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Population and environment interaction: the case of gilgel abbay catchment,northwestern Ethiopia

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Unevenly distributed and concentrated in highlands; population in Ethiopia has degraded the resource base. Ethiopian population was 79 million with 2.9% growth per year in 2008. In Ethiopia as the result of rapid population increase forest base were affected and soil fertility was severely deteriorated. For the present study, the Ethiopian population information from censuses and different estimates and the last 25 years population size, distribution and growth rate of Gilgel Abbay Catchment districts were evaluated to understand the impact of population over the resource bases. There was rapid increase of population with growth rates 2.3% and 2.2 %(1984-1994 and 1994-2007) respectively per annum which has caused land cover changes in the catchment districts. In Gilgel Abbay catchment, within the last 35 years about 72.3% of forests, 55% of grass lands, 47.2% of wetlands and 6.3% of lake areas were converted to farm and settlement areas which have been increased by 57.6% within stated periods.

Keywords: Population Increase; Environment; Resource Degradation; Environmental Impact; Land Cover Change

1. INTRODUCTION

Ethiopia with its 79 million (CSA, 2008) people living in a geographical extent of 1.1 million km^2 has a GDP of US $ 6.1 billion, 39% of which is contributed by Agriculture, upon which 85% of the population are dependent for livelihoods. As per the UN Human Development Index (Estimates for 2010), Ethiopia is ranked as 157 and falls under low development country, with a HDI of 0.328. Over the past 30 years, the GDP of Ethiopia has grown from 190 to 398 (USD), while the population rise during this period was alarming (UNHDI, 2010).

There has been a steady increase in the population growth rate since 1960 but after 1960's population in Ethiopia started to increase rapidly because of changes in socio-economic conditions in the world. The (CSA, 2004) projected that Ethiopia's population could be 115 million by the year 2015 owing to declining death and rapid birth rates (40 and 5.4 per thousand) respectively. The spatial distribution of Ethiopia's population generally is related to altitude, climate, and soil. These physical factors explain the concentration of population in the highlands, which are endowed with moderate temperature, rich soil, and adequate rainfall. About 90 percent of the population lives in areas above 1,500 and only 11 percent are living below 1,500 meters (hot climatic zone), although the hot zone encompasses more than half of Ethiopia's territory (Sahlu, 2004; Muluneh, 2001).This shows population in Ethiopia is growing rapidly and distributed unevenly and it has negative implication to environmental resources.

Parallel to low socio-economic and rapid population growth, there is land degradation which has affected the country's ecological integrity. For instance, the forest cover of Ethiopia was 40% at the beginning of 20^{th} century but has declined to 2.2% at present. Soil degradation process makes large areas unsuitable for agriculture. Because the top soil and even part of the sub soil in some areas has been removed, and stones or bare rock are left at the surface. Up to half of the arable land in the Ethiopian highlands is estimated to be moderately to severely eroded, and as a result, previously cultivable lands are being (or have been) turned to wasteland. Estimates of soil erosion in the Ethiopian highlands indicate that 2 million hectares of land have been severely degraded, and that, if management practices

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are not changed, as much as an additional 7.6 million hectares will deteriorate to the same status by 2010. The situation as is indicated above is very deteriorating and leads to severe environmental degradation (Gete,2000: Kebrom, and Hedlund 2000; Muluneh, 2001).

Rapid population growth and the low economic standard of living in Ethiopia have brought in their awake numerous consequences to land cover and use changes, change in climate and hydrological status in the country. In Ethiopia studies have indicated that as there is agricultural land expansion at the expense of other land uses. Ethiopian highlands are fragile and forest, water and its biodiversity is climate dependant, which are currently under stress due to population pressure and mismanagement of natural resources. The poverty-stricken economy of Ethiopia needed scientific management of its natural resources and balancing the population to cope up with the climate change and the challenges of the globalization of economy. Thus, there is a need to review the population and environment interrelation at the country level in order to suggest the means to minimize adverse effect of population pressure on environment.

1.1 Review on Population –Environment Interaction

Humans have sought to understand the relationship between population dynamics and the environment since the earliest times (Petersen, 1972; Cohen, 1995), but it was Thomas Malthus' Essay on the Principle of Population (Malthus, 1960) in 1798 that was credited with launching the study of population and resources as a scientific topic of inquiry. However, it was not until the 1960s that significant research interest was revived on World Population (Natl. Acad, 1963), a report that reflected scientific concerns about the consequences of global population growth, which was then reaching its peak annual rate of 2 percent. By 1972, the Club of Rome had released its World Model (Meadows et al., 1972) which represented the first computer-based population-environment modeling effort, predicting "go beyond" of global carrying capacity within 100 years.

Population and Environment Nexus: Theories

Wide arrays of theories have emerged to describe the relationship among the variables of interest and each of these theories leads to basically different conclusions and policy recommendations. Here are review of some of the most prominent theories in the field of population and environment related to the present review. It then proceeds to provide a state of the-art review of Ethiopian population change and studies that have examined population changes and their relationship to the environmental issues in Ethiopia and GAC.

Linear Perspectives

The Malthusian and Boserupian could be described as the linear views and they emphasized the one-sided, linear and direct relationships between population and environment. Malthusian view analyses population growth as a threat to the natural limit of arable land to provide food, shelter and subsistence. Malthus (1960) postulated that human population has a trend to grow geometrically; agricultural production of food grows only arithmetically. Thus, population growth tends to surpass the productive capabilities of land resources to meet the demands for food, owing to the ecological constraints imposed by natural resources (Ehrlich and Holdren, 1974; Commoner, 1992). According to Malthus if not checked by either by preventive or positive checks the consequence would famine, poverty and increased mortality. However, Malthusian theory was highly criticized because of not foreseeing the future technological advancement.

As an extension of the Malthusian theory, Moretimore (1993) on his study in Kenya stated that increase in population density brings about a corresponding increase in frequency of cultivation and the shortening of the fallow period that is needed to rejuvenate soil fertility. As fallow length is reduced, soil fertility is bound to decline and this leads to declining yields. Falling output is experienced, which eventually culminates in food scarcity. The problem of food shortage subsequently leads to further accelerated degradation of environmental resources. Boserup (1981), however, explicitly takes into account technological change as means of innovation under population pressure. Moreover, Boserup suggested that increasing population density might encourage technological changes that allow food production to keep pace with population growth. Similarly, Simon (1996) went further to suggest that population growth induces sufficient technological change to expand food output faster than population. Boserupian theory focuses on the relationships between these three factors: population, environment, and technology.

However, both the Malthusian and Boserupian perspectives entail linear relationships between population and the environment. Boserupian concept of population, like Malthus, refers mainly to land resources and related factors such as c1imate and soil quality. It is important to recognize that neither Boserupn nor Malthus

specifically addressed population, environment, and technology per se but rather the topics of land use or food production. Social and natural scientists have, however, also introduced other nonlinear ways of thinking about population-environment relationships. These non-linear views may consider the multiplicative effects between population and other factors in producing environmental impacts or, alternatively, the "mediating" effect that other factors (socioeconomic, institutional and cultural) may have on population-environment relationships.

Multiplicative Perspectives

Multiplicative perspectives present the view that population (size, growth, density and distribution) interacts in multiplicative way with other factors, such as levels of consumption and technology, to have impacts on the environment. One of the most frequently used multiplier approaches, is the "I=PAT" equation. Total environmental impacts (I) are seen as a product of population size (P), the level of affluence or per capita consumption (A), and the level of technology (T) (Ehrlich and Holdren, 1974; Commoner, 1992).The IPAT equation implies that although population, consumption or technology might be considered as independent causes of environmental impact, it is their combined effect which is of most interest. However, the "I=PAT" approach has been criticized on the basis that "P", "A" and "T" are, in fact, not independent, as the equation implies, and that important political and institutional variables affect resource use, for example, the distribution of land, are not accounted for (Shaw, 1993). Shaw has proposed population as not ultimate cause but, rather, as an aggravating factor that multiplies the scale at which the ultimate causes of environmental degradation operates with other factors.

Mediating Perspectives

Mediating perspectives emphasize that social, cultural and institutional factors play a mediating role in determining population-environment relationships. Social scientists are inclined to consider the impact of social, cultural and institutional factors on population-environment relationships, and much recent research implicitly or explicitly reflects this viewpoint. Blaikie and Brookfield (1987) and Bilsborrow (1992) emphasize the mediating role played by social, economic and institutional factors, in particular, that of policy and the state. The influence of those factors on population-environment relationships is viewed as multilevel so that layers of mediating variables at the household, community, national and international levels must be considered. This view believed that population is not the only cause of environmental degradation but combined with other causes.

Development-Dependency Perspectives

Another perspective within the mediating viewpoint collapses all social, cultural and institutional factors that mediate population-environment relationships into the larger concept of "development". This view focuses on the way in which development processes mediate population and the environment relations and reflects what Marquette, (1997) has termed a "dependency perspective" and which stresses the overwhelming role that international political and economic forces and the process of dependent development has played in shaping both demographic and environmental outcomes in developing countries.

This viewpoint suggested that environmental degradation and population growth were interrelated since both derived from poverty resulting from core-periphery dynamics. Duplication of this model in rapidly growing developing countries, as is the current tendency, is seen as only compounding negative environmental impacts. The systems developed in more developed countries may have negative consequences in fewer developing countries.

Complex System and Adaptive Strategy Perspectives

An additional approach considers mediating factors as well as environment and population in a structured way or as a complex of interrelated systems. This approach aims to understand how ecological and human-driven systems (socio-cultural, demographic and economic) dialectically interact and interconnect to form larger "socio-ecological systems" (Gallopin et al.,1988) within which population and environment relationships are embedded. Studies using this approach have addressed situations in which large scale structured changes due to economic development processes have caused radical shifts in the existing relationships between human population and ecological systems.

Population and environment interrelationship is complex and dynamic. Each of the above theories identifies one or more ultimate causes for environmental degradation, which if remedied would solve the problem. In the case of neo-Malthusianism, population growth is the primary

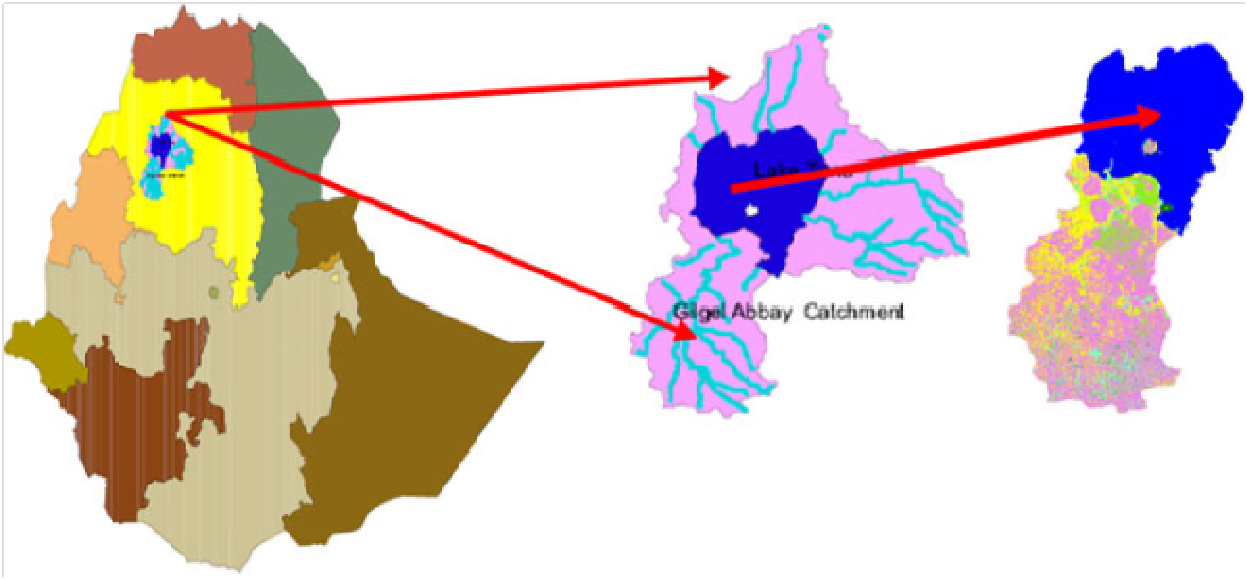


Figure1: Study area map

problem, and the solution is population programs. In the case of Cornucopian, market failures are the primary problem, and the solution is to fix them. For political ecologists, inequalities at different scales are the main problem, and policies should address those inequalities. Multivariable theories offer few magic bullets but do underscore the need for action on multiple fronts to bring about sustainability.

There is also spatial temporal variation on the interrelationships. Not only do population variables include stock elements (size, distribution, and composition/structure) and flow elements (fertility, mortality/morbidity, migration/mobility) which influence each other, but equally environmental variables include interrelated primary elements (air, water, energy, land/materials) and secondary elements (built, non-built, uninhabited environments). And between population and environment lie many intervening or intermediate variables which affect both: social and cultural differences; levels of technological advance, development and consumption; types of economic activities and institutions; and the growing influence of political decisions at both national and international level. These factors have become apparent between, as well as within, individual regions and countries, e.g. with respect to changes in fertility rates and their pace, or alterations of the population's age structure. Many agreed without appropriate policies, higher population will lead to degrading trends. At the same time, some studies have presented optimistic scenarios in which local populations have been able to counter degradation trends. Thus, the diversity of demographic changes must be considered within the regional variations.

2. Study Area and Methodology

2.1. Study Area

Gilgel Abbay catchment, study area, is located northwestern Ethiopia and stretches between latitudes 10°57′–11°54′N and longitudes 36°38′–37°23′E. The Gilgel Abbay River catchment contributes more than 40 % of the volume of the lake's water and covers about 32 % of Lake Tana's total catchment with total area of about 4,865 km2. Within the catchment, elevation varies from 1,750 to 3,400 m.a.s.l. and the very elevated areas are concentrated at the southern part of the catchment and declines northwards. The climate of catchment is mainly controlled by seasonal migration of inter-tropical convergence zone and associated atmospheric circulation but the topography has also an effect on local climate conditions. According to CSA (Central Statistics Authority 2008), there were about 1.5 million people in catchment and about 90 % of population live in rural areas and depend on agriculture.(Figure1)

2.2. Data Sources and Methods of Analysis

There were two types of data used for this study: land cover and population data. The source for land cover and use analysis was the works of (Amare, 2010). This research has identified the land cover changes in GAC (Gilgel Abbay Catchment) by considering 1973, 1986, 1995, and 2008 landsat images for the study area. The major land classes were: forest, agriculture and settlement area, wood- and bush lands, grass and bare lands, water bodies, and wetlands. After classification

Table1: Projected_population size of Ethiopia from 1900 – 1980

Year	Population*	Year	Population
1900	11,754.30	1940	16,281.00
1905	11,871.80	1945	17,534.60
1910	12,121.10	1950	19,182.90
1915	12,424.10	1955	21,197.10
1920	12,933.50	1960	23,550.00
1925	13,606.00	1965	26,281.00
1930	14,367.90	1970	29,488.20
1935	15,258.70	1975	33,085.80
		1980	37,684.70

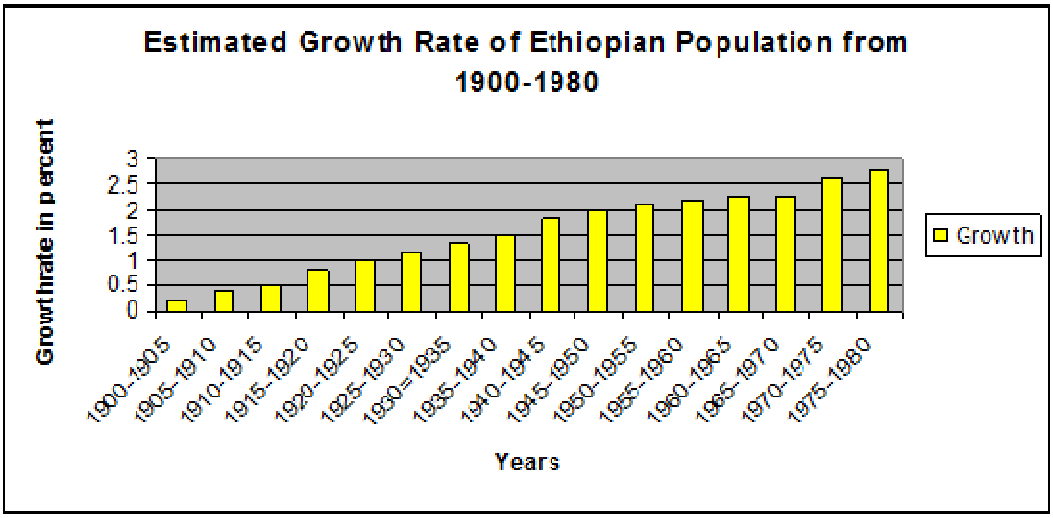


Figure 2: estimated growth rate of Ethiopian population from 1900-1980

and calculation of the area in hectares, comparison of the land use land cover statistics within and between land class units and years was performed. Population and Demographic information of the Ethiopian and GAC was obtained from Central Statistical Authority (CSA) and surveys and estimates done for different purposes. These data were used to understand the population dynamics of the study area.

3. RESULTS AND DISCUSSION

3.1. Population Change In Ethiopia In Historical Perspective

Ethiopian population change analysis can be broken into two main parts: those prior to census and after census of 1984. Population data prior to first census (1984) was scant in Ethiopia and based on sample surveys which have done in different times. Available data indicated that the population has increased fourfold between 1900 and 1988. At the beginning of the 20th century the crude birth rate was estimated at 0.2% per annum. The total population in 1900 was estimated at 11.8 million. It took 60 years for this to double to 23.6 million in 1960. It took only 28 years for the population in 1960 to double to 47.3 million in 1988 and growth at 2.9% between 1980 and 1989. After, 1950's there was change in environmental health and improvement of medical technology as well as excess food production from more developed countries and directly transferred to developing countries which have declined the death rate. Two demographic factors responsible for this dramatic growth have been a continuing high birth rate and slowly declining mortality rate. The projected population of Ethiopia before census has shown continuous increase of population in the country (Table1). The estimated growth rate of population in Ethiopia from 1900-1980 by five years interval is indicated (Figure2). For long time the growth was slow but showing continues increase. But after 1950's

Table 2: percentage distribution of population by sex and census year

Census Year	sex	Population size Number	%	Growth rate
1984	Both Sexes			
	Male	39868572	100.0	1984-1994
	Female	20062490	50.3	3.4%
		19806082	49.7	
1994	Both Sexes			
	Male	53477265	100.0	1994-2007
	Female	26910698	50.3	2.9%
		26566567	49.7	
2007	Both Sexes		100.0	
	Male	73918505	50.5	
	Female	37296657	49.5	
		36621848		

Source: 2007 census report draft, CSA, 2007

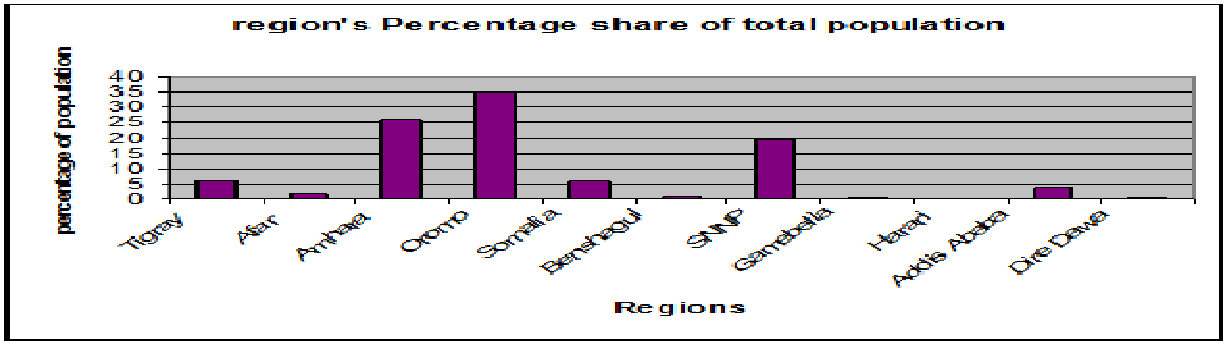


Figure3: percentage share of each Region from total population of the country, 2007

because of worldwide change on socio-economic dimensions and health facilities there was rapid growth rate in the country. This has brought rapid increase in population in Ethiopia after this period.

In Ethiopia census is the recent phenomena and the first national census was conducted in 1984, and the second in 1994 and the third was conducted in 2007. With an estimated population of 79,221,000 million in 2008 (CSA, 2008), Ethiopia has the second largest population in Sub Saharan Africa. The total number of persons enumerated in the third Population and Housing Census by aggregating the May and November data sets was 73,918,505. Of these, 37,296,657 (50.5%) were males and 36,621,848 (49.5%) were females. The population of the country in the previous censuses of 1984 and 1994 were 39,868,572 and 53,477,265, respectively (CSA, 2008). Each successive Population and Housing Census demonstrates that national population size increased in Ethiopia in high proportions. For instance, a comparison of the 2007 census results with 1994 shows that the population of the country increased by more than 20 million persons over the last 13 years. Similarly, in the previous decade (1984 to 1994), the population of the country increased by 13.2 million people.

The country's population has almost doubled within 23 years. The growth rates were very rapid, 3.4% from 1984-1994 and 2.9% from 1994-2007 per annum (Table2). Although, it has shown declining rate, it is still one of the highest in the world. It is typical characteristics of developing countries where population growth is greater than socio-economic development and dependency of people on the environmental resources increase and leads to degradation of environment.

Because of regional variation of population, boundary and regional delimitation problems to compare regions to all census times is difficult. There are 11 administrative regions in Ethiopia at present time. Addis Ababa, Dire Dawa and Harari are urban administrative units. Oromiaya is the most populous region with 36.7% share from country in 2007, Amhara's share was 23.3% on the same census and SNNP's share was 20.4% and so on. These three regions together constitute 80.4% of population but the decline of Amhara's region population from 1994-2007 was not clear. From 1994-2007 the highest growth rate was recorded for Gambella, where as the lowest was for Amhara 4.1% and1.7%, respectively. Regarding density, Addis Ababa has the highest (5,608 persons per km^2), followed by Harari and Dire Dawa. Gambela, Beneshangul-Gumuz, Afar and Somali are sparsely populated regions (Figure 3).

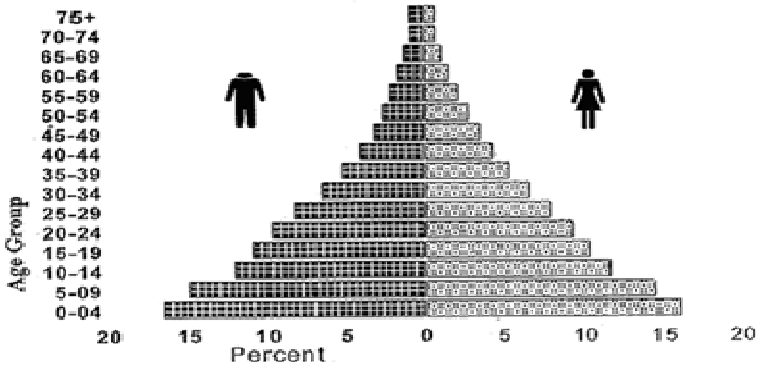


Figure4: Population pyramid of Ethiopia, 2008

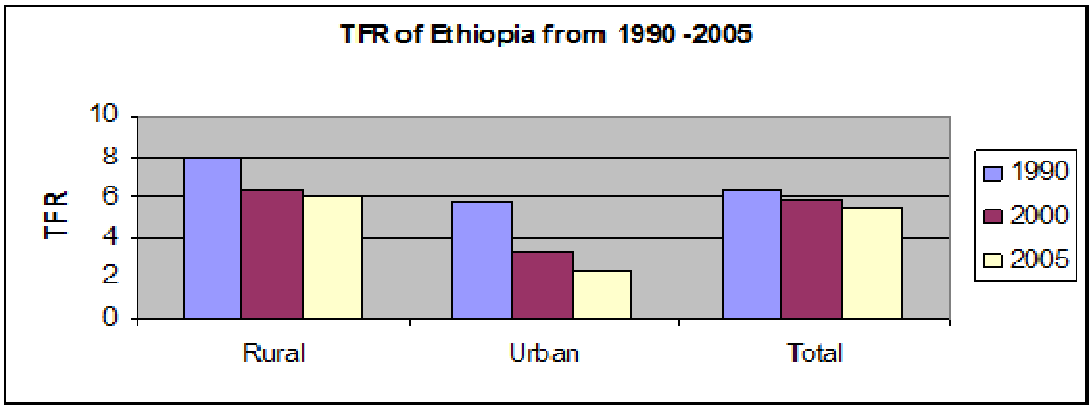


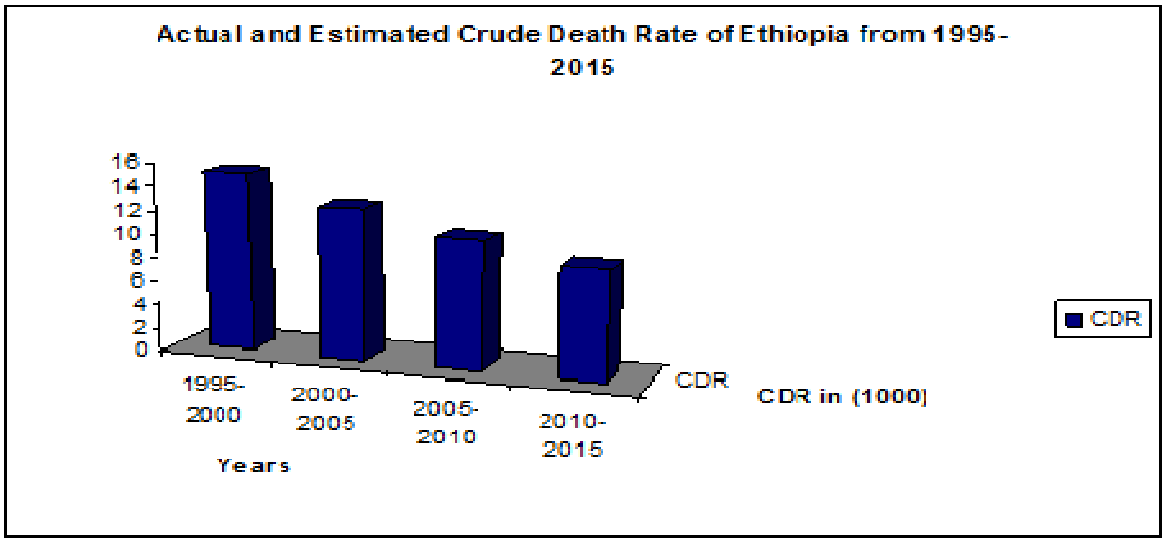
Figure5: Trends in total fertility rate in rural and urban

3.2 Age and Sex Composition

Sex is one of the basic characteristics of a population. Sex composition is very important for any analysis, as data on sex provides useful information about reproductive potential, human resources, level of school attendance by each sex, and the potential fertility. Male population is slightly higher (50.5%) than female population (49.5%) at the country level in 2007 census. The age-sex pyramid depicts the typical types of developing countries with rapid population growth and high proportion of young population (Figure4). Age data are useful for demographic analysis and for various types of socio-economic development planning. It is determined by the effects of past fertility, mortality and migration. It also indicates the potential fertility. The distribution of the national population by broad age groups shows that the proportion of young population under age 15 has declined from 49.8 percent in 1984 to 45.0 percent in 2007 (Figure4). . Conversely, the proportion of population in the working age group 15-64 has increased from 50.2 percent in 1984 to 51.9 percent in 1994. The proportion of population aged 65 years and over was 3.4 percent in 1984 and remained constant at 3.2 percent both in 1994 and 2007 Censuses. It is broader at base and tapers up because of lower proportion of old age population.

3.3 Population Dynamics

Population dynamics encompasses population change over time due to births, deaths and migration. Fertility is one population dynamics that determines the size and age structure of a given population. The current total fertility rate (TFR) is 5.4 for Ethiopia. The fertility level is considerably higher in rural than urban areas. The TFR in the rural areas is 6.0, 2.5 times higher than the TFR in urban areas (2.4). Assessment made on fertility shows a declining trend from 6.4 births per women in 1990 ((NFFS, 1993) to 5.4 births in 2005 (EDHS, 2005), a one child drop in the past 15 years. A more pronounced decline in the later years was in urban than rural areas (Figure5). Total fertility rate is one of the highest in the world because as indicated above contraceptive



Source: NOP, Population Profile of Ethiopia, 2001

Figure 6: Actual and estimated CDR of Ethiopia from 1995-2005

prevalence rate is low (15%) and unmeet need for married women are wide (34%).

Although there has been a declining trend in all measures of mortality and improvements in the health sector service provision systems, mortality levels still remain high in Ethiopia. The crude death rate has shown modest decline in the last two decades. The current maternal mortality rate (673/100,000) is among the highest in the world. Data from the 2005 EDHS showed that infant mortality has declined by 19 percent over the last 15 years. Under five mortality has gone down by 25 percent. Even though both infant and child mortality rates are declining, the current levels of infant mortality rate (77/1000) and child mortality rate (123/1000) are still highest. This implies that one in every thirteen Ethiopian children dies before reaching age one, while one in every eight does not survive to the fifth birthday. The estimated rate of CDR in Ethiopia from 1995-2015 is declining because of betterment of health facilities (Figure 6).

In Ethiopia although, there were no data for long time, the existing data has shown that the growth of population became rapid after 1950's. Some of demographic variables seem to decline slightly but they are still the highest in world. This population momentum will have effect on the future population growth. It is clear that rapid increase with no parallel socio-economic development has threatened the environment of the country at present and will influence in the future.

3.4. Population And Environment Linkages In GAC

Ecological and economic evidence have shown that loss of biodiversity and decrease in land productivity are the major problems in Ethiopia. With continued population growth the problem is likely to be even more challenging in the future (Berry, 2002; Keyser and Sonneveld, 2001). An Ethiopian Highland Reclamation Study (EHRS, 1993) conducted two decades ago revealed a frightening trend in environmental degradation where by 27 million ha. or almost 50% of the highland area was significantly eroded, 14 million ha seriously eroded and over 2 million ha beyond reclamation. Environmental degradation is most severe in the highlands, especially in the northern half of the country due to exponential growth in population, long history of settlement, primitive land-use practices which included clearing of vegetation cover for farming and fuel, and lack of innovation in farming practices. A more recent accounting of available forest cover reveals that the 1990-2000 decade in Ethiopia saw an average yearly deforestation rate of 0.8 percent; among the highest in the world. It is said that, in the year 2000 alone, 87.5 million m of timber were cut down for fuel wood. With an estimated forest-land loss of 150,000-200,000 hectares annually, environmental degradation in Ethiopia has been persistent, widespread, and costly (FAO, 2000). Similarly, Amare (2010) on his study on Gilgel Abbay catchment was found expansion of agriculture and settlement areas and decline of forest and wetland cover with increase of population in one of the highland areas of Ethiopia (Table3). Land cover changes in Gilgel Abbay Catchment were attributed to anthropogenic factors mainly of population increase.

The population of catchment districts has shown a rapid increase and in less than 20 years population of the catchment has doubled. The increment of population was very rapid and has implication to the resource base of the catchment. Parallel to this period, in the catchment there was very rapid land cover and use change as stated above because of population increase. In the GAC

Table 3: land cover and use change in Gilgel Abbay catchment from 1973 to 2008

Land cover classes	Year 1973		Years 1986		Year 1995		Year 2008		1973-2008
	Area in ha*.	%	Area in ha.	%	Area in ha.	%	Area in ha.	%	Total loss or gain
Forest	9328	1.2	4527	0.6	3298	0.4	2581	0.3	**-6747**
Wood and shrub land	24645	3.1	39980	5.1	60148	7.6	60863	7.7	36218
Grass and bare land	162481	20.6	109550	13.9	91748	11.6	73026	9.3	**-89455**
Farm and settlement land	205993	26.1	274947	34.9	286261	36.3	324536	41.2	118543
Lake Tana	301899	38.3	302946	38.4	301082	38.1	282990	35.9	**-18909**
Wet lands	84069	10.7	56465	7.2	45878	5.8	44419	5.6	**-39650**
Total	788415	100	788415	100	788415	100	788415	100	

Table 4: Correlation of population size and land cover units in GAC

Census years		1984	1994	2007	2017
Population		580258	863432	1162956	1554206*
Land cover and use units	1973	1986	1995	2007	2017
Farm and settlement lands	42.3%	56.7%	58.8%	66.7%	77.0%*
Forest	1.9%	0.9%	0.7%	0.5%	0.4%*

** projected*

Source: 1984, 1994 and 2007 census result reports and Amare, 2010

region, most of the population is below the poverty line and living with less than 1 ha of land where the agricultural output also is very low compared to many countries. There was demand for agriculture and settlement lands for increasing population and obtaining fuel wood from open access forest and wood lands. This has led to expansion of agriculture and settlement lands by clearing forest, grass and wetlands.

There was relationship between population size and land cover changes in GAC. The population in GAC districts and selected land cover units were correlated (Table4). There was strong positive relationship between population size and farm and settlement lands that is there was increase in population size and there was proportional expansion of farm and settlement lands in the catchment. But the relationship between population size and forest has shown strong but negative that means as population size increased; there was decline of forest and its cover (Table4). This implies that population growth in GAC was one of the causes of conversion of forest, water and wetland into farm and settlement lands within the stated periods and its final consequence is disturbance of the ecosystems of the catchment.

CONCLUSION

Ethiopia's unsustainable population growth contributes to the country's environmental degradation, especially in the densely populated highlands. Deforestation, wetland degradation, overgrazing, rapid soil erosion and biodegradation in the country were directly or indirectly related to the existing rapid growth of the population. Hence, there should be strategies that are proposed to strengthen family planning programs to provide women with the knowledge and means to regulate their fertility; emphasize human development, in particular education, gender equality and child health, and encourage delays in childbearing by addressing the needs of young people and the momentum of population growth due to young age structure.

Urgent priority should be given to arrest environmental degradation and conservation of natural resources, and biodiversity. Investment in agricultural research and technology in order to increase agricultural production while, at the same time, protecting the natural environment. Develop local techniques and dissemination of soil management practices to the society and compensation for externalities that may adversely affect natural resources.

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