THE IMPACT OF DEFORESTATION ON SOIL EROSION AND CLIMATE CHANGE: STRUCTURAL EQUATIONS MODELING

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PROGRAM OF GRADUATE STUDIES

DEPARTMENT OF STATISTICS

Addis Ababa

June, 2010

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A Thesis Submitted to the Department of Statistics of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Statistics

Addis Ababa

June, 2010

Research Title: The Impact of Deforestation on Soil Erosion and Climate Change: Structural Equations Modeling

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Acknowledgment

I am very much grateful to express thanks to Professor Eshetu Wencheko who advised me in the planning, preparation and production of this thesis. Without his assistance the final outcome of this thesis could have been impossible.

This study was conducted by financial assistance from the Gamo-Gofa Zone Head Administration and data from Gamo-Gofa Zone Agricultural Department. I am also indebted to all (Ato Tuma Ayele, Ato Muntas Muda and Ato Yabebal Ayalew) who assisted me during data gathering up to final work.

Abstract

The goal of this study is to model the impact of land use system considering deforestation, soil erosion and climate change using structural equations model through confirmatory factor analysis technique. Moreover, it aims to provide additional information and also to create public awareness for effective conservation and utilization of forest and soil resources.

The covariance structure of the land use variables is used to study the linear structural relations among the model variables. The covariance matrix of the model is used to test whether structural equations model is overidentified or not and that consistent with the observed data that was obtained from the Agriculture Department of Gamo-Gofa Zone and collected since 2005. The confirmatory factor analysis of this study shows that increase of soil erosion or climate change effect lead to decrease in forest and bush land coverage and change fertility of land. Thus, new crop land demands have been increased and implemented through deforestation. Forest and vegetation cover in Gamo-Gofa depleted alarmingly, and as a result soil erosion and climate change rate speedy. This decline was caused by intensive use of land through deforestation, overgrazing, clearing trees and grasslands to take it under cultivation. We advocate the planning and management of land resources that is integrated and holistic with awareness of land users. This will ensure the long term quality of the land use system.

Key words*: climate change, confirmatory factor analysis, deforestation, land use system, soil erosion, structural equations model*

Acronym and Abbreviation

CFA	Confirmatory Factor Analysis
CFI	Bentler’s Comparative Fit Index
CSE	Conservation Strategy of Ethiopia
EFA	Exploratory Factor Analysis
EFAP	Ethiopian Forestry Action Program
FAO	United Nations Food and Agriculture Organization
FCUP	Forest Conservation and Utilization Policy
GFI	Goodness of Fit Index
IPCC	Intergovernmental Panel for Climate Change
ML	Maximum Likelihood
MoFED	Ministry of Finance and Economic Development
NFI	Bentler & Bonett's (1980) Normal Fit Index
NNI	Bentler & Bonett's (1980) Non-Normed Index
PCF	Probability of Close Fit
PROC CALIS	Procedure (Covariance Analysis of Linear Structural Equations)
REDD	Reducing Emission from Deforestation and Forest Degradation
RMSEA	Root Mean Square for Error Approximation Estimates.
SAS	Statistical Analysis Software
SE	Standardized Estimate
SEM	Structural Equation Modeling
ULS	Unweighted Least Squares
WLS	Weighted Least Squares

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Declaration

I, the undersigned, hereby declare that this thesis entitled, "The Impact of Deforestation on Soil erosion and climate Change: Structural Equations Modeling" is my own work, and that all the sources I have used or quoted have been indicated or acknowledge by means of completed references.

Name	Signature and date

1. INTRODUCTION

1.1 Background

During the next few decades, global ecological changes are expected to have major impacts on ecological, social, economic, and political aspects of human society (Dale, 1997). The ecological impacts include changes to biodiversity, productivity, migration, safety, and sustainability. Climate and land use changes are two major global ecological changes predicted for the future. Therefore causes and consequences of human-induced climate change and land use activities have largely been examined independently (Turner et al., 1993). However, climate change and land use affect each other. Land use activity contributes to climate change and soil erosion, and changes in land cover patterns are one way in which the effects of climate change is expressed.

Land use is the human modification of natural environment or wilderness to build fields, pastures, and settlements. The major effect of land use on land cover has been deforestation of temperate regions (IPCC, 2007). More recent significant effects of land use include urban spread out, soil erosion, soil degradation, salinization, and desertification.

Land use and land management practices have a major impact on natural resources including water, soil, nutrients, plants, and animals. According to a report by the United Nation Food and Agriculture Organization (FAO, 1995), land degradation has been exacerbated where there has been no effective land use planning, or of its orderly execution, or the existence of financial or legal incentives that have led to the wrong land use decisions, or one-sided central planning leading to overutilization of the land resources - for instance for immediate production at all costs. As a consequence, the result has often been misery for large segments of the local population and destruction of valuable ecosystems. Such narrow approaches should be replaced by a technique for the planning and management of land resources that is integrated and holistic and where land users are central. This will ensure the long term quality of the land for human use, the prevention or resolution of social conflicts related to land use, the conservation of ecosystems of high biodiversity value, and mitigation of the rate of climate change.

Land use effects on climate change and soil erosion include both implications of land use change on atmospheric flux of carbondioxide (CO_2) and its subsequent impact on climate and soil, and the alteration of climate change impacts through land management. An effect of climate change on land use refers to both how land use might be altered by climate change and what land management strategies would mitigate the negative effects of climate change.

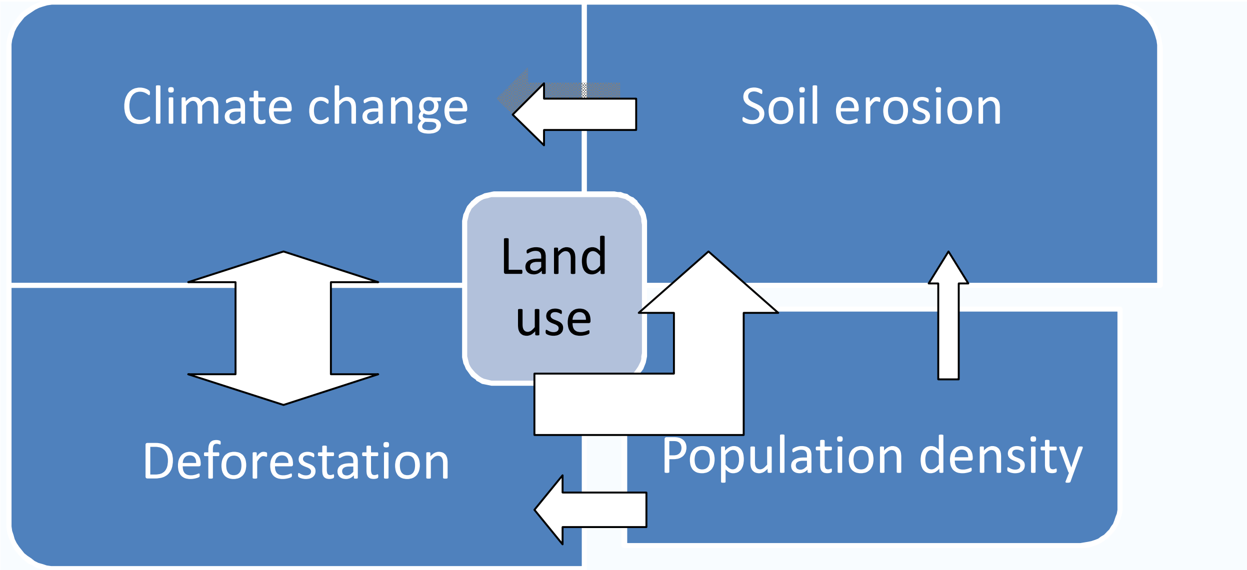

Figure 1. Forward and backward structural relations (causations) of study variables.

The direct ecological effects of land use and climate change are dominated by the land use change effects, at least over a period of a few decades (Dale, 1997). Because climate change effects are largely determined by land cover patterns, land use practices set the stage on which climate alterations can act. Determining the effects of climate change on land use involves resolving direct biophysical effects as well as management responses to climate impacts. The population density on given land use system links deforestation with soil erosion and facilitates their effects on climate change through land use of human activity. There are two aspects to considering impacts of land use: effects of land use on climate change and soil erosion; and the effects of human induced climate change on land use (Figure 1).

Deforestation is a major concern in Ethiopia as studies suggest loss of forest contributes to soil erosion, loss of nutrients in the soil, loss of animal habitats and reduction in biodiversity, averting of water quality, and climate change. The vegetation resources and ecology of Ethiopia, including forests, woodlands and bush lands, conservation of soil, have been studied by several scholars who have employed different methods and have studied different localities to come up with conclusions.

1.2The study area

The study area, Gamo-Gofa is a province in the southern part of Ethiopia, named after two of the ethnic groups living within its boundaries, the Gamo and the Gofa. First incorporated into Ethiopia by Emperor Menelik II in the 1880s, its capital was Chencha, and then around 1965 the capital was moved to Arbaminch.

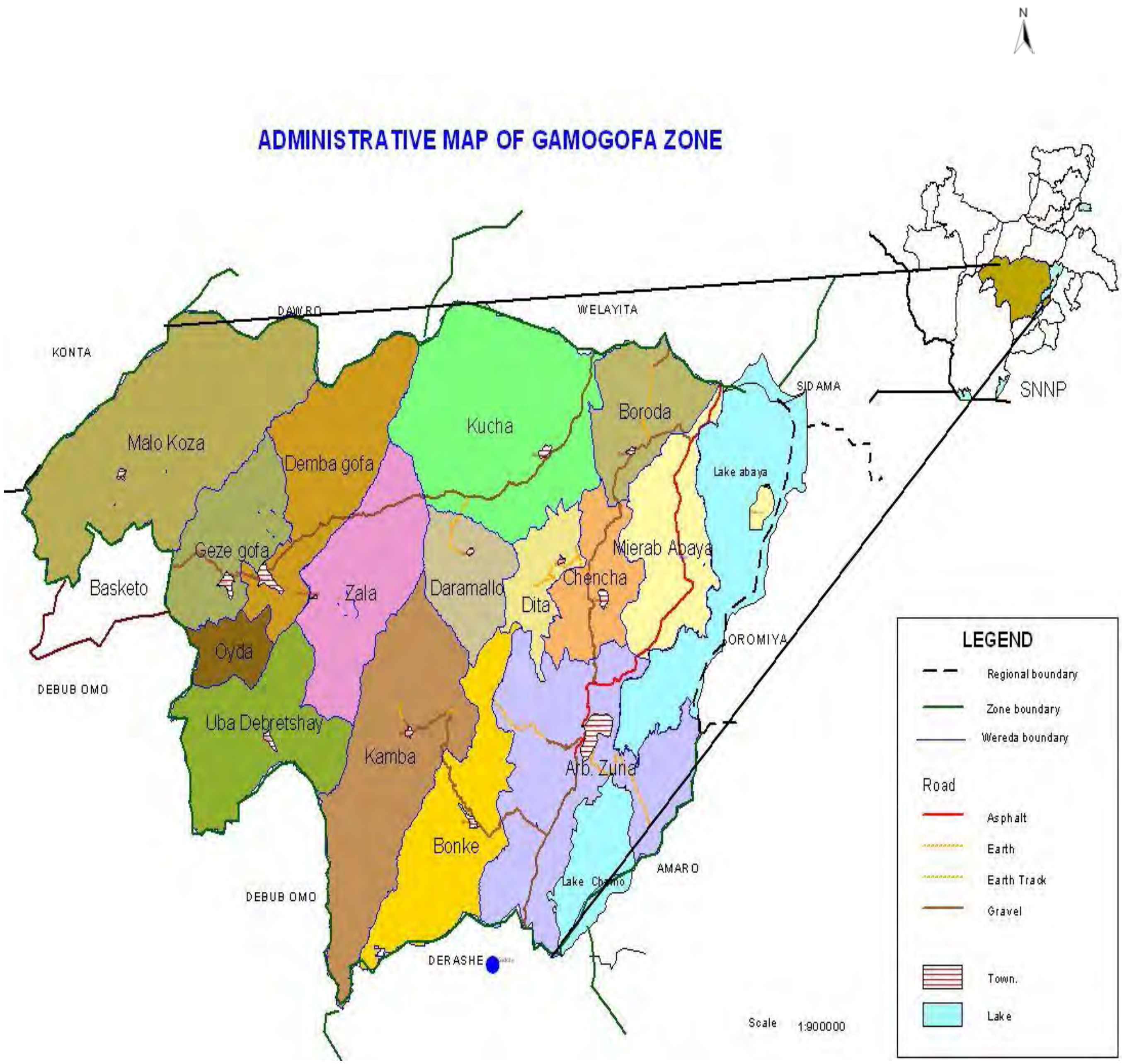

Figure 2. Map of Gamo-Gofa Zone

Source: Department of Finance and Economic Development of Gamo-Gofa Zone

The highlands of Gamo-Gofa are characterized by nine rainy months, which occur from March to October and in January. Furthermore, the southern parts of Gamo-Gofa are characterized by eight rainy months from February to July and from September to October (Daniel Gamachu, 1977). High concentration of rainfall occurs in the month of April which helps rapid vegetation growth. Despite these realities, the vegetation resources, particularly forests, are disappearing at a very alarming rate in Gamo-Gofa. If this trend of deforestation/devegetation continues without any control, there is a great danger of serious decline or loss of biodiversity. Since the population is growing at a rate of about 3% per year, the need for more arable land to cultivate crops becomes inevitable, aggravating the rate of deforestation and associated land degradation. It is, therefore, urgent and important to study and conserve the vegetation resources (forests) and soil of the country by providing appropriate management strategies or tools with modeling relation to soil erosion and climate change.

An ancient people speaking an Omotic language, the Gamo-Gofa protect remnant forests, burial grounds and traditional assembly places across Ethiopia’s vast southwestern plateau. Today, the highlands are home to about more than a million people, of which the Gamo are the main ethnic group. Subsisting on small holdings and communal grazing areas (Gubbe) rich with sheep and cattle, the Gamo-Gofa cultivate a variety of crops, including cereals and fruit trees, coffee and the all important staple enset (false banana). They are known internationally for their beautiful, detailed weaving. Now wholly located within Southern Nations, Nationalities and People’s Region, the Gamo Highlands spreads over 1,600 square miles, rising above lakes Abaya and Chamo. Gughe Mountain, at 9,842 feet, is the highest peak along the undulating chain that overlooks the Rift Valley extending south to Kenya. The highland region contains a diversity of plant and animal life, encompassing several ecosystems including Afroalpine grasslands and evergreen Afromontane forests. There are great sections of rare native bamboo forest, especially on the flanks of Gughe Mountain. The monsoonal rains and deep aquifers feed the Sago, Zage, Maze, Dombe, Deme, Kulano, Gogora, Saware, Wajifo, Baso, Harre, Kullufo, Biltte, Sile and Elgo rivers and provide water for the people and the fertile fields in the lowlands. The Gamo culture is bound intimately with the land. The Gamo’s traditional activities depend on a harmonious relationship with the local environment, which frequently contributes to minimizing environmental disruption and thereby maintaining an overall ecological equilibrium. In the highlands, the Gamo have protected at least 272 sacred groves along waterways and on the tops of hills, these being the remnant forests of formerly vast Afromontane woodlands (Desalegn Dessisa, 2008). Within the groves, the people keep their ritual relics and perform sacrifices, healings, harvest rituals and fire ceremonies that symbolize the connection between the past and the future. There is rainmaking and rain-stopping ceremonies and thanksgiving rituals, all of which recognize the peoples' dependence upon the earth sustain their livelihoods. Many groves are also Bossa (burial grounds). Surrounding these burial forests is Ballee (grasslands) where people mourn but which also function as buffer areas that are off limits to grazing and cultivation. Besides protecting sacred groves, the Gamo continue to practice organic and terraced cultivation and composting, which has greatly controlled soil erosion and water pollution and allowed them to cultivate 91 percent of their total land area. Careful use of manure as fertilizer is a key to soil fertility throughout the region.

However, now a day these important traditions which are helpful to conserve forest and soil, and their values have been dissolved by modern cultures and religion lessons. As a result the resource conservation functions are not as is or reduced and contribute to environmental crises. Thus, this study attempts to model the impact of land use in considering deforestation, soil erosion and climate change. Also, the study attempts to identify the effect of deforestation on climate change and soil erosion by applying land use data considering / reviewing current practice of environmental policies and strategies of the country. The emphasis is on regional landscapes, for these are the spatial scales at which land use cover pattern, soil loss and climate change interactions occur through human influence. The Structural Equation Modeling (SEM) is applied to the study variables. The covariance structure among the observed random variables is used to study the linear structural relations among the model variables and the covariance matrix of the model is used to test whether SEM is overidentified or not and that consistent with the observed data. The discussion implicitly focuses on effects of greenhouse gas emissions or sinks (especially carbndioxide) due to land use rather than those due to industrial activities and other sources and/or consumptions of carbndioxide.

A review of the literature deals with the relationship between land use changes on deforestation, soil erosion, and climate change emphasizing carbondioxide emission or sink that resulted through high rate of deforestation. It clearly shows that in recent centuries land use change had greater effects on ecological variables than has climate change; humans will change land use, and especially land management, to adjust to climate change and these adaptations will have some ecological effects. Therefore, understandings of the non-climatic causes of land use change (socioeconomics, culture and politics) are necessary to manage ecological functions effectively on regional and global scales.

1.3 Statement of the Problem

In Ethiopia, environmental degradation and deforestation have been taking place for hundreds of years. Forest coverage, in the entire country, declined from 35% to an estimated 2.4% in 1992 (Sayer et al., 1992). The low level of living standard and illiteracy of the majority of the people coupled with lack of alternatives are the fundamental factors responsible for the decline in forest areas of Ethiopia. This is due to the increasing demand for crop and grazing land, and wood for fuel and construction (Taye Bekele et al., 2002). Moreover, new settlements in forest are increasing and have resulted in the conversion of forest land into agricultural and other land use systems (Kitessa Hundera and Bishaw Deboch, 2008). Conversion of natural forests into cultivated fields can affect soil fertility and carbon sequestration; as a result carbondioxide induces climate change phenomena. The cumulated results of these and related actions cause a rapid change of climate, which is a great risk for today's world to sustain natural environment as is.

The ever increasing deforestation, soil erosion and the associated problems of decline in soil fertility and loss of biodiversity have resulted in making livelihood improvement a very challenging task to countries like Ethiopia that are highly dependent on agricultural and natural resource products. High population growth, climate variability and change, drought and associated famine, are reinforced resource depletion, poverty, and political instability. Clearly and explicitly the problem is a question of consequences of rapid rate of deforestation that exposes our environment to desertification and furthermore it creates environmental crisis. This study contributes its role by supplying information regarding deforestation reasons, soil erosion causes, and climate change through land use system and modeling the factors.

1.4 Objective of the Study

A successful environmental management constitutes a means to keep a balance between utilization and conservation of both natural and manmade resources. This can be achieved when consumers have a sound understanding about conservation, proper utilization, concern for coming generations and creating functioning policies, laws and regulations as well as stable organizations. So, the main objective of this study is to show the effect of deforestation on soil erosion and climate. With the above intention, this study has the following specific objective:

- ✓ To model the relationship between deforestation, soil erosion, and climate change.

1.5 Significance of the Study

This study has the purpose to model the impact of land use in considering deforestation, soil erosion and climate change. It provides additional information for policy makers to develop effective conservation and utilization policies of natural and artificial resources. Also it creates public awareness about resource conservation and reforestation. This will ensure the long term quality of land for human use, the prevention or resolution of social conflicts related to land use, the conservation of ecosystems of high biodiversity value, and reduce the rate of climate change.

1.6 Limitation of the Study

There is doubt about the 2005 land use data to reflect current status of forest coverage and crop land of Gamo-Gofa. Because today most of forest covered areas since 2005 have been used to farmland. That means current forest coverage is expected to be less than since 2005 and crop land area is expected to be higher than 2005. Video and photo documents do not support the 2005 data.

2. Literature Review

2.1 International Context

Deforestation is the clearing of naturally occurring forests and bushes from forested area by cutting and /or burning of trees. There are several reasons why deforestation occurs: trees or derived charcoal can be sold as commodity and used by humans, while cleared land is used as pasture, farming, plantations of commodities and human settlement. The removal of trees without sufficient reforestation has resulted in damage to habitat, biodiversity loss, aridity, soil erosion, and climate change. Deforested regions typically incur significant adverse soil erosion and frequently degrade into wasteland. Moreover these disregard or ignorance of intrinsic value, lack of ascribed value, careless forest management and incomplete environmental law are some of the factors that allow deforestation to occur on a large scale. There are many root causes of deforestation, including corruption of government institutions (Burgonio, 2008; WRM Bulletin Number 74), the inequitable distribution of wealth and power, population growth (Alain, 2000) and overpopulation (Butler, 2009) and urbanization. Globalization is often viewed as another root cause of deforestation, though there are cases in which the impacts of globalization (new flows of labor, capital, commodities, and ideas) have promoted localized forest recovery.

In many countries, deforestation is an ongoing issue that is causing extinction, changes to climatic conditions, desertification, and displacement of home-grown people. In 2000 the United Nations Food and Agriculture Organization (FAO, 2000) found that the role of population dynamics in a local setting may vary from decisive to negligible and that deforestation can result from a combination of population pressure and stagnating economic, social and technological conditions (Alain, 2000). Moreover, it facilitates the rate of drought occurrences, limits poverty reduction goals, and leads to low living standard of people and is a cause for political instability of country. However, among countries with a per capita gross domestic product (GDP) of at least $4,600, net deforestation rates have ceased to increase (The New York Times, 2009).

Figure 3. Jungle burned for agriculture in southern Mexico.

Source: http:en.wikipedia.org/wiki/File:Lacanja_burn.JPG

Many important forest functions have no markets, and hence, no economic value that is readily apparent to the forest owners or the communities that rely on forests for their well-being (Pearce, 2001). From the perspective of the developing world, the benefits of forest as carbon sinks or biodiversity reserves go primarily to richer developed nations and there is insufficient compensation for these services. Developing countries feel that, the poor shouldn't have to bear the cost of preservation when the rich created the problem (Erwin et al., 2000).

Damage to forests and other aspects of nature could halve living standards for the world's poor and reduce global GDP by about 7% by 2050, a major report concluded at the Convention on Biological Diversity (CBD) meeting in Bonn (BBC News, 2008). Historically utilization of forest products, including timber and fuel wood, have played a key role in human societies, comparable to the roles of water and cultivable land. Today, developed countries continue to utilize timber for building houses, and wood pulp for paper. In developing countries almost three billion people rely on wood for heating and cooking (http://atlas.aaas.org/pdf/63-66.pdf).

Reducing emissions from the tropical deforestation and forest degradation in developing countries has emerged as new potential to complement ongoing climate policies. The idea consists in providing financial compensations for the reduction of greenhouse gas emissions from deforestation and forest degradation.

Deforestation is a contributor to global climate change (Philip and Laurance 2004), and is often cited as one of the major causes of the enhanced greenhouse effect. Tropical deforestation is responsible for approximately 20% of world greenhouse gas emissions (Foundation Chirac). According to the Intergovernmental Panel on Climate Change (IPCC) deforestation, mainly in tropical areas, account for up to one-third of total anthropogenic carbondioxide emissions. Trees and other plants remove carbon (in the form of carbondioxide) from the atmosphere during the process of photosynthesis and release oxygen back into the atmosphere during normal respiration. Actively growing trees or forests can remove carbon over an annual or longer timeframe. Both the decay and burning of wood release much of this stored carbon back to the atmosphere. In order for forests to take up carbon, the wood must be harvested and turned into long-lived products and trees must be re-planted (Prentice, 1999). Deforestation may cause carbon stores held in soil to be released. Forests are stores of carbon and can be either sinks or sources depending upon environmental circumstances.

Carbondioxide is used by plants during photosynthesis to make sugars, which may either be consumed in respiration or used as the raw material to produce other organic compounds needed for plant growth and development. It is produced during respiration by plants, and by animals, fungi and microorganisms that depend either directly or indirectly on plants for food. It is thus a major component of the carbon cycle. Carbondioxide is generated as a by-product of the combustion of fossil fuels or the burning of vegetable matter, among other chemical processes. Small amounts of carbondioxide are emitted from volcanoes and other geothermal processes such as hot springs and geysers, and by the dissolution of carbonates in crystal rocks. Emissions of carbondioxide by human activities are currently more than 130 times greater than the quantity emitted by volcanoes, amounting to about 27 billion tones per year (VGTE, 2007). Up to 40% of the gas emitted by some volcanoes during sub-aerial volcanic eruptions is carbondioxide (Sigurdsson and Houghton, 2000). It is estimated that volcanoes release about 130-230 million tones of carbondioxide into the atmosphere each year. This is about a factor of 1000 smaller than the sum of the other natural sources and factor of about 100 smaller than the sources from human activity. However, the incineration and burning of forest plants in order to clear land releases tones of carbondioxide, which contributes to global warming (Philip and Laurance, 2004).

In 1850, atmospheric carbondioxide was about 280 parts per million (ppm), and today it is about 385ppm (Tans, 2008). As of March 2009[update], carbondioxide in the earth's atmosphere is at a concentration of 387 ppm by volume. Atmospheric concentrations of carbondioxide fluctuate slightly with the change of the seasons, driven primarily by seasonal plant growth in the Northern Hemisphere. Concentrations of carbondioxide fall during the northern spring and summer as plants consume the gas, and rise during the northern autumn and winter as plants go dormant, die and decay. Carbondioxide is a greenhouse gas it transmits visible light but absorbs strongly in the infrared and near-infrared.

Human activities such as the combustion of fossil fuels and deforestation have caused the atmospheric concentration of carbondioxide to increase by about 35% since the beginning of the age of industrialization. Yearly average increase of atmospheric carbondioxide in the 1960s was 37% of the 2000-2007 average (Tans, 2008).

Carbon exists in the earth's atmosphere primarily as gas. Although it is a small percentage of the atmosphere (approximately 0.04% on a molar basis, and increasing), it plays an important role in supporting life. However, for short-term (under ten minutes) exposure, the United State National Institute for Occupational Safety and Health (NIOSH, 2003) and American Conference of Government Industrial Hygienists (ACGIH) limit is 30,000 ppm (3%). NIOSH also states that carbondioxide concentrations exceeding 4% are immediately dangerous to life and health (NIOSH, 2003). Other gases containing carbon in the atmosphere are methane and chlorofluorocarbons (the latter is entirely anthropogenic). The overall atmospheric concentration of these greenhouse gases has been increasing in recent decades. Trees convert carbondioxide into carbohydrates during photosynthesis, releasing oxygen in the process. This process is most prolific in relatively new forests where tree growth is still rapid. The effect is strongest in deciduous forests. This is visible as an annual signal in the keeling curve of measured carbondioxide concentration. Northern hemisphere spring predominates, as there is far more land in temperate latitudes in that hemisphere than in the southern.

Carbon storage in the biosphere is influenced by a number of processes on different time-scales: while net primary productivity follows a diurnal and seasonal cycle, carbon can be stored up to several hundreds of years in trees and up to thousands of years in soils. Changes in those long term carbon pools may thus affect global climate change. Forests store 86% of the planet's above-ground carbon and 73% of the planet's soil carbon (Sedjo, 1993).

A change in the type, distribution and coverage of vegetation may occur given a change in the climate; this much is obvious. In any given scenario, a mild change in climate may result in increased precipitation and warmth, resulting in improved plant growth and the subsequent sequestration of airborne carbondioxide. Larger, faster or more radical changes, however, may well result in vegetation stress, rapid plant loss and desertification in certain circumstances (Bachelet et al., 2001).

Land use and land management practices have a major impact on natural resources including water, soil, nutrients, plants and animals. Land use information can be used to develop solutions for natural resource management issues such as salinity, ecosystem balance and water quality. For instance, water bodies in a region that has been deforested or having erosion will have different water quality than those in areas that are forested. Increased carbondioxide in the atmosphere has led to decreasing alkalinity of seawater and there is some concern that this may adversely affect organisms living in the water. In particular, with decreasing alkalinity, the availability of carbonates for forming shells decreases (Garrison, 2004).

The water cycle is also affected by deforestation. Trees extract groundwater through their roots and release it into the atmosphere. When part of a forest is removed, the trees no longer evaporate away this water, resulting in a much drier climate. Deforestation reduces the content of water in the soil and groundwater as well as atmospheric moisture. Deforestation reduces soil cohesion, so that erosion, flooding and landslides ensue. As a result, the presence or absence of trees can change the quantity of water on the surface, in the soil or groundwater, or in the atmosphere. This in turn changes erosion rates and the availability of water for either ecosystem functions or human services. Tropical rainforests produce about 30% of our planet's fresh water (Field, 2006).

Deforested areas become sources of surface water runoff, which moves much faster than subsurface flows. That quicker transport of surface water can translate into flash flooding and more localized floods than would occur with the forest cover. Deforestation also contributes to decreased evapo-transpiration, which lessens atmospheric moisture which in some cases affects precipitation levels down wind from the deforested area.

Deforestation generally increases rates of soil erosion, by increasing the amount of runoff and reducing the protection of the soil from tree litter. Tree roots bind soil together, and if the soil is sufficiently shallow they act to keep the soil in place by also binding with underlying bedrock. Tree removal on steep slopes with shallow soil thus increases the risk of landslides, which can threaten people living nearby. However most deforestation only affects the trunks of trees, allowing for the roots to stay rooted, negating the landslide for short run.

Anthropogenic factors are human activities that change the environment. In some cases the chain of causality of human influence on the climate is direct and unambiguous (for example, the effects of irrigation on local humidity), whilst in other instances it is less clear. Various hypotheses for human-induced climate change have been argued for many years. Presently the scientific consensus on climate change is that human activity is very likely the cause for the rapid increase in global average temperatures over the past several decades (IPCC, 2007). Consequently, the debate has largely shifted onto ways to reduce further human impact and to find ways to adapt to change that has already occurred.

Of most concern in these anthropogenic factors is the increase in carbondioxide levels due to emissions from fossil fuel combustion, followed by aerosols and cement manufacture. Other factors, including land use, ozone depletion, animal agriculture (Steinfeld et al., 2006) and deforestation, are also of concern in the roles they play - both separately and in conjunction with other factors - in affecting climate.

A key factor in controlling deforestation could come from the Kyoto Protocol. Reducing Emission from Deforestation and Forest Degradation (REDD) mechanisms, which provide financial incentives for avoided deforestation, could be implemented in a future Kyoto Protocol (Walsh, 2008). At the moment, REDD is not implemented in any of the flexible mechanisms defined under the Kyoto Protocol (Clean Development Mechanism, Joint Implementation and Emission Trading).

Many structural equation models are represented by path diagrams, with which researchers describe there theories about the relationships among observed and unobserved variables. The path diagram representation of complicated structural relationships is much more than a description of a few predictors and outcomes blocked. This means that we cannot simply use multiple regression techniques to analyze such structural model (Yung, 2008). The technique of analyzing the path is not only intuitive but also facilitates a good understanding of the relation of various parts of the model and provides a clear picture of reactions of parameters to a misspecification.

Confirmatory and Exploratory Factor Analysis are powerful statistical techniques of structural equations modeling (Suhr, 2000). CFA allows the researcher to test the hypothesis that a relationship between the observed variables and their underlying latent construct(s) exists. The researcher uses knowledge of the theory, empirical research, or both, postulates the relationship pattern a priori and then tests the hypothesis statistically. The techniques have similarities and differences. Determine the type of analysis a priori to answer research questions and maximize our knowledge.

SEM, and covariance structural analysis in particular, has been widely used in the medical, social and behavior sciences. Due to the effort of many methodologists, the capacity of SEM in modeling more complex data structures is increasing (Yuan et al., 2008).When simultaneously modeling the relation among manifest and latent variables as well as measurement errors, misspecification is inevitable.

2.2 The Ethiopian Context

Agriculture in Ethiopia employs more than 80% of its labor force, accounts for about 45% of the gross domestic product and over 85% of the national export earnings (MoFED, 2006). Land, water and forests are the primary resources of agricultural production and are essential to maintain human life and well being (FAO, 1995). At present, Ethiopia is widely believed to be facing an environmental crisis of greater magnitude faced than ever before. The degradation and loss of the soil resulting from soil erosion and depletion of organic matters and nutrients are much faster than their rate of replacement. Various attempts have been made to quantify the magnitude of soil erosion and its effects in the highlands. Since the beginning of this century, the forest cover has been reduced from 40% of the country to less than 3% at present. In spite of forestation activity, the rate of deforestation is still greater than the rate of a forestation. Forests, in the entire country, decline from 35% to an estimated 2.4% in 1992 (Sayer et al., 1992).

Historical evidence indicates that the whole of Arbaminch area and 70-80% of the surrounding was covered with natural forest (Jensen, 1997). The only natural forest area found today is in the Nech-Sar National Park, which covers an area of 840 hectares. This decline results from the intensive use of the land by the rapidly growing population and livestock, through deforestation, overgrazing, cutting trees and burning down the grassland to take it under cultivation. The forest resource and the vegetation cover of the region have been depleted alarmingly which causes land degradation and scarcity of fire wood and timber supply.

According to Jensen (1997), Degashara, one of the kebels surrounding Arbaminch town, is dominated by scattered bush land which is highly degraded. Only a few agriculture steps are practiced in this area, still, some remaining mixed forest sites and parts of grazing land are found. In addition to this, a very serious problem in Gentamech area is that people of Gentamech come to Degashara and the nearby town Arbaminch to pick up fuel wood. Moreover, cultivation of the land is going on even on very steep slopes. As a result the west part of Gentamech has already become wasteland, through farming practices, overgrazing, cutting trees and shrubs without conservation measure.

Conservation measures are not visible in these areas, because conservation measures are only applied to protect cultivated land while Degashara is mostly used as source for energy. Hence it can be concluded that there is no interest in soil and forest conservation. An example for the success of soil conservation measures in Ethiopia is provided by the Konso area in the south Ethiopia near by Gamo-Gofa Zone, where terracing of the land has reduced the soil erosion and thereby relatively improved the standard of living. But Gamo-Gofa people have not gained knowledge of soil conservation from Konso.

The distribution of the land use in the study area has been changing greatly over time because of subsequent cultivation after deforestation due to high population and economic pressures, and infrastructure and irrigation development (Tuma Ayele, 2007). A small part of the border area near Lake Abaya was covered with forest, whereas the top of mountains that was previously covered by grass and bushes was deforested. In the escarpment between lowland catchments and highland areas, the scattered trees were also disappearing from those places.

Soil, as the most basic of all resources is non-renewable. Once lost, it is difficult to replace soil within a foreseeable span of time. New soil formation, development of a biologically productive and economically fertile soil from parent rock, is a slow process measured only on a geological time scale. Literally speaking, the soil formed over hundreds to thousands of years can be washed away in a single climate event (Lal, 1990). Soil erosion is mostly caused by water and wind. Water erodes soil with the force of impact runoff. Wind tears off soil particles from its location. Excessive utilization of land for farming is likely to strip the ground of its productive cover and destabilize the top soil. Rain will then detach soil particles which will be carried away by runoff. Consequently, the fertile top soil whose formation takes a great many years is lost (FFTC, 1995).

2.3 Environmental Policies and Strategies of Ethiopia

Historical evidences indicate that the reasons for century old lack of sustainable natural resource management and environmental protection tradition are mainly related to the instability of successive governments, their rapidly changing political economy (land tenure systems, rural development policies or lack of it) and non-participatory top-dawn development programs. Natural resource and environmental protection policies often reflect ideological preferences of those in the power and are not allowed maturing in continuous manner (Melaku Bekele, 2008). In March1975 the age old tenure system changed into almost completely contrasting system when all lands were nationalized and put under state control. The vent created a new, if not improved, management approach in the ownership and management of natural resources. Contrary to the principle of prudence in policy making, it is guided more by ideological and political rupture than by economic issue.

The military government drew ambitious rural development programs, in the field of natural resource management and rehabilitation of degraded lands, a Ten Year Perspective Plan (1984-94) was prepared to survey and demarcate, take inventory and prepare management plan for tens of thousands of hectare of natural forests, and establish community, fuel wood and industrial plantations. Rehabilitation of large tracts of degraded lands, soil and water conservation were among the plans. In reflection of ideological inclinations, the 1980 forestry proclamation fixed the forest property regimes at state and public (Kebele) levels. Thousands of land belonging to communities and individual households came under plantation by force. However, most of the conservations and development activities ended in destruction during the 1991 change of government. Because of the transition from unitary to federal state had created a power vacuum destruction of resources took place on a large scale (Melaku Bekele, 2008).

After the change of government in 1991, no radical change has been made in the property relation of land and natural resource. The 1995 Constitution of the Federal Government declared (Article 40) the ownership of rural and urban land and all natural resources, as being "exclusively vested in the state and in the people of Ethiopia." And "land is a common property of the Nations, Nationalities and People of Ethiopia and shall not be subject to sale or to other means of exchange."

The Ethiopian Forestry Action Program (EFAP, 1994) is an initiative that emerged from successive previous efforts that attempted to deal with natural resources and environmental degradation in Ethiopia like that of reforestation and soil conservation efforts. The action program aimed to increase production of forest products on a sustainable basis, to conserve forest ecosystems and genetic resources, to increase productivity of agriculture through reduced land degradation and increased soil fertility, and to increase welfare of rural community, especially women. The action program also comprised a set of complementary primary programs (Tree and Forest Production Program, Forest Resource and Ecosystem Management Program, Forest Industries Development Program, and Wood Energy Development Program) and supportive development programs (Technology Development and Dissemination Program; Sectoral Integration Program; Planning, Monitoring, and Evaluation Program; and Human Resource Development Program). These programs were integrated and mutually supportive to one another. The 45 projects that EFAP proposed satisfactorily address those primary and secondary development programs. Hence, the programs and projects of EFAP were well designed for the target it set.

EFAP is the first comprehensive document produced concerning the current situation, the future trends, and the development needs of forestry and related sectors of the country (Melaku Bekele, 2008). It addresses inter-sectoral linkages between forestry and related sectors (agriculture, livestock, industry, energy, etc.). But since EFAP was developed partly within the political/administrative structure of the unitary government and partly under the earlier transitional years of the new federal government structure that was just being introduced, the program did not have appropriate provisions for its implementation under the new decentralized federal structure due to various reasons. The Ministry of Natural Resources Development and Environmental Protection of the Transitional Government, which coordinated the production of the EFAP, was mandated to be the lead institution under which the EFAP implementation unit would operate. However, that ministry was dissolved in a new government restructuring that took place not so long after the completion of preparation of the EFAP document. Hence, EFAP was left without an owner to oversee its implementation at the Federal level. EFAP was originally developed as a country-wide program, had to be reformulated by each regional state and become a regional program. Although some of the regions developed regional forestry action programs that best suit their specific conditions, not much has been done in implementing the plans.

On the other hand, there have also been supportive policy and institutional developments that address part of the EFAP concern and program components. This includes the establishment of the Institute of Biodiversity Conservation and Research, as well as the Environmental Protection Authority.

Forest Conservation and Utilization Policy (FCUP, 2007) is the first policy strategy document ever issued in the forest management history of the country. All previous forestry laws and legislations were issued in the absence of any policy to guide the future direction of country’s forest conservation and management. The main objective of the new policy and strategy is to meet the forest product demands of the society and increase the contribution of forest resource to the national economy through appropriate conservation and management of the country’s forest resources. The specific components the policy strategies attempt to address include: promoting private forest development and conservation; promoting forest development technologies; strengthening forest product markets; administering and managing state forests; preventing deforestation; and establishing up-to-date information database.

The Conservation Strategy of Ethiopia (CSE, 1997) is a five-volume document constituting information on the resource base, policy and strategy framework, institutional questions to implement the policy, plan of actions within the framework of eleven cross-sectional and the same number of sectorial programs, and projects. The 1997 CSE can be seen as the second (improved) edition of the 1994 (5 volume) National Conservation Strategy document. The policy goal is to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment as a whole so as to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. Policy objectives are developed for both the cross-sectional and sectorial issues.

The policy document addresses almost all major natural resource and environmental protection issues in the country. Policy statements, objectives, strategies and programs are set. But a few critical questions remain to be answered (Melaku Bekele, 2008): is there a time frame for their implementation? What type of organizational settings and human capacity are required? What legal provisions (laws, regulations) have to be put in place to assist implementation? What are the sources of finance?

3. Data and Methodology

3.1 Data Sources

The data for this study have been obtained from secondary sources on the land use system and human population. Land use data had been collected since 2005 for the research purpose of Rift Valley and Omo-Gibe Basin. The data were organized by the Department of Agriculture of Gamo-Gofa Zone. They were organized into six land use variables such as crop land, grazing land, forest and bush, fertile, not fertile, and others. Each variable data was collected from fifteen woredas of Gamo-Gofa Zone.

The population data are taken from 2007 population census results which are conducted at national level. From these we analyzed population density of Gamo-Gofa.

To support the data and get a closer look at the current status of the land use system, a sample survey had been conducted by using photo and video documents. It was possible to document the land use status for further studies of the area.

3.2 Structural Equations Modeling

We study linear relationships between a random dependent (endogenous) variable and random independent (exogenous) variables where either can be directly observed (manifest variables) or unobserved hypothetical variables (latent variables). The covariance structure among the observed random variables is used to study the linear structural relations among the model variables. In the social and behavioral sciences, such models are called “causal” models and involve the analysis of the covariance matrix for the manifest variables derived from a linear structural model. This terminology is unfortunate since most models do not establish causality, but only establish an empirical linear association among the latent and manifest variables under study (Freedman, 1987, Dawid, 2000).

In multivariate regression models, the two sets of variables in the formulation of the model are random observed dependent variables and fixed (non-random) observed independent variables or covariates. While the general theory of the linear model is valid when the independent variables are random, the basic assumption for the model is that the independent variables are distributed independently of error. The assumption allows one to think of a regression model as a structural model which may imply causation. For the model to be structural, we must argue that the unspecified causes (random variables) on the dependent variables, usually included in the error term, are uncorrelated with the random independent variables in the model.

In path analysis, or more general in structural equation modeling (SEM), all variables are defined as random and new terminology is used. The first distinction made among variables in the model is between observed and unobserved random variables. Observed variables are called manifest variables and are directly observed. Unobserved variables (factors, latent variables) are hypothetical constructs that are not directly measured or observed. In addition to manifest and latent variables, the variables in a SEM are characterized as endogenous, exogenous, and as disturbances or errors. A final distinction made in SEM is whether the model is recursive or non-recursive. Recursive models are models in which causation is unidirectional. There is no backward causation, causal loops, or bidirectional paths in the model. In non-recursive models, causation may flow in both directions. In general, non-recursive models are more difficult to analyze (Berry, 1984).

The structural model for latent variables is

$$\underset{m\times 1}{\boldsymbol{\eta}} = \underset{(m\times m)}{\mathbf{B}}\underset{(m\times 1)}{\boldsymbol{\eta}} + \underset{(m\times n)}{\Gamma}\underset{(n\times 1)}{\boldsymbol{\xi}} + \underset{m\times 1}{\boldsymbol{\zeta}} \tag{3.1}$$

where $\boldsymbol{\eta}, \boldsymbol{\xi}$ *and* $\boldsymbol{\zeta}$ are respectively random vectors of latent endogenous variables, latent exogenous, and latent errors, where $\boldsymbol{\xi} \sim N_n(\mathbf{0}, \Phi)$, $\boldsymbol{\zeta} \sim N_m(\mathbf{0}, \Psi)$, $\boldsymbol{\xi}$ *and* $\boldsymbol{\zeta}$ are independent, **B** is a matrix with zeros on the diagonal, and (**I-B**) is nonsingular. The model has the reduced form

$$\boldsymbol{\eta} = (\mathbf{I}-\mathbf{B})^{-1}\Gamma\boldsymbol{\xi} + (\mathbf{I}-\mathbf{B})^{-1}\boldsymbol{\zeta} = \pi\boldsymbol{\xi} + \boldsymbol{e} \tag{3.2}$$

Relating the unobserved latent constructs to observed variables, the measurement model is

$$\underset{p\times 1}{\boldsymbol{y}} = \underset{(p\times m)}{\Lambda_y}\underset{(m\times 1)}{\boldsymbol{\eta}} + \underset{p\times 1}{\epsilon} \tag{3.3}$$

$$\underset{q\times 1}{\boldsymbol{x}} = \underset{(q\times n)}{\Lambda_x}\underset{(n\times 1)}{\boldsymbol{\xi}} + \underset{q\times 1}{\boldsymbol{\delta}}$$

where **y** and **x** are vectors of observed relation with the latent endogenous vector $\boldsymbol{\eta}$, and the latent exogenous vector ξ respectively. The vectors $\boldsymbol{\epsilon}$ and $\boldsymbol{\delta}$ are vectors of measurement errors, and Λ_y and Λ_x are regression coefficients relating **y** to $\boldsymbol{\eta}$, and **x** to $\boldsymbol{\xi}$, respectively. Finally, we assume that $\boldsymbol{\epsilon} \sim N_p(\mathbf{0},\ \Theta_\epsilon)$, $\boldsymbol{\delta} \sim N_q(\mathbf{0},\ \Theta_\delta)$, and that $\boldsymbol{\epsilon}$, $\boldsymbol{\delta}$, $\boldsymbol{\eta}$, ξ and ξ are mutually independent. Thus, the joint SEM is

$$\begin{aligned} \boldsymbol{\eta} &= \mathbf{B}\boldsymbol{\eta} + \Gamma\boldsymbol{\xi} + \boldsymbol{\zeta} \\ \boldsymbol{y} &= \Lambda_y \boldsymbol{\eta} + \epsilon \\ \boldsymbol{x} &= \Lambda_x \boldsymbol{\xi} + \boldsymbol{\delta} \end{aligned} \tag{3.4}$$

The matrices B, Γ, $\Lambda_y,\ and\ \Lambda_x$ are coefficients of direct effects.

The covariance matrix for (**y, x**) is

$$\sum(\boldsymbol{\theta}) = \begin{bmatrix} \sum_{yy} & \sum_{yx} \\ \sum_{xy} & \sum_{xx} \end{bmatrix} \tag{3.5}$$

where **θ** represents the unknown vector of model parameters, and

$$\begin{aligned} \textstyle\sum_{yy} &= \Lambda_y \textstyle\sum_{\eta\eta} \Lambda_y' + \Theta_\epsilon \\ &= \Lambda_y[(\mathbf{I} - \mathbf{B})^{-1}(\Gamma\Phi\Gamma' + \Psi)(\mathbf{I} - \mathbf{B})^{-1\prime}]\Lambda_y' + \Theta_\epsilon \\ \textstyle\sum_{xx} &= \Lambda_x \Phi \Lambda_x' + \Theta_\delta \\ \textstyle\sum_{xy} &= \Lambda_x \textstyle\sum_{\xi\eta} \Lambda_y' = \Lambda_x \Phi \Gamma' (\mathbf{I} - \mathbf{B})^{-1\prime} \Lambda_y' \end{aligned}$$

The population covariance matrix $\sum(\boldsymbol{\theta})$ in (3.5) is a function of all the structural parameters so that the covariance structure is also called a structural model. Letting **θ** represent the independent free and distinct (non redundant) constrained parameters in the parameter matrices **B**, Φ, Λ_y, Λ_x, Ψ, Θ_ϵ and $\Theta\delta$, the vector **θ** contains the structural parameters to be estimated. The issue of estimability is called the (global) identification problem. A parameter **θ** in a SEM is identified if it can be estimated and underidentified (or unidentified) otherwise. If **θ** is uniquely estimable, the model is said to be exactly (or just) identified or saturated. Overidentified models yield a family of solutions.

Identification is critical to the analysis of covariance structures; (Bollen, 1989) defines global model identification as follows.

Definition: *If an unknown parameter in* $\boldsymbol{\theta}$ *can be written as a function of one or more elements of* $\sum$*, then the parameters in* $\boldsymbol{\theta}$ *are identified. If all unknown parameters in* $\boldsymbol{\theta}$ *are identified, then the model is identified.*

To solve for the model parameters in a SEM, the number of equations must be larger than or equal to the number of unknowns. The total number of equations as given by the distinct elements in $\sum(\boldsymbol{\theta})$ is $\nu = (p + q)(p + q + 1)/2$. If t is the number of parameters to be estimated, a necessary condition for model identification is that

$$\nu^* = \nu - t \geq 0 \tag{3.6}$$

provided $\nu^* > 0$ and the model is correct and identified, the hypothesis

$$H_0\colon \sum = \sum(\boldsymbol{\theta}) \tag{3.7}$$

is said to be testable. This hypothesis tests whether an overidentified SEM is consistent with the observed data and is called an overidentification or goodness-of-fit test.

To analyze a SEM, one begins by specifying the model using a path diagram that relates the latent and observed variables specified using (3.4) with covariance structure given in (3.5). Following model specification, one determines whether a model is identified. This is usually a very difficult task since except for some simple structural models, general sufficient conditions for model identification have not been developed. Given an identified model, one must estimate the model parameters in $\sum(\boldsymbol{\theta})$for the SEM. To estimate the parameters in $\sum(\boldsymbol{\theta})$ for any SEM, one obtains a sample estimate S of $\sum(\boldsymbol{\theta})$ and chooses a scalar error-in-fit continuous function F(**S**, $\sum(\boldsymbol{\theta})$)$\geq 0$. Minimizing the fit function at $\boldsymbol{\theta} = \widehat{\boldsymbol{\theta}}$, the value of the function at $\sum(\widehat{\boldsymbol{\theta}}) = \widehat{\sum}$ represented as $F(\mathbf{S}, \widehat{\sum})$ is a measure of closeness of fit of S by $\widehat{\sum}$.

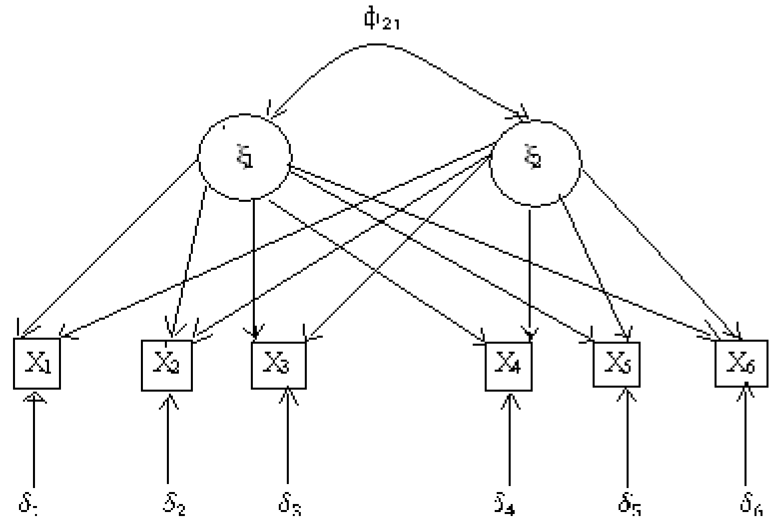

Figure 4. Two Factor Exploratory Factor Analysis Path Diagram.

For $\mathbf{S} = \widehat{\Sigma}$, the fit function is defined to be zero so that $\mathbf{S}-\widehat{\Sigma}$ should be approximately the zero matrix, $\mathbf{0}$. Two general fit functions used in SEM are a variant of the log likelihood under multivariate normality of the manifest variables, the maximum likelihood (ML) fit function, and several variants of matrix norms that compare **S** with weighted estimates of $\Sigma(\widehat{\boldsymbol{\theta}}) = \widehat{\Sigma}$, the weighted least squares (WLS) fit function. The two functions are defined as

$$F_{ML} = log|\Sigma(\boldsymbol{\theta})| + tr(\mathbf{S}\Sigma(\boldsymbol{\theta})^{-1}) - log\mathbf{S} - (p + q) \tag{3.8}$$

$$F_{WLS} = \frac{1}{2}tr\left[\mathbf{W}^{-1}[\mathbf{S} - \Sigma(\boldsymbol{\theta})]\right]^2 = \frac{1}{2}\|W^{-1}[\mathbf{S} - \Sigma(\boldsymbol{\theta})]\|^2 \tag{3.9}$$

where $\mathbf{W} = \mathbf{S}$, weighted least squares is called the generalized least squares (GLS) fit function. If $\mathbf{W}^{-1} = \mathbf{I}$ it becomes the unweighted least squares (ULS) fit function. Because the estimate for the model parameter $\boldsymbol{\theta}$ using the F_{ML}error-in-fit function is identical to the full information maximum likelihood estimate obtained assuming joint multivariate normality, the estimate $\widehat{\boldsymbol{\theta}}$ is always a consistent estimate of $\boldsymbol{\theta}$, given that the model holds in the population and provided $\boldsymbol{\theta}$ is globally identified. This is not necessarily the case of other fit functions. The other fit functions also require the vector **x** to be weakly exogenous for the parameters of interest.

Minimization of the functions given in (3.8) is complex since it involves a constrained nonlinear system of equations. Jöreskog (1969b) shows how to minimize F_{ML} using the Davidon-Fletcher-

Powell method which only involves first-order derivatives. More recently, Newton-Raphson and Gauss-Newton algorithms that involve second-order derivatives with Levenberg-Marquadt adjustments are used (Thisted, 1988).

Given that a model is identified and an error-in-fit function $F\left(\mathbf{S}, \sum(\widehat{\boldsymbol{\theta}})\right)$ is selected such that $\widehat{\boldsymbol{\theta}}$ is a consistent estimate of $\boldsymbol{\theta}$, the next step in the evaluation of a SEM is the assessment of overall fit. The criteria used to evaluate model fit include chi-square tests, fit indices, root mean square residuals, and others, all of which depend upon the error-in-fit function selected, distribution assumptions of manifest variables, sample size, whether the fit function selected is scale invariant, and whether the estimation method is scale free.

4. RESULTS

4.1 Partition of Land Use System

Deforestation is a major concern in Ethiopia. As studies suggest loss of forest contributes to soil erosion, loss of nutrients in the soil, loss of animal habitats and reduction in biodiversity, averting of water quality, and climate change. The vegetation resources and ecology of Ethiopia, including forests, woodlands and bushlands, conservation of soil, have been studied by several scholars who have employed different methods and have studied different localities to come up with conclusions.

The ever increasing deforestation, soil erosion and the associated problems of decline in soil fertility and loss of biodiversity have resulted in making livelihood improvement a very challenging task to countries like Ethiopia that are highly dependent on agricultural and natural resource products. The factors, high population growth, climate variability and change, drought and associated famine, are reinforced resource depletion, poverty, and political instability.

In Ethiopia, environmental degradation and deforestation have been taking place for hundreds of years. Forest coverage, in the entire country, declined from 35% to an estimated 2.4% in 1992 (Sayer et al. 1992). The low level of living standard and illiteracy of the most people coupled with lack of alternatives are the fundamental factors responsible for the decline in forest areas of Ethiopia. In line with this the forest coverage of Gamo-Gofa is only 16.37% of the total area. Now days, sample video and photo documents of current status of forest cover of Gamo-Gofa do not support the survey result of the 2005 data. Deforestation is ongoing activity. If this trend of deforestation/devegetation continues without any control, there is a great danger of serious decline or loss of biodiversity. Since at national level the population is growing at a rate of about 3% per year, the need for more arable land to cultivate crops becomes inevitable, aggravating the rate of deforestation and associated land degradation. It is, therefore, urgent and important to study and conserve the vegetation resources (forests) and soil of the country by providing appropriate management strategies or tools with modeling relation to soil erosion and climate change.

Land use system of Gamo-Gofa has been classified as cultivate land, grazing land, forest and bush cover, fertile (not cultivated) land, not fertile, and others (lakes, rocks and towns).

According to these classifications, Figure 5 demonstrates the area coverage of land use system in percentage of total area.

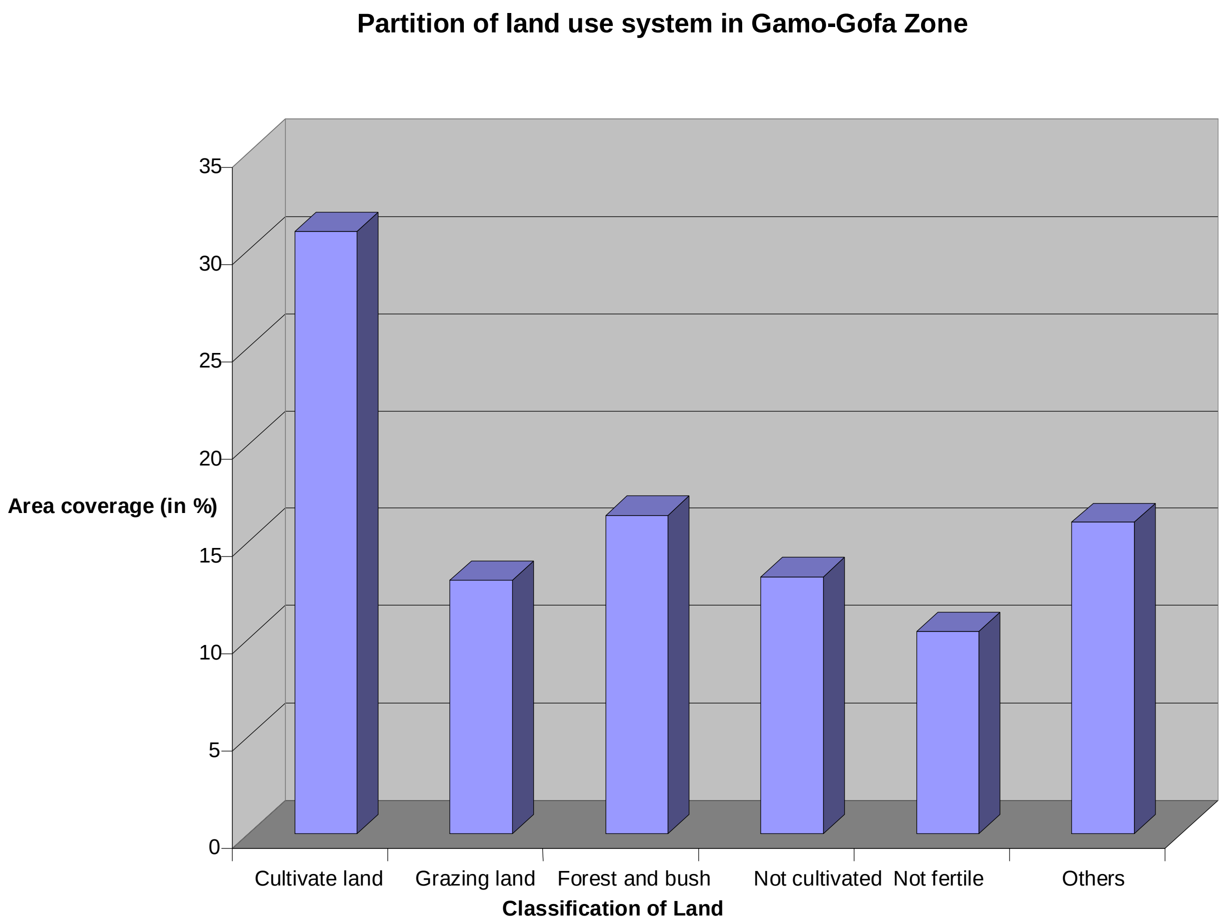

Figure 5. Partition of land use system in Gamo-Gofa

4.2 Estimation and Fit of Confirmatory Factor Analysis Model

The aim of this study is to model the impact of land use in considering deforestation, soil erosion and climate change. The regression model is as a structural model which may imply causation.

$$Forest\ and\ bush = \beta_0 + \beta_1 crop\ land + \beta_2 grazing\ land + \beta_3 fertile\ land + \beta_4 not\ fertile + \beta_5 others + error\ term \quad (4.1)$$

The multiple regression model (4.1) of land use variables is significant for the data.

TABLE 1. *Analysis of variance for multiple regression model and fit test*

Source	DF	Sum Squares	mean Square	F Value	Pr > F
Model	5	2449203255	489840651	26.67	<.0001
Error	8	146960830	18370104		
Corrected Total	13	2596164084			

Root MSE	4286.03590	R-Square	0.9434
Dependent Mean	14311	Adj R-Sq	0.9080
Coeff Var	29.94852		

In structural equation modeling, the covariance structure among the observed random variables is used to study the linear structural relations among the model variables. Using covariance of the multiple liner regression model parameter estimators of land use variables, we can easily demonstrate the linear structural relations among deforestation, soil erosion and climate change. The parameter estimates are computed through SAS procedures.

TABLE 2. *Analysis of variance for multiple regression model and parameter estimate test*

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	4278.84863	3171.66364	1.35	0.2142
Cropland	1	-0.34842	0.16383	-2.13	0.0661
Grazing land	1	0.08685	0.12056	0.72	0.4918
Fertile land	1	0.77238	0.09236	8.36	<.0001
Not fertile	1	1.41029	0.38690	3.65	0.0065
Others	1	0.15797	0.26483	0.60	0.5673

To analyze a SEM, we begin by specifying the model using a path diagram that relates the latent (soil erosion & climate change) and observed variables specified using (3.4) with covariance structure given in (3.5).

The goal of the exploratory factor analysis (EFA) is to find a small number of latent factors that account for the observed covariance among the p observed variables. Having found a small number of latent factors, all factors are simultaneously transformed to determine a small number of 'simple structure' orthogonal or oblique factors.

When performing an exploratory factor analysis, we have no prior knowledge of the number of common factors, the pattern of the regression coefficients that relate the latent factors to variables. Moreover, the model imposed the restriction that the covariance matrix for errors is diagonal.

Centering the observed data to have mean zero, the EFA model of SEM notation has the general form

$$\underset{q \times 1}{\boldsymbol{x}} = \underset{(q \times n)}{\Lambda_x} \underset{(n \times 1)}{\boldsymbol{\xi}} + \underset{q \times 1}{\boldsymbol{\delta}}$$

$$\Sigma_{xx} = \Lambda_x \Phi \Lambda_x' + \Theta_\delta \tag{4.2}$$

where Θ_δ is assumed diagonal.

In confirmatory factor analysis (CFA), we also use model (4.2), the major difference is that we specify the number of latent factors n before we begin our analysis; we allow Θ_δ to be symmetric, unspecified covariance matrix so as to allow for correlated errors of measurement; and we restrict the elements of $\Lambda_x$to be associated with specific variables to hypothesize a prior 'pattern' matrix of regression coefficients where the covariance matrix Φ is unspecified. This allows us to estimate all of the qn parameters in Λ_x, the $n(n+1)/2$ parameters in Φ, and the $q(q+1)/2$ parameters in Θ_δ simultaneously provided that the model is identified. From (3.6), a necessary but not sufficient condition for model identification is that

$$t = qn + n(n+1)/2 + q(q+1)/2 \leq q(q+1)/2 \tag{4.3}$$

so that the CFA is usually not identified. For identification or over identification to occur, we must place restrictions on the parameters in the matrix $\sum_{xx} \equiv \Sigma(\theta)$.

From equation (4.2), implicit in the relationship of ξ_i and δ_i is that δ_i appears only once for each χ_i. Because δ_i is not observed, in order to give the latent variable ξ_i a scale, the latent variable must have a metric. This is accomplished in one of two ways. The reference variable solution sets at least one indicator variable, λ_{ij} in each column of Λ_x to 1, the indicator solution, or the variance of each latent variable is set to 1, the standardized solution. In either case, on average we expect that a unit change in ξ_i implies a unit change in χ_i. We may also set some λ_{ij} to zero, constrain some of λ_{ij} to be equal, and set other parameters to zero or to known values to reduce the number of unknown parameters.

Now consider a two factor model in which at least two measures have been obtained for the correlated latent exogenous variables soil erosion and climate change with independent measurement errors. The SEM is

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & \lambda_{22} \\ \lambda_{31} & \lambda_{32} \\ \lambda_{41} & \lambda_{42} \\ \lambda_{51} & \lambda_{52} \\ \lambda_{61} & \lambda_{62} \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix} \qquad (4.4)$$

where

$$\Sigma(\theta) = \Lambda_x \begin{bmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{bmatrix} \Lambda_x' + diag[\sigma_{\delta i}^2] = \begin{bmatrix} \sigma_1^2 & & & & & (sym) \\ \sigma_{21} & \sigma_2^2 & & & & \\ \sigma_{31} & \sigma_{32} & \sigma_3^2 & & & \\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_4^2 & & \\ \sigma_{51} & \sigma_{52} & \sigma_{53} & \sigma_{54} & \sigma_5^2 & \\ \sigma_{61} & \sigma_{62} & \sigma_{63} & \sigma_{64} & \sigma_{65} & \sigma_6^2 \end{bmatrix} \qquad (4.5)$$

The PROC CALIS procedure (covariance analysis of linear structural equations) estimates and tests the appropriateness of structural equations models using covariance structural analysis. PROC CALIS procedure provides the results such as number of observation, estimated parameters, and information related to model specifications. It also gives fit statistics, manifest variable equations with estimates, manifest variable equations with standardized estimates, variance of exogenous variables, and covariances among exogenous variables. Now we can consider three model specifications to analyze the data and use model with better fit.

Model Specification: Case 1. In this case we can follow equation (4.4), all factor loadings determined from analysis. The number of unknown parameters in Λ_x, Φ and Θ_δ is t =21. The number of known elements in **S**, an estimate of $\Sigma(\theta)$, is $q(q+1)/2=21$. Since $t = q(q+1)/2$, the model is identified.

Covariance Structure Analysis: Maximum Likelihood Estimation

Observations	14	Model Terms	1
Variables	6	Model Matrices	4
Informations	21	Parameters	21

Variable	symbol	Mean	Std Dev
Crop land	x1	26561	11466
Grazing land	x2	11400	12214
Forest and bush	x3	14311	14132
Fertile	x4	11878	14459
Not fertile	x5	5516	3913
Others	x6	8498	6718

Some of the fit statistics that the CALIS procedure of maximum likelihood estimation, are given in Table 3.

TABLE 3. *Fit statistics for model specification case 1*

Fit Function	0.9753
Goodness of Fit Index (GFI)	0.8126
Chi-Square	12.6788
Chi-Square DF (v*=v-t=21-21=0)	0
Pr > Chi-Square	<.0001
Independence Model Chi-Square	58.185
Independence Model Chi-Square DF	15
RMSEA Estimate	0.0000
Probability of Close Fit	.
Bentler's Comparative Fit Index	0.7064
Normal Theory Reweighted LS Chi-Square	7.2161
Akaike's Information Criterion	12.6788
Bozdogan's (1987) CAIC	12.6788
Schwarz's Bayesian Criterion	12.6788
Bentler & Bonett's (1980) Non-normed Index	.
Bentler & Bonett's (1980) NFI	0.7821
Z-Test of Wilson & Hilferty (1931)	.
Bollen (1988) Non-normed Index Delta2	0.7821

The manifest variable equations with estimates, standard error and t-value of full factor loading model specification is

```
Manifest Variable Equations with Estimates

x1       =   5288.6*F1       +  9955.2*F2       +  1.0000 e1
Std Err      1026.8 L11         1265.5 L12
t Value      5.1507             7.8666

x2       =   6870.0*F1       +  2748.7*F2       +  1.0000 e2
Std Err      2447.6 L21         3016.6 L22
t Value      2.8069             0.9112

x3       =  13926.8*F1       + -4371.9*F2       +  1.0000 e3    (4.6)
Std Err       980.0 L31         1207.8 L32
t Value     14.2115            -3.6197

x4       =  12665.3*F1       + -2752.1*F2       +  1.0000 e4
Std Err      1270.0 L41         1565.3 L42
t Value      9.9726            -1.7582

x5       =   2908.9*F1       +   548.0*F2       +  1.0000 e5
Std Err       830.4 L51         1023.5 L52
t Value      3.5029             0.5355

x6       =   2702.1*F1       +  5458.8*F2       +  1.0000 e6
Std Err      1244.6 L61         1533.9 L62
t Value      2.1711             3.5587
```

Covariance, variance and correlation among exogenous variables are depicted in Table 4.

TABLE 4. *Covariance, variance and correlation estimates and test of exogenous variables for model specification case1*

Var1	Var2	Parameter	Estimate	Standard Error	t Value
F1	F2	covf1f2	-0.06240	0.28074	-0.22
F1	F2	covf1f2	-0.07163 (correlation)		

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
F1	covf1f1	0.97389	0.40702	2.39
F2	covf2f2	0.77935	0.38757	2.01
e1	vare1	39747653	0.08596	4.624E8
e2	vare2	101562286	0.03811	2.665E9
e3	vare3	-10348305	0.09116	-1.14E8

```
e4        vare4           56541882        0.02355    2.401E9
e5        vare5            8357165        0.05070    1.648E8
e6        vare6           19402910        0.11555    1.679E8
```

Manifest variable equations with standardized estimates are

```
x1      =   0.4448*F1        +  0.7491*F2        +  0.5374 e1
                       L11                  L12
x2      =   0.5516*F1        +  0.1974*F2        +  0.8200 e2
                       L21                  L22
x3      =   0.9693*F1        + -0.2722*F2        +  1.0000 e3     (4.7)
                       L31                  L32
x4      =   0.8370*F1        + -0.1627*F2        +  0.5035 e4
                       L41                  L42
x5      =   0.7039*F1        +  0.1186*F2        +  0.7088 e5
                       L51                  L52
x6      =   0.3853*F1        +  0.6963*F2        +  0.6365 e6
                       L61                  L62
```

To see whether the model is overidentified, we compare the elements of $\Sigma(\theta)$ with **S** using different specification of model loadings than that of case 1.

The SEM is

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & \lambda_{22} \\ \lambda_{31} & \lambda_{32} \\ \lambda_{41} & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix} \tag{4.8}$$

Model Specification: Case 2. In this case we can follow equation (4.8), in this some factor loadings determined intentional to simplify identification of the model. The number of unknown parameters in Λ_x, Φ and Θ_δ is t =16. The number of known elements in **S**, an estimate of $\Sigma(\theta)$, is $q(q+1)/2$=21. Since t =16 < $q(q+1)/2$ =21, the model is overidentified.

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Observations	14	Model Terms	1
Variables	6	Model Matrices	4
Informations	21	Parameters	16

Variable	Mean	Std Dev
x1	26561	11466
x2	11400	12214
x3	14311	14132
x4	11878	14459
x5	5516	3913
x6	8498	6718

TABLE 5. *Fit statistics for model specification case2*

Fit Function	0.2705
Goodness of Fit Index (GFI)	0.9272
GFI Adjusted for Degrees of Freedom (AGFI)	0.6944
Chi-Square	3.5160
Chi-Square DF (v*=v-t=21-16=5)	5
Pr > Chi-Square	0.6210
Independence Model Chi-Square	58.185
Independence Model Chi-Square DF	15
RMSEA Estimate	0.0000
Probability of Close Fit	0.6379
Bentler's Comparative Fit Index	1.0000
Normal Theory Reweighted LS Chi-Square	3.0606
Akaike's Information Criterion	-6.4840
Bozdogan's (1987) CAIC	-14.6793
Schwarz's Bayesian Criterion	-9.6793
Bentler & Bonett's (1980) Non-normed Index	1.1031
Bentler & Bonett's (1980) NFI	0.9396
Z-Test of Wilson & Hilferty (1931)	-0.3145
Bollen (1988) Non-normed Index Delta2	1.0279

The manifest variable equations with estimates, standard error and t-value for model specification case 2 are

```
x1       =   -0.3292*F1       +  2.5271*F2       +  1.0000 e1
Std Err       0.6619 L11         0.3720 L12
t Value      -0.4973             6.7933

x2       =    0.9703*F1       +  0.6917*F2       +  1.0000 e2
```

```
Std Err      0.7943 L21          0.6906 L22
t Value      1.2217              1.0015

x3       =   8.6919*F1       + -1.3691*F2       +  1.0000 e3
Std Err      0.5873 L31          0.2825 L32
t Value     14.7995             -4.8457
```
(4.9)

```
x4       =   4.8143*F1       +  0.0000 F2       +  1.0000 e4
Std Err      0.7647 L41
t Value      6.2959

x5       =   1.0000 F1       +  0.0000 F2        + 1.0000 e5
x6       =   0.0000 F1       +  1.0000 F2        + 1.0000 e6
```

TABLE 6. *Covariance, variance and correlation estimate and test of exogenous variables for model specification case2*

Covariance and correlation Among Exogenous Variables

Var1	Var2	Parameter	Estimate	Standard Error	t Value
F1	F2	covf1f2	5743446	3.15507E-7	1.82E13
F1	F2	covf1f2	0.51928	(correlation)	

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
F1	covf1f1	5261392	7.6964E-7	6.84E12
F2	covf2f2	23250741	4.60095E-8	5.05E14
e1	vare1	-8026392	9.86897E-9	-813E12
e2	vare2	125396243	6.14338E-9	2.04E16
e3	vare3	-104680271	1.29762E-8	-807E13
e4	vare4	87126805	5.22357E-8	1.67E15
e5	vare5	10049049	1.21647E-7	8.26E13
e6	vare6	21882978	1.30019E-8	1.68E15

Manifest variable equations with standardized estimates of model specification of case 2 are

```
x1       =  -0.0658*F1       +  1.0627*F2       +  1.0000 e1
                        L11                  L12
x2       =   0.1822*F1       +  0.2731*F2       +  0.9168 e2
                        L21                  L22
x3       =   1.4108*F1       + -0.4671*F2       +  1.0000 e3
                        L31                  L32
```
(4.10)

```
x4      =   0.7637*F1      +  0.000 F2        +  0.6455 e4
                    L41
x5      =   0.5862 F1      +  0.0000 F2       +  0.8102 e5
x6      =   0.0000 F1      +  0.7177 F2       +  0.6963 e6
```

We can also consider another type of model specification that is not allowed to determine the two factor loadings simultaneously for each observed variable except crop land.

The SEM is

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & 0 \\ 1 & \lambda_{32} \\ \lambda_{41} & 0 \\ 0 & \lambda_{52} \\ 0 & \lambda_{62} \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix} \tag{4.11}$$

Model Specification: Case 3. In this case we can follow equation (4.11), in this some factor loadings determined intentional to simplify identification of the model. The number of unknown parameters in Λ_x, Φ and Θ_δ is t =16. The number of known elements in **S**, an estimate of $\Sigma(\theta)$, is $q(q+1)/2$=21. Since t =16 < $q(q+1)/2$ =21, the model is overidentified.

```
                 The CALIS Procedure
    Covariance Structure Analysis: Maximum Likelihood Estimation

          Observations          14     Model Terms            1
          Variables              6     Model Matrices         4
          Informations          21     Parameters            16

                   Variable          Mean        Std Dev

                   x1               26561          11466
                   x2               11400          12214
                   x3               14311          14132
                   x4               11878          14459
                   x5                5516           3913
                   x6                8498           6718
```

TABLE 7. *Fit statistics for model specification case3*

Fit Function	0.5742
Goodness of Fit Index (GFI)	0.8655
GFI Adjusted for Degrees of Freedom (AGFI)	0.4350
Chi-Square	7.4652
Chi-Square DF	5
Pr > Chi-Square	0.1883
Independence Model Chi-Square	58.185
Independence Model Chi-Square DF	15
RMSEA Estimate	0.1947
Probability of Close Fit	0.2041
Bentler's Comparative Fit Index	0.9429
Normal Theory Reweighted LS Chi-Square	6.0773
Akaike's Information Criterion	-2.5348
Bozdogan's (1987) CAIC	-10.7301
Schwarz's Bayesian Criterion	-5.7301
Bentler & Bonett's (1980) Non-normed Index	0.8287
Bentler & Bonett's (1980) NFI	0.8717
Z-Test of Wilson & Hilferty (1931)	0.8888
Bollen (1988) Non-normed Index Delta2	0.9536

The manifest variable equations with estimates, standard error and t-value of model specification case3 are

```
x1        =   -0.0526*F1       +  1.2181*F2       +  1.0000 e1
Std Err        0.0140 L11         0.3665 L12
t Value       -3.7660             3.3232

x2        =   -0.0147*F1       +  1.0000 F2       +  1.0000 e2
Std Err        0.0101 L21
t Value       -1.4567

x3        =    1.0000 F1       + -6.1082*F2       +  1.0000 e3   (4.11)
Std Err                           0.1946 L32
t Value                         -31.3864

x4        =    0.1063*F1       +  0.0000 F2        +  1.0000 e4
Std Err       0.00633 L41
t Value       16.8012

x5        =    0.0000 F1        +  0.3392*F2       +  1.0000 e5
Std Err        0.0929 L52
t Value        3.6521

x6        =    0.0000 F1        +  0.3630*F2       +  1.0000 e6
Std Err                            0.1691 L62
t Value                            2.1466
```

TABLE 8 . *Variances of exogenous variables*

Variable	Parameter	Estimate	Standard Error	t Value
F1	covf1f1	5336395813	2.04618E-9	2.61E18
F2	covf2f2	80533240	9.88797E-8	8.14E14
e1	vare1	72572592	6.9713E-10	1.04E17
e2	vare2	84302485	2.4477E-10	3.44E17
e3	vare3	-929938775	2.19435E-9	-424E15
e4	vare4	148441830	1.40523E-9	1.06E17
e5	vare5	5998820	2.20044E-8	2.73E14
e6	vare6	34467981	8.7498E-10	3.94E16

TABLE 9. *Covariance and correlation among exogenous variables for model specification case3*

Var1	Var2	Parameter	Estimate	Standard Error	t Value
F1	F2	covf1f2	589888437	2.85299E-8	2.07E16
F1	F2	covf1f2	0.89983	(correlation)	

Manifest variable equations with standardized estimates of model specification of case3 are

```
x1     =  -0.3355*F1      +  0.9542*F2      +  0.7436 e1
                  L11                  L12
x2     =  -0.0884*F1      +  0.7362 F2      +  0.7532 e2
                  L21
x3     =   5.1039 F1      + -3.8298*F2      +  1.0000 e3
                                       L32
x4     =   0.5374*F1      +  0.000 F2       +  0.8433 e4
                  L41
x5     =   0.0000 F1       +  0.7791*F2     +  0.6269 e5
                                        L52
x6     =   0.0000 F1        +  0.4852*F2     +  0.8744 e6
                                        L62
```

(4.12)

4.3 Interpretation and Model Fit Test

CFA is used to verify the factor structure of a set of observed variables postulating the relationship pattern a priori. It allows testing the hypothesis that a relationship between observed variables and their underlying latent construct(s) exist.

First, determine criteria a priori to access model fit and confirm the factor structure. Traditional statistical methods normally utilize one statistical test to determine the significance of the analysis. However, structural equations modeling, CFA specifically, relies on several statistical tests to determine the adequacy of model fit to the data. It is helpful to access the overall fit of the model by looking at chi-square and fit indices such as fit function, goodness of fit index (GFI), Bentler’s comparative fit index (CFI), Bentler & Bonett's (1980) non-normed index (NNI), Bentler & Bonett's (1980) normal fit index (NFI) and root mean square for error approximation (RMSEA) estimates.

Chi-square describes similarity of the observed and expected covariance matrices. A chi-square value close to zero indicates small differences between the expected and observed covariance matrices. Moreover, the probability level (p-value) must be grater than 0.05 when chi-square is close to zero. This means an acceptable model fit is indicated by a chi-square probability grater than or equal to 0.05. Here the CFA models (4.8) and (4.11) with chi-square 3.5160 and 7.4652 with respective p-values 0.6210 and 0.1885 indicate better fit than that of model (4.6) with chi-square 12.6788 and p-value <0.0001.

In many CFA problems the chi-square statistic will usually be significant even if the model fits. Thus, it should not be the only index investigated. For Z-Test of Wilson & Hilferty (1931) absolute z-value less than or equal to 5 indicate a good fit. Thus, CFA models (4.8) and (4.11) with values 0.3145 and 0.8888 indicate good fit.

The comparative fit index is equal to the discrepancy function adjusted for sample size. It ranges from 0 to 1 with a large value indicating better fit. Acceptable model fit is indicated by a CFI value of 0.90 or greater (Hu and Bentler, 1999). PROC CALIS out put includes many fit indices including the fit function, GFI, CFI, NNI, NFI, standardized RMSEA and probability of close fit (PCF). Table 10 summarizes fit indices and show model with good fit.

TABLE 10. *Summary of fit indices and model with good fit*

Fit index	Model specification case / Model equation number			Model(s) with good fit
	Case1/ (4.6)	Case2 /(4.8)	Case3/ (4.11)	
Fit function	0.9753	0.2705	0.5752	Case2
GFI	0.8126	0.9272	0.8655	Case2
CFI	0.7064	1.000	0.9429	Case2 and case3
NNI	.	1.1031	0.8287	Case2
NFI	0.7821	0.9396	0.8717	Case2
RMSEA	0.0000	0.0000	0.1947	Case1 and case2
PCF	.	0.6379	0.2041	Case2

For the purpose of these specifications of model parameters, the 7 fit indices indicate acceptable fit for model (4.9). Thus, model specification case2 indicates better/acceptable model fit.

If the model fit is acceptable, the parameter estimates are examined. We investigate the maximum likelihood estimates for lambda-x (Λ_x,), phi (Φ) and theta-delta (Θ_δ). Observe that no asymptotic standard error is really small (< 0.0005) that the ratio of each parameter estimate to its standard error is distributed as z/t-statistic and is significant at 0.05 levels if its value exceeds 1.96 (Hoyle, 1995). And observe that all standardized loadings are larger than 0.60. Now model under case 2 is acceptable, we can examine the parameter estimates.

TABLE 11. *The model parameter estimate and test of significance*

Parameter	Estimate	Standard error	t-value	Significant at 0.05 level (√)	Standardized Estimate (SE)	SE> 0.60 (√)
λ_{11}	-0.3292	0.6619	-0.4973		-0.0658	
λ_{12}	2.5271	0.3720	6.7933	√	1.0627	√
λ_{21}	0.9703	0.7943	1.2217		0.1822	
λ_{22}	0.6917	0.6966	1.0015		0.2731	
λ_{31}	8.6919	0.5873	14.7995	√	1.4108	√
λ_{32}	-1.3691	0.2825	-4.8457	√	-0.4671	
λ_{41}	4.8143	0.7647	6.2959	√	0.7637	√
ϕ_{11}	5261392	7.6964E-7	6.84E12	√	----	
ϕ_{12}	5743446	3.15507E-7	1.82E13	√	----	
ϕ_{22}	23250741	4.60095E-8	5.05E14	√	----	

$\sigma^2_{\delta 1}$	-8026392	9.86897E-9	1.68E15	√	1.0000	√
$\sigma^2_{\delta 2}$	125396243	6.14338E-9	8.26E13	√	0.9168	√
$\sigma^2_{\delta 3}$	-104680271	1.29762E-8	1.67E15	√	1.0000	√
$\sigma^2_{\delta 4}$	87126805	5.22357E-8	-807E13	√	0.6455	√
$\sigma^2_{\delta 5}$	10049049	1.21647E-7	2.04E16	√	0.8102	√
$\sigma^2_{\delta 6}$	21882978	1.30019E-8	-813E12	√	0.6963	√

The t-tests of several parameters in Table 11 are significant at 0.05 levels. Two parameter tests of lambda-x matrix are close to significant at 0.10 levels. Thus, we conclude that the land use data confirm with CFA model (4.8) or (4.9).

5. Conclusion and Recommendation

5.1 Conclusion

In 2000 the United Nations Food and Agriculture Organization (FAO, 2000) found that the role of population dynamics in a local setting may vary from decisive to negligible and that deforestation can result from a combination of population pressure and stagnating economic, social and technological conditions (Alain, 2000). The distribution of land use in the study area has been changed greatly over time because of subsequent cultivation after deforestation due to high population and economic pressures, and infrastructure and irrigation development (Tuma Ayele, 2007). Based on population density of Gamo-Gofa, we can easily see that the demand of farmland has been rapidly increasing over time.

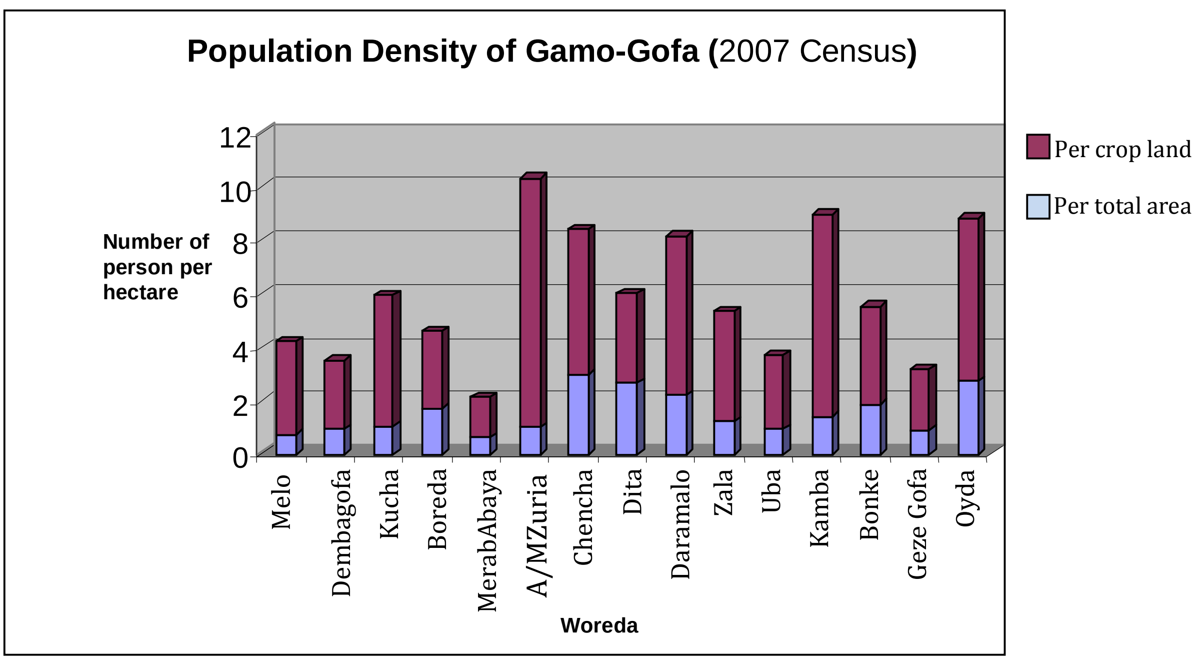

Figure 6. Population density of Gamo-Gofa

This demand shows deforestation is an ongoing issue that is causing extinction, changes to climatic conditions, desertification, and displacement of home-grown people. Moreover, it facilitates the rate of drought occurrences, limits poverty reduction goals, and leads to low living standard of people and is a cause for political instability of country.

Damage to forests and other aspects of resources is serious in Gamo-Gofa as well as in other parts of Ethiopia due to lack of proper management or the presence of non-participatory top-dawn development programs. For instance, settlement programs, food security programs, and small scale enterprises were contributors of deforestation activities. Instead, we advocate the planning and management of land resources that is integrated and holistic where land users are central and to be had aware of benefits. This will ensure the long term quality of the land for human use, the prevention or resolution of social conflicts related to land use, the conservation of ecosystems of high biodiversity value, and reduce the rate of climate change.

Deforested areas become sources of surface water runoff, which moves much faster than subsurface flows. That quicker transport of surface water can translate into flash flooding and more localized floods than would occur with the forest cover. A good example for this was Anduro-Ealli flooding in study area that damaged eighteen persons to death in May 2010. Deforestation also contributes to decreased evapo-transpiration, which lessens atmospheric moisture which in some cases affects precipitation levels down wind from the deforested area.

Soil erosion occurs when the soil shifts from its original place to another by means of water and wind. Major factors which bring up soil erosion are: nature of the soil (loose type), nature of the land (slopping land), lack of vegetation cover, rainfall, and wind velocity. Various human activities cause soil erosion. Such as deforestation, overgrazing, steep slope farming, farming without terracing, clearing forest places and curry out farming. To overcome problem of soil erosion we must keep the vegetation cover of land that is exposed to erosion. To do this we may follow and implement highly integrated, long term oriented, land users are aware and participated, and free from side risk programs. The confirmatory factor analysis of this study shows that the increase of soil erosion effect lead to decrease in crop land coverage and change fertility of land to non fertile. In line with this, increase in deforestation lead to increase the effect of soil erosion and climate change.

The forest resource and the vegetation cover of Gamo-Gofa have been depleted alarmingly which causes climate change, land degradation and scarcity of fire wood and timber supply. This decline results from the intensive use of the land by the rapidly growing population and livestock, through deforestation, overgrazing, cutting trees and burning down the grass land to take it under cultivation. Some of highly depleted areas are Zigiti-Merche, Degashara, Bere, Durbe-Chenge, Koyira-Mukula, Wusha-Tolla, Anduro-Ealli, and so on. Three Development Assistants enquired at each peasant association/kebele confirmed that soil and forest conservation measures have been not practiced in most part of Gamo-Gofa.

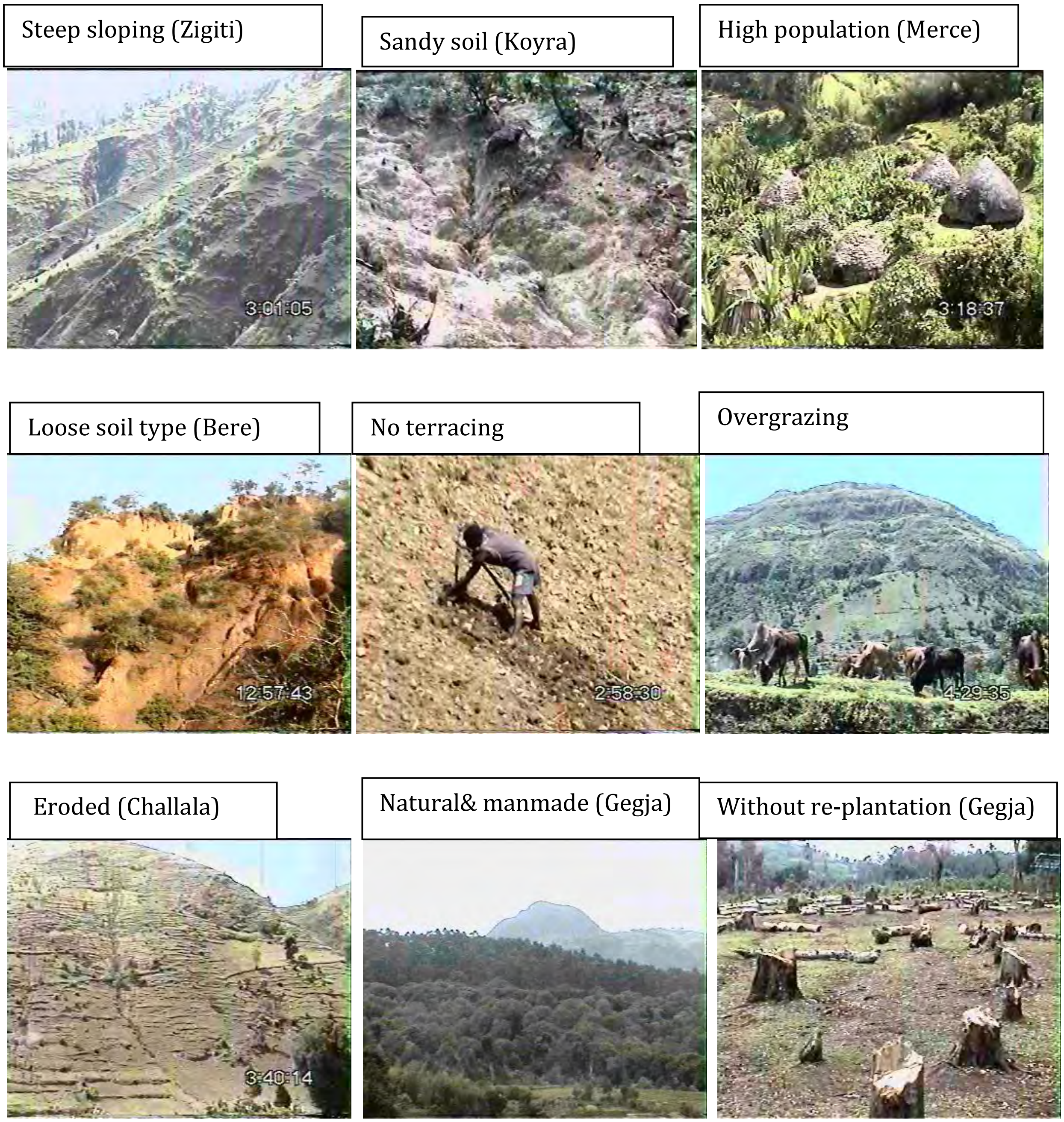

Figure 7. Sample photos of study area

What do we visualize from photos? Do we show concern for coming generation? We know that our economy depends on agriculture lead to industrialization and poverty reduction policies. Do we believe that our farming style would lead to those goals? How can we sustain our ecology, biodiversity, climate and both natural and artificial resources? What solutions can we think of? Do we have effective conservation strategy in Ethiopia?

We can conclude that there is no effective/sufficient program for soil and forest conservation. An example for the success of soil conservation measures in Ethiopia is provided by the Konso area in the south Ethiopia near by Gamo-Gofa Zone, where terracing of the land reduced soil erosion and thereby relatively improved the standard of living style. But Gamo-Gofa people have not been gained knowledge of soil conservation from Konso.

The structural model (4.9) shows that the increase of either soil erosion or climate change effect leads to a decrease in forest and bush land coverage. This effect leads to increase fertile (not cultivated) land coverage. This means there is huge activity of deforestation/devegetation practice in study area. On the other hand grazing land has been positively related with both factors. It is, therefore, important to model structural relation of deforestation to soil erosion and/or climate change. For this study, we conclude that the land use data confirm to CFA model (4.9).

During the 1991 change of government most of the conservations and development activities ended in destruction of resources, because of the transition from unitary to federal state had created a power vacuum. Nevertheless, many people believe that the military government had better commitment towards natural resource development than what was seen subsequent years. What ever, peaceful government power transition will be needed to maintain natural resources as is and to proper utilization.

5.2 Recommendation

The low level of living standard and illiteracy of most of the people coupled with lack of alternatives contribute to the decline in forest areas of Ethiopia. Conversion of natural forests into cultivated fields can affect soil fertility and carbon sequestration; as a result carbondioxide induces climate change phenomena. A successful environmental management constitutes a means to keep a balance between utilization and conservation of both natural and manmade resources. This can be achieved when consumers have a sound understanding about conservation, proper utilization, concern of coming generation, and creating functioning policies, laws and regulations as well as stable organizations to implement efficiently.

Some development programs, such as settlement programs, food security programs, and small scale enterprises were contributors of deforestation activities. This may not confirm with land resource management. Instead, we advocate the planning and management of land resources that is integrated and holistic where land users are central and have to be aware of benefits. The government or concerned bodies take into account relationship between deforestation, soil erosion and climate change through structural models when planning to develop land use programs. This will ensure the long term quality of the land for human use, the prevention or resolution of social conflicts related to land use, the conservation of ecosystems of high biodiversity value, and reduce the rate of climate change.

Reducing emissions from the tropical deforestation and forest degradation in developing countries has emerged as new potential to complement ongoing climate policies. The idea consists in providing financial compensations for the reduction of greenhouse gas emissions from deforestation and forest degradation. Developed countries are expected to finance the programs/projects that are aiming resource conservation and keeping ecological balance.

The crop land demand has been increasing in study area by highly growing population. In this thesis, one of the loadings which relates factor with crop land coverage is not significant in acceptable model (4.9), but it is significant for model (4.11). This may demand further studies on this area to have good enough model that satisfy both good fit criteria and significant loadings.

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APPENDIX

PROC CALIS procedures in SAS

```
data forest;
input   x1-x6;
cards;
.
.
.
proc calis data=FOREST  METHOD=ML COV stderr maxiter=1000 ;

lineqs
    x1 = L11 F1 + L12 F2 + e1,
    X2 = L21 F1 + L22 F2 + e2,
    X3 = L31 F1 + L32 F2 + e3,
    X4 = L41 F1 + 0 F2 + e4,
    X5 = 1 F1 + 0 F2 + e5,
    X6 = 0 F1 + 1 F2 + e6;
std
e1 = vare1,
e2 = vare2,
e3 = vare3,
e4 = vare4,
e5 = vare5,
e6 = vare6,
F1 = 1, F2 = 1;
cov
F1 F2 = covf1f2,
F1 F1 = covf1f1,
F2 F2 = covf2f2;
var x1 x2 x3 x4 x5 x6;
run ;
```

The Impact of Deforestation on Soil Erosion and Climate Change: Structural Equations Modeling

BY
DEFARU DEBEBE

1

Outline

- Introduction
- Objective of the study
- Study area
- Data and Methodology
- Findings
- Conclusion and Recommendation

2

Introduction

- Climate and land use changes are two major global ecological changes
- Climate change and land use affect each other
- Land use activity contributes to soil erosion and climate change
- Deforestation cause a major effect on land cover

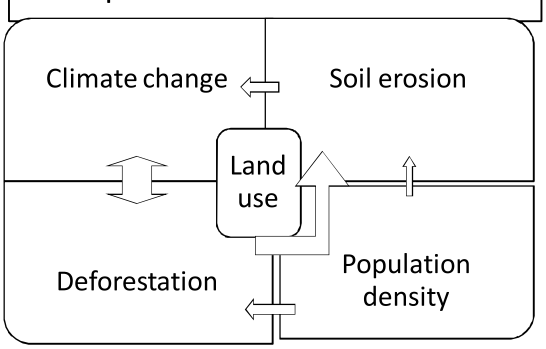
3

Objective of the study

- This study attempts to model the impact of land use on
  - soil erosion and
  - climate change
- Moreover, it aims to
  - Provide additional information and
  - Also create public awareness for effective conservation and utilization of resources

4

Conceptual frame work

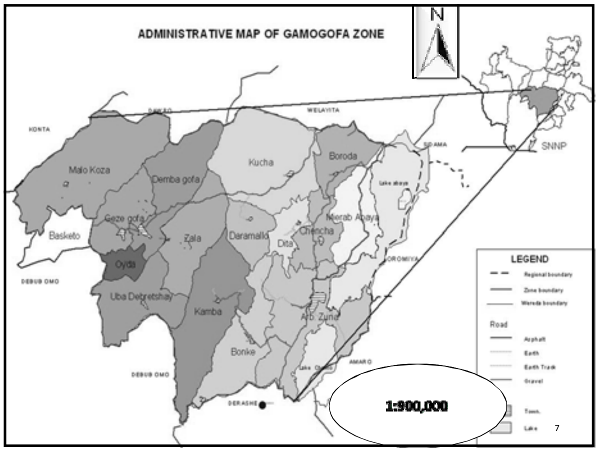


5

Study area

- **Gamo-Gofa**
  - is a province in the southern Ethiopia
  - is named after two ethnic groups, Gamo and Gofa
  - its capital is Arba Minch
  - and area cover more than 1.2 million hectares
  - population size is around 1.6 million (female 50.2%)

6



Data and Methodology

- **Data**
  - **Obtained from Gamo-Gofa Zone Department of Agriculture**
  - **Collected and Organized since 2005 into six land use variables**
  - **Sample photo and video documents were conducted to visualize**

8

Methodology

- **SEM used to model linear relationship b/n a random dependent and independent**
- **Either variables can be observed (manifest) or unobserved (latent)**
- **The covariance structure among the observed random variables is used**

9

Methodology (cont.)

- **The structural model for latent variables is**

$$\underset{m\times 1}{\eta} = \underset{(m\times m)}{B}\,\underset{(m\times 1)}{\eta} + \underset{(m\times n)}{\Gamma}\,\underset{(n\times 1)}{\xi} + \underset{m\times 1}{\zeta}$$

Zeros in diagonal

- **The reduced form**

$$\eta = (I-B)^{-1}\Gamma\xi + (I-B)^{-1}\zeta = \pi\xi + e$$

10

Methodology (con.)

- **Relating unobserved latent constructs to observed variables**
- **The measurement model is**

$$\underset{q\times 1}{x} = \underset{(q\times n)}{\Lambda_x}\,\underset{(n\times 1)}{\xi} + \underset{q\times 1}{\delta}$$

11

Methodology (cont.)

- **The covariance matrix for SEM is**

$$\Sigma(\theta) = \Sigma_{xx} = \Lambda_x \Phi \Lambda_x' + \Theta_\delta$$

- **The issue of estimability is called global identification**
- **A parameter θ in a SEM is identified if it can be estimated**

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Methodology (con.)

- If θ is uniquely estimable, the model is said to be just identified/saturated
- To solve for the model parameters in a SEM, # of equations must be >= to # of unknowns
- Let the total # of equations in $\Sigma(\theta)$ is v and
- If *t* is the # of parameters to be estimated

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Methodology (cont.)

- a necessary condition for model identification is that *v*=v-t*>=0
- The hypothesis $H_0: \Sigma = \Sigma(\theta)$ is testable
- It tests whether an overidentified SEM is consistent with the observed data

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Methodology (cont.)

- To analyze a SEM
  - We begin by specifying the model using a path diagram
  - That relates the latent and observed variables
  - Next we determine whether model is identified
  - Given an identified model, estimate model parameters

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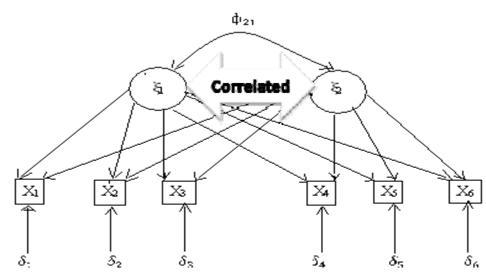
Path diagram



16

Methodology (cont.)

- To estimate model parameters in $\Sigma(\theta)$, obtain a sample estimate S of $\Sigma(\theta)$ and
- Choose a scalar error-in-fit function

$$F_{ML} = log|\Sigma(\theta)| + tr(S\Sigma(\theta)^{-1}) - log S - (p+q)$$

- The fit function is defined to be zero so that

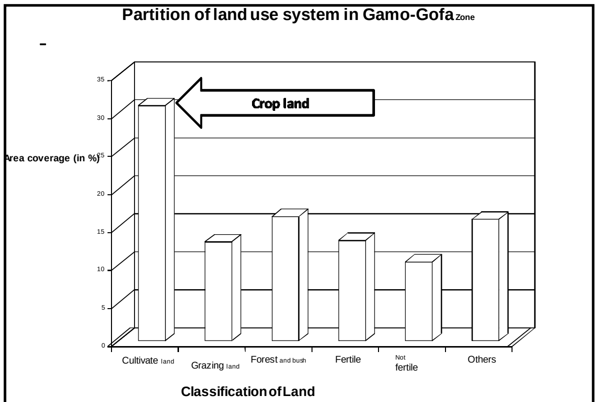
$$S - \hat{\Sigma} \approx 0$$

17

Methodology (cont.)

- Next step in the evaluation of a SEM is assessment of overall fit
- Criteria used to evaluate model fit include
  - »Chi-square test
  - »Fit indices
  - » t-test for parameter estimates

18



Findings (cont.)

- **Before Estimation and model fit of CFA**
- **Let as see the EFA**
  - **The goal of EFA is to find a small number of latent factors**
  - **Having that, determine simple structure**
- **When performing EFA, no prior knowledge of**
  - **# of common factors**
  - **Pattern of regression coefficients**
  - **– Restriction: covariance matrix for error is diagonal**

Findings (cont.)

- **Taking observed data, the EFA model of SEM is also** $\underset{q\times 1}{x} = \underset{(q\times n)}{\Lambda_x}\underset{(n\times 1)}{\xi} + \underset{q\times 1}{\delta}$
- **We also use this model for CFA**
- **The major differences in CFA are that**
  - **Specify priori number of latent factors**
  - **Allow error covariance to be symmetric (correlated errors of measurement)**

Findings (cont.)

- **Pattern of regression coefficients to be hypothesized a priori**
- **The phi matrix is unspecified**

- **This allow to estimate parameters in simultaneously**

Findings (cont.)

- **The PROC CALIS estimates and tests the appropriateness of SEM**
- **PROC CALIS procedure provides the results**
  - **# of estimated parameters**
  - **Fit indices**
  - **Manifest variable equations with estimates**
  - **variance and covariance of exogenous variables**

Model specification

- Case1
  - t=21 (# of parameters)
  - q(q+1)/2=21 (# of equations)
  - t=q(q+1)/2 (model is identified)

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & \lambda_{22} \\ \lambda_{31} & \lambda_{32} \\ \lambda_{41} & \lambda_{42} \\ \lambda_{51} & \lambda_{52} \\ \lambda_{61} & \lambda_{62} \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix}$$

Model specification (cont.)

- Case2
  - t=16
  - q(q+1)/2=21
  - t<q(q+1)/2 (model is overidentified)

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & \lambda_{22} \\ \lambda_{31} & \lambda_{32} \\ \lambda_{41} & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix}$$

- Case3
  - t=16
  - q(q+1)/2=21
  - t<q(q+1)/2 (model is also overidentified)

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & 0 \\ 1 & \lambda_{32} \\ \lambda_{41} & 0 \\ 0 & \lambda_{52} \\ 0 & \lambda_{62} \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix}$$

No response

Unit change

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Interpretation and model fit test

- **CFA is used to verify the factor structure**
- **First, determine criteria a priori to access model fit**
- **Traditional statistical tests utilize one test statistic**
- **However, SEM relies on several tests**
  - **Chi-square**
  - **Fit indices (fit function, GFI, CFI, NNI, NFI, PCF, RMSEA)**

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Model fit test

- **Chi-square value close to zero with p-value >0.05 indicates small differences b/n expected and observed covariance matrices**
  - **Also |z|<=5 (z-test of Wilson & Hilferty)**
  - **small fit function**
  - **large GFI**
  - **CFI, NNI >=0.90**
  - **Small RMSEA, large PCF**
    - **» indicate good fit**

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Model with better fit

Fit index	Model specification case / Model equation number			Model(s) with good fit
	Case1/ (4.6)	Case2 /(4.8)	Case3/ (4.11)	
Fit function	0.9753	0.2705	0.5752	Case2
GFI	0.8126	0.9272	0.8655	Case2
CFI	0.7064	1.000	0.9429	Case2 and case3
NNI	.	1.1031	0.8287	Case2
NFI	0.7821	0.9396	0.8717	Case2
RMSEA	0.0000	0.0000	0.1947	Case1 and case2
PCF		0.6379	0.2041	Case2

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Model with better fit

- **If the model fit is acceptable, the parameter estimates are examined**
- **Observe that standard error not <0.0005**
- **t-statistic is significant at 0.05 level if value>1.96**
- **Observe standardized loadings are >0.60**
- **CFA model (4.8) confirm with land use data**

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Conclusion and Recommendation

- **The CFA model relates soil erosion, climate change and land use variables**
- **No effective conservation program for soil and forest resources**
- **Concerned bodies take into account relationship b/n deforestation, soil erosion, and climate change through structural relations when planning to develop land use programs**

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THANK YOU!

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