives, friends	2	2	4
Total	202	50	252*

The result on the causes of climate change showed that punishment from God, clearing of forests and bush lands due to cropland expansion, and both accounted for 39, 25, and 36 percent, respectively. The result of perceived attitude of sample farmers on precipitation indicated that 97 percent of farmers from both agro-ecology have responded that they agreed in the decrease of precipitation as compared to the trend decade ago. They explained that the pattern and the distribution of both seasons (*Belg* and *Meher*) have shown variation and fluctuations. The extent of fluctuations was explained by 83 percent of the respondents as high and 16 percent as moderate. The result indicates uniformity of opinions among farmers and they perceive that the rain is less predictable and short. They also believed that they had witnessed a change in the timing of the rains.

Male respondent (66 percent) in *Dega* (cool, humid, and highland) area perceived the decrease of rainfall more than the male (36 percent) in *Wurch* (cold and highland) *kebeles*. *Dega* dwellers feel the variability of the rain more than *Wurch* dwellers where as *Wurch* inhabitants still benefit the cold humidity for agriculture that gives them a lesser feeling on perception.

Similarly, female respondent in *Dega* area (70 percent) perceived the variability of the rainfall more than female (30 percent) from *Wurch* area. This is because *Dega* areas are bordered with *Woina Dega* and *Kolla* areas and sense the feeling of these *kebeles*. However, *Wurch* dwellers benefit out of the relative humidity and the dewdrops.

About 65 percent male respondents from *Dega* (cool, humid, and highland) and 35% from *Wurch* (cold, highland) *kebeles* reported that there is unpredictable variation in pattern and distribution of the rain in both seasons. About 72 percent of female respondents from *Dega* and 28 percent from *Wurch* area reported similarly as the males. Generally, 67 percent of respondents from *Dega kebeles* were aware of the variation of rain better than from *Wurch kebeles*.

The survey has also assessed the future expectation and prediction of farmers about the rain, and 60 percent reported that there will be low rain while 28 percent said it will be moderate rain but the intensity of the rain would remain high and the pattern would vary.

From the survey, it was found out that, three decades ago, the area was well known as one of the best *belg* producing *woredas* and used *meher* as a minor season to produce agricultural crops. There was sufficient rain, soil moisture, minimal crop diseases, absence of frost, and less frequent drought occurrences in the *woreda*. Absence and/or shortage of *belg* rain, population pressure, soil erosion, God's wrath, and soil infertility were mentioned as reasons to shift from *belg* to *meher* production season. *Meher* season has also its own characteristics like excess rain, hail storm, severe erosion, frost, and crop diseases. Now the major production season remained to be *meher* than *belg*.

As far as the perception of temperature is concerned, their response indicates that 99.4 percent (179) of them observed an increase in temperature as compared to the last decade. Seventy percent of the respondents reported that the extent of the increase of the temperature is moderate, 20 percent high and 10 percent replied as low. Their response was in line with the report by Temesgen *et al.* (2009) and NMA (2001) that explained most farmers are aware of the fact that temperature is increasing. The highland dwellers have sensed that change of temperature is real in their surrounding and sensed more as never before. The inhabitants from humid (*Wurch*) sensed the change in temperature as low because they still benefit from cool

weather. Their prediction of temperature in the future indicated that 82 percent of households believed that the temperature would rise higher than the present. However, the remaining believes that the temperature in the future will be moderate as far as trees plantation, and soil and water conservations practices will be done.

Following an increasing temperature about 98.9 percent has changed their clothing styles. They used to wrap themselves with locally made thick clothes to keep themselves warm. But now their style has changed to lighter dresses. About 95.6 percent responded that they avoided walking to distant places to escape from the scorching-sun during the day time; 82 percent of the farmers reported that they have changed the working time to early in the morning and increased water consumption (13 percent) in the household.

3.3 Farmers Perception of the Impacts of Climate Change and Climate Variability

3.3.1. Recurrent drought

In 1984 (they refer to it as "*Seba-Sebat Dirk*"), 1990 and 2000/2001, there were serious drought occurrences in the *woreda* that caused many people to suffer and livestock to perish. During these years, due to the failure of *belg* season and poor harvest of the *meher* season, the local community was dependent on food aid and medical supports. The recorded meteorological data indicated that the area received the lowest *belg* and *meher* precipitation for crop production in those years. Moreover, the area has become one of the food insecure *woredas* in the zone having recurrent drought (*woreda* Office of Agriculture and Rural Development unpublished report, 2010).

All respondents indicated that an increase in temperature had a negative effect not only on the availability of water but also on the quality and quantity of water. About 99.4 percent people reported that climate variability and climate change had a negative effect on agricultural activity, which in turn affected the household economy of farmers. In 2020, the likely reduction of 50 percent yields from rain-fed agriculture is expected in some countries (IPCC, 2007).

3.3.2. Loss of biodiversity (Local wheat and barley)

During the survey, focus group participants, households, key informants and experts informed that before three decades, there were indigenous varieties of wheat well known to the area called *Temezh, Gundle, Dimeto*, and *Bullo* and barley typically known as *Netch Mawugie, Tikur Ferkie, Workiye*, and *Kibutie*. However, at present these varieties are disappearing from the *woreda*. In line with this, Fischer *et al.* (2005) reported that wheat production is likely to disappear from Africa by 2080's. Thereby, local government officials gave the varieties to the Ethiopian Institute

Biodiversity (EIB) for *ex-situ* conservation before extinct. North Shoa zone has been identified as the possible areas where greater genetic erosion of grains is expected because of the recurrent drought in the area.

3.4. Household Responses and Local Adaptation Strategies

Respondents identified the following major coping strategies for climate-induced problems. These are, adjustment of household food consumption (100 percent), borrowing of grain and/or money from relatives (97 percent), undertaking crop and vegetable gardening using micro-irrigation (83.8%) on a small homestead plot of land, seeking food aid (97 percent), searching for daily labour (96 percent), eat the seeds (95 percent), sale of livestock and their by-product (82.7%). and others (26 percent). As the climate variability and the change keep continuing for extended duration, farmers also continue to keep implementing adaptation measures. Moreover, use of traditional water wells, planting highland fruits (such as apple), and construction of soil and water conservation structures are addition mechanisms.

4. CONCLUSIONS

The erratic pattern and distribution nature of the rainfall and a rise of temperature in the *woreda* have tremendous influences upon the production and productivity of rain-fed agriculture. The rainfall variability, recurring frequently, and the temperature rise have deteriorated their adaptive capacity of highland farmers. An unpredictable *belg* and *mehe*r seasons in the *woreda* have also made them to shade frustration upon their livelihoods. Thus, the ever-changing climate variables has been resulting a negative impacts on their rain-fed agricultural practices and the livelihood of the rural smallholder farmers.

The loss of biodiversity, indigenous wheat and barley crop cultivars, have been a serious threat in the area. With all these and other major effects of rainfall variability and temperature rise, highland farmers are struggling to adapt the changes. The adaptation effort of smallholder highland farmers is beyond their capacity to handle the harm effectively and their limited adaptive capacity demands the concerted efforts and intervention of concerned stakeholders. Their local adaptation practices need to be encouraged and further explored to strengthen their adaptive capacity.

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PAYMENTS FOR ECOSYSTEM SERVICES: CHALLENGES, OPPORTUNITIES, AND FUTURE PROSPECTS FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

Ecosystems and biodiversity, among others, provide major life support services of food, clean water, recreational, and climate regulation. Despite these values, worldwide biodiversity is being lost at a rapid rate. This calls for urgent need of polices and incentives to promote conservation and sustainable use of biodiversity and ecosystem services as well as efficient use of the scarce finance in existing biodiversity programs. The basic features of these environmental services are that they present externalities and considered as public goods. This makes owners (beneficiaries) not to give due attention when making land use decisions. As a response, the recognition of environmental values has led to efforts to internalize environmental services through direct Payments for Ecosystem Services (PES). The internalization process is needed because a better road towards sustainable development involves better integration of the environment into economic decision making through the use of economic techniques for the appraisal of the projects and policies. A method central to this effort is economic valuation of ecosystem services. The objective of this review paper was to address the controversies surrounding the economic valuation of biodiversity for sustainable development. For this, PES studies selected based on the criterion of being published in peer – reviewed journals were used. The results obtained from different studies indicate that there was uneven distribution with regard to the experience of implanting PES schemes. Accordingly, most countries that have experience are those in Latin America and East Asia, while practice of using PES schemes was found to be at its infant pilot stage in most African countries.

Keywords: biodiversity, externalities, public goods, sustainable development, internalizing.

1. INTRODUCTION

Payment for Ecosystem Services (PES) refers to a voluntary transaction in which a well defined ecosystem service (or corresponding land use) is bought by at least one ecosystem service buyer from at least one ecosystem service provider if and only if ecosystem service provision is secured, called conditionality. The public nature of most ecosystem services and the difficulty in finding reliable measures for ecosystem services lead to application of proxies (such as changes in land use or management). Failure to fulfil all criteria of PES results in some approaches being termed PES-like schemes (Wunder, 2005).

Inability of the traditional fiscal tools to finance the physical and financial demand for environmental services calls for alternative tools. Among alternatives, the market-based tool called Payment for Ecosystem/Environmental Services (PES) is advocated (Scherr *et al*., 2006).

Given the importance and advanced nature of PES, the following five criteria have been identified as the pre-conditions for its successful implementation. First, transaction must be voluntary against the command and control approaches to conserve biodiversity. Second, the environmental service (or the land used for provision of the service) for which the payment is going to be arranged need to be well defined. Third, there must be at least one buyer of the environmental service. Fourth, there must be at least one seller of the environmental service. Fifth, the payment for the environmental service is conditional up on the receipt of the service by the buyer(s) (Wunder, 2005b; Van Noordwijk *et al*., 2007; Pagiola, 2008).

Due to the dynamic nature of environmental services, the conditional requirements for PES implementation also vary through time. Hence, sufficient awareness of stakeholders (buyers and sellers of the environmental service) at different level; incorporation of intermediary institutions that can support operations of PES markets in case of weak governance structure; and clearly defined property rights are also considered as requirements needed for successful practicing of PES (Mayrand and Paquin, 2004; Tomich *et al*., 2004; Huang and Upadhyaya, 2007; Wunder, 2007).

2. EMPIRICAL FINDINGS

2.1 Payment for Ecosystem Services vs. Indirect Conservation Approaches

Different authors in different times highlighted the success of PES scheme over traditional and indirect biodiversity conservation and valuation of ecosystem services. Some of them are institutionally simple nature; cost effective in delivering benefits to buyers; effective in generating economic growth among suppliers by improving cash flow; possibility of diversifying income sources and reducing income variance, and provision of new sources of finance for conservation were the main advantages of using PES than the traditional approach (Ferraro, 2001; Ferraro and Kiss, 2002; Pattanayak *et al*., 2010).

Despite the existence of advantages of using PES for biodiversity conservation and ecosystem services valuation, authors indicated difficulty of implementing PES with regard to some conditions. Accordingly, direct payments for ecosystem service (PES in this case) are indicated to be institutionally complex to implement in developing countries and poor communities. This is due to the prevalence of insecure land tenure system, weak institutions and preference for other non-PES approaches to provide

collective benefits such as schools and health clinics in developing countries (Leimona *et al*., 2009; Milne and Niesten, 2009).

The implementation status of PES is not uniformly distributed in different parts of the world. In Latin America and South-East Asia the market based PES schemes are successfully implemented. While in Africa, most PES schemes are at their pilot stage, heavily supported by donors and NGOs, are not self sustained financially and technically, and adequate lack proper monitoring mechanisms to ensure fulfilment. In Africa, the PES schemes are characterized by lack of conditionality and monitoring mechanisms to ensure delivery of ecosystem services made them operationally similar to integrated conservation and development projects i.e. initial popularity ends when expensive pilot projects were shown to deliver few livelihood benefits and sustainably proved elusive (Mc Shane and Wells, 2004; Ferraro, 2009; Clements *et al*., 2010).

2.2. Experience of PES Implementation

Different authors and agencies indicated that, countries like Costa Rica, Australia and United States, capitalize the commercial value of ecosystem services through different approaches. In Costa Rica, the government is administering a nation-wide scheme of payments for ecosystems services (Pagiola, 2002). In Australia, the Wentworth Group (known to be a high-level advisory group) has called for new approach to environmental protection that focuses on provision of ecosystem services (The Wentworth Group, 2002). While in USA, the United States Environmental Protection Agency (EPA) has created a science advisory board on valuing the protection of ecological systems and services (Science Advisory Board, 2003).

George *et al*. (2009) identified the main potentials and limitation of PES to manage the watershed services in Northern Thailand and found the following results. Pre-existing organizations and effective coordination among farmers as well as the perception of farmers as legal owners of land are identified as favourable conditions for the implementation PES scheme. In contrast, the prevalence of a belief that services from natured need to be provided freely is considered as major obstacle to successfully implement PES. The very low willingness to pay for PES among stakeholders made any PES market unlikely to emerge without external support in the area. Finally, preference for strong liaising between the farmers and the authorities are found to be a major prerequisite for successful establishment of PES markets, even without direct government funding.

Andrew and Masozera (2010), after indicating the two major challenges confronting Rwanda (Reducing poverty among rural households and protecting ecosystems), indicated that connecting PES with the rural poor could make a significant contribution to both. The authors also added that, most Rwandan smallholder

subsistence farmers heavily depend on local ecosystems for their survival and hence be directly affected by any changes in the availability of ecosystems goods.

The ability of farmers to invest more in fertilizers, improved seeds, and small-scale irrigation helps as a cushion against meagre times such as droughts depending on their income level (Polak, 2008). For this PES is advocated. This is due to the impact of PES on farmers' income i.e. using their land, smallholder farmers can provide valuable services, such as carbon sequestration, water flow or biodiversity conservation that can generate additional income.

2.3 The Three Common Markets for Ecosystem Services

Salzman (2005) classified the markets for different ecosystem services into three groups of: Mitigation markets, purely business to business (B2B) markets, and government payment markets.

2.3.1. The mitigation markets

The mitigation markets are those developed purely by governments. The confirmation from government parties is needed to develop land to mitigate for the loss of habitat and loss of services from the proposed development. The US wetlands mitigation banking and the proposed Clean Development Mechanism (CDM) is the best example of mitigation markets for ecosystem services.

2.3.2. The Business to Business markets (B2B)

The Business to Business markets (B2B) are markets for ecosystem service in which private buyers and seller exchange payments for ecosystem services based on their self-interest. In this market, the role of government is only to enforce contracts. The largest bottler of mineral water in the world, Perrier Vittel, is the best example for B2B markets. In the early 1990s, with the objective to reduce the nitrates and pesticides entering the springs around its bottling operations in North Eastern France, Perrier Vittel applied different payment mechanism to change land used in the catchment area. Through the payment scheme, the bottler company reduced non-point source pollution, changed the local dairy farming and animal waste management practices and eliminated cultivation of corn and use agricultural chemicals. This implies that any effort to improve one aspect of the environmental service leads to a trade-off.

2.3.3. The government payment markets

The government payment markets are the public good nature of most ecosystem services creates difficulty to find markets for proper valuation of these diverse services provided by ecosystem. This necessitated the government intervention and

hence the government payment schemes. The rationale for this market is that most operating ecosystem services markets are neither B2B nor mitigation markets. One example for this type of market is that of government provision of drinking water to New York City residents.

2.4 Market for Ecosystem Services, Economic Growth, and Economic Development

Compared to other ecosystems services (such as regulating and supporting, cultural and recreational) the provisioning of materials service is largely included in the market transaction systems. So, the experiences gained from this ecosystem service can possibly be used to create and develop markets for the remaining ecosystem services (Rodríguez *et al*., 2006; Wallace, 2007).

The necessity for developing markets for ecosystem services stemmed from the assumption that, properly developed markets for ecosystem services paves the way to proper valuation of these resources and hence leads to economic growth as well as economic development. However; some authors found completely contrasting result from markets for ecosystem services. Ross (2001) and Dube and Vargas (2006) found that resource revenues, from markets for ecosystem services, have turned to be counterproductive and aggravated economic problems instead of creating prosperity. This scenario leads to the emergence of *the resource curse hypothesis*. The hypothesis mainly reflects case of non-renewable resources, similar phenomenon is also observed in renewable resources of timber and agricultural products.

The resource curse concept, that received attention in the 1990s, primarily refers to the developing countries experience in the second half of the 20th century (Mehlum *et al*., 2006 a, b). They explained the situation in such a way that, the effects of resource abundance on economic growth depends on the quality of institutions in that country. In line with these authors funding, Brunnschweiler and Bulte (2008) and Wick and Bulte (2009) indicated that with the absence of good institutions, resource revenues form ecosystem services remove incentives to improve infrastructures and encourages rent seeking.

The possibility that abundant resources, with proper markets expected to be catalyst for economic growth, may have adverse effects on economic growth is best explained by the Prebish-Singer hypothesis (Prebish and Singer, 1950). According to this hypothesis, the declining price of commodities, provided by ecosystem services, relative to manufactured goods price indicate the detrimental effect of resource abundance and markets for ecosystem service on economic growth.

Corden and Neary (1982) explained the negative effects of markets for ecosystem services and revenues obtained on economic growth through the concept called the Dutch-disease. According to the Dutch-disease, large revenues obtained from

ecosystem services may lead to inflation pressure and shifts factors of production to the extractive sector by leading detriment of other productive sectors.

The protection of ecosystem services through integrating them into the market system makes PES a promising and efficient approach (Swallow *et al*., 2009). Despite the prevalence and development of PES on international scale, PES has been developed mostly on regional scale. As a result, the PES schemes did not made significant impacts on economies in which they were implemented. With rapid adoption of PES, however, their effects are likely to change in the future. In line with the changing role of PES, Carroll and Jenkins (2008) found that PES related transactions are likely to mount up to 1.1 trillion USD by the year 2050. This is a huge advancement when compared with 87 billion USD in 2006. Milder *et al*. (2010) estimated that, ecosystems service markets may generate benefits for six hundred to eight hundred million rural poor by 2030.

3. SUMMARY AND CONCLUSIONS

Despite the heavy dependence of people survival and wellbeing on biodiversity and ecosystem services, the world is experiencing higher biodiversity loss and degradation of ecosystem. As far as the effects of loss in biodiversity and ecosystems are concerned, the world poor are at the forefront of the adverse effect. This is mainly due to their direct dependence on ecosystem services for food, clean water, fuel, medicine, and shelter. This implies that, the poor people will be challenged disproportionately by any catastrophic changes related to biodiversity and ecosystem services. Ecosystem services are the benefits that society and economy derives from the environment. In this relationship, the environment, as a service provider, become a partner for decision makers at local, regional, national, and international levels. Due to the frequent and adverse effects of climate change, the issue of proper valuation of ecosystem services gained popularity and due attention by various responsible bodies. Different countries and organizations, both governmental and NGOs, are applying a market based economic valuation of ecosystem services called Payment for Ecosystem services (PES). In this PES, there will be at least one seller of a predetermined ecosystem service and at least one buyer of that service. Besides, PES is based on voluntary transaction approach between stakeholders. The rationales for choosing this approach are the inability of the indirect conservation approaches and successful experience by some Latin American and Asian countries. Hence, the experience of these countries can possibly be used by other developing countries, like in the Sub-Saharan, to achieve reduced vulnerability of the poor, poverty reduction and sustainable development. Achieving these objectives is not a simple task, rather calls for collaboration of different actors in various levels.

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HIGHLIGHTS OF THE CONFERENCE FINDINGS

- A large new database presented at the conference on the continental distribution of species shows that Ethiopia and its neighbouring states hold the richest biodiversity in Africa.
- Ethiopia's has an extraordinary diversity of landscapes and cultures in addition to biodiversity.
- Land use, population growth, and pressure on resources are the gravest threats to biodiversity.
- Wildlife populations have declined sharply within parks as well as countrywide in recent decades.
- Ethiopia needs clear policy guidelines and conservation strategies for conserving critical areas in and outside-protected areas and to foster the collaborative management.
- The impact of climate change was severe and greatly amplified by land fragmentation and degradation.
- Current global climate models are too coarse to provide reliable forecasts of regional and local changes. Finer scale models are urgently needed to increase the resolution of forecasts and guide adaptation measures.
- Restoration is an expensive and lengthy process and can be avoided by immediate conservation measures that avert further environmental degradation and bring quick benefits to impoverished communities.
- There is urgent need of a national integrated environmental policy that reflects the constitutional principles of environmental rights, devolution and governance to guide all sectors of the economy.
- Parks can no longer be considered in isolation. Protected area planning must be nested within ecosystem and landscape conservation strategies in order to sustain ecological integrity and viable species populations.
- A policy and legal framework specific to endangered and threatened species is needed as a matter of urgency.
- The trans-border movements of species and the regional scale of biodiversity distribution calls for conservation strategies prepared with neighbouring states under the aegis of the East African Community.
- Biodiversity policies and conservation strategies must reinforce landowner initiatives and encourage voluntary environmental management practices in parallel with the devolution of political and environmental governance.
- Ethiopia should develop and formally adopt a national framework that identifies the biodiversity gaps in conservation coverage and conservation area needed for sustainability, taking into account-projected changes in land use and climate.

Important Lessons Learned from the Conference

- We depend on mother Earth for our survival and the Earth also depends on us to provide the best service we may demand from her.
  - The more we care for Earth the more we get from her and we get it sustainably
  - Human beings are the most aggressive contributors to degradation of natural resources in their effort to cope up and make their livelihood in such a challenging environment
  - Some of the witnesses for our changing habitat from the presentations include:
    - The case of Babile Elephants Sanctuary (shrinking of the area, change in vegetation structure, killing of the Elephants)
    - Drying up of springs/stream/lakes/rivers in various parts of Ethiopia and the world at large
    - Threats related to in appropriate exploitation of lakes (the case of Lake Tana)
    - Conflict among wildlife and humans
    - Rising in the sea level and its impact on the coastal areas
    - Pollution of the environment (water, air, soil, etc)
    - Threatened biodiversity due to land use changes and encroachment by notorious invasive weeds
    - Encroaching desertification
    - Death and migration of wild animals,
    - Reduction in snow caps on Mount Kilimanjaro (shining mountain) and Environmental degradation in general
- The world is so unfair that the innocent people in developing countries are the victims of and the most vulnerable to climate change brought about by others enjoying opulent lives.
- The good news is that most of the solutions are also in the hands of human beings: For instance, in Ethiopia,
  - Renewable energy sources being emphasized
  - Green economy component part of our GTP
  - Climate Resilient Green Economy Strategy being in place
  - Carbon neutral Green economy coming up (by 2020)
  - Adaption programs reaching at village level
- Coping, adaptation, and mitigation mechanisms of climate change impacts (Experiences from different countries:
  - The case of pastoralist of Kenya, Ethiopia and India
  - Mainstreaming gender in biodiversity conservation
  - involvement of civil society and the community in biodiversity conservation

- Mainstreaming marketing in biodiversity management

- The question is, is it possible for the living organisms, especially human beings to survive without disturbing nature? Can mother earth satisfy the needs of uncontrolled growing population as another challenge?
- Population pressure and its increasing demand is also one of the main drivers of the imbalance on nature especially in developing countries exacerbating impacts of climate change on the environment and living organisms.
- Based on the highlights given and the overall presentations and discussions held during the three-day workshop, the participants should come up with the ways forward, which may contribute to the enrichment of policies related to biodiversity utilization and conservation and research needed to widen the knowledge in sustainable use of biodiversity under the changing climate.

Policy Briefs and Recommendations

- Incorporate the multiple values of biodiversity and ecosystem services into policy and management decisions
- Incorporate biodiversity and ecosystem services into water and land-use planning at all scales from local to national, including both protected areas and production landscapes and seascapes
- Implement policies and practices that reduce inequities in access to the benefits derived from biodiversity and ecosystem services, and ensure that those who bear the cost of their provision are fairly compensated
- Restructure ecosystem governance and management to recognize that ecosystems transcend political boundaries
- Quantify the many values of biodiversity, including natural capital, ecological services, and the diversity of life
- Enumerate and quantify the importance of biodiversity to land and natural resource productivity, resilience to drought and environmental shocks, and adaptability to climate change
- Establish the institutional mandates and capacity at national, county, and local level for auditing and monitoring biodiversity, natural resources and land health, and for forecasting the key environmental threats
- Bring environmental policy in general, and biodiversity policy in particular, in line with the constitution, recognizing individual rights to a clean, safe environment, the conservation of biodiversity, the devolution of environmental rights and responsibilities, the need for the integration of natural resource management based on sustainability, and the importance of environmental security based on the precautionary principle
- Promote voluntary environment management, and new tools and practices that build public-private sector partnerships and local initiatives for conservation
- Promote integrated and multi-sectoral approaches to the formulation and implementation of biodiversity conservation strategies in line with the National Land Policy. The strategies should include zoning, best-use practices, the maintenance of land health, building resilience and adaptation to current inimical human activities and future anticipated climate change
- Develop and promote the use of Payments for Ecosystem Services for costing and sustaining biodiversity
- Base an evaluation of the benefits of biodiversity and ecosystem services on sound scientific and sustainable development principles and on reliable databases