THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Climate Change Mitigation and Adaptation Planning in Addis Ababa City

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Abstract:
The hazards which were related to climate changes such as drought, heavy rain and high temperature have social and economic impacts on Addis Ababa City's population. This was motivated points for this work. The objective of this seminar was to investigate the climate change and proposed mitigation and adaptation plan of Addis Ababa city. The data collection for this study were collected from secondary sources which were mainly raw temperature and rainfall data of two main stations of Addis Ababa city observed for 30 years by National Metrological Agency. Literature review of other documents from different Libraries and internet concerning about status qua analysis were also made to complement and refine the information that had been collected. The status qua analysis had shown that, the city of Addis Ababa has experienced both warm and cool years over the last 30 years. There has been an increasing warming trend in the annual maximum temperature over the past 30 years. However, the trend analysis had shown almost, the constant minimum average annual temperature of the city. The most vulnerable sectors to climate variability and change were agriculture, water and human health. It could also be said that, the sources and cause of emission for carbon dioxide of Addis Ababa city were energy, transport, waste, industry, livestock and agriculture.

Keywords: *Climate change, mitigation and adaptation plan, temperature and rainfall, metrological agency and addis ababa city*

1. Introduction

Climate change has become one of the most challenging global issues facing humanity. This is an issue created by human induced driving forces such as the combustion of fossil fuels, which has wide ranging consequences to our natural world and to human settlements all around the world. The range of effects has included a warming of sea water temperatures that has given warning signs such as the collapse of the ice shelves (Lagadec, 2002). These changes to our natural world seriously threaten the health and quality of life of many urban dwellers. Human responses have likewise been varied in scale, ranging, for instance, from a country's commitment to control emissions to an individual's decision to take public transportation rather than driving to work. Responses to global warming can, and must, operate at different temporal and spatial scales (Wilbanks etal, 2007).

The international climate change regime and its organizations have provided a forum in which, through interactions and negotiations between different actors, the interests of countries around climate change have been defined and contested. National governments have the primary responsibility for signing international agreements, reduction of Green house gas emissions and coping with climate hazards. It is also within their sphere of responsibility to encourage their local administrations to take appropriate steps to enhance urban planning, and mobilize the necessary support from the public and private sectors to control Green house gas emissions and adapt to climate change. National mitigation strategies as well as adaptation and disaster management plans often neglect urban area (Bulkeleyetal, 2003, Pelling, 2005, Satterthwaite et al, 2007). National states are unable to meet their international commitments for addressing both mitigation and adaptation without local action. Not only because green house gas emissions originate in activities, individual behavior, and processes embedded in cities, urban centers and other local places.

Cities are increasingly involved in transnational and sub national networks which represent a form of environmental governance, "multilevel-governance", happening across multiple scales (Bulkeley etal, 2003), namely the Cities for Climate Protection, the Cities for, Climate Alliance. ICLEI is the International Council for Local Environmental Initiatives. Local governments participating in ICLEI's Cities for Climate Protection (CCP) Campaign commit to undertake and complete five performance milestones, namely a) conduct an energy/emissions inventory and forecast, b) establish an emissions target, c) develop and obtain approval for the Local Action Plan, d) implement policies and measures, and e) monitor and verify results. See ICLEI 2006: April 20 2006 www.icle.org). The Large Cities Climate Leadership Group which includes Chicago, Cairo, Mumbai and Sydney committed to both reducing urban

carbon emissions and adapting to climate change. This plays an important role because cities contain around 50% of the world's population, and consume a high share of the world's energy. The Climate Alliance is an alliance of European cities and municipalities that have developed a partnership with indigenous rainforest communities. Its aim is to preserve the global climate through a two-fold mechanism: reduction of GHG emissions by high-income countries and conservation of forests in middle- and low-income countries.

2. Material and Method

2.1. Materials

The materials used for this seminar were; References books, Internet services and papers for printing the seminar.

2.2. Methods

The data collections for this seminar study were collected from secondary sources. These sources were mainly raw temperature and rainfall data of two main stations of Addis Ababa City observed for 30 years from National Metrological Agency. Literature review of other documents from different Libraries and internets were also made to complement and refine the information that has been collected

2.3. Study Area

Addis Ababa is located in the central highlands of Ethiopia, covering an area of 540 km ^{2}. The city has an elevation of 2000-2800 m a.s.l. The current annual maximum temperature is 23.3^{0}c with annual minimum temperatureof10.7^{0}c.The average annual maximum rainfall is 1230.mm (NMA, 2010). It is Capital city of Ethiopia, Seat of the African Union and the United Nations Economic Commissions for Africa. It is also Gate-way for diplomats and tourists. The Population of the city is about 3 million people. Currently, the city has three layers of government: City Government at the top, 10 sub-city Administrations in the middle, and 99 kebele at the bottom. Addis Ababa lies at an altitude of 7,546 feet (2,300 meters) and the natural vegetation is dominated by grassland biome. The city lies at the foot of Mount Entoto. From its lowest point, around Bole International Airport, at 2,326 meters (7,631 ft) above sea level in the southern periphery, the city rises to over 3,000 meters (9,800 ft) in the Entoto Mountains to the north (Calverton, 2008).
Addis Ababa has a Subtropical highland climate. The city possesses a complex mix of highland climate zones, with temperature differences of up to 10 °C, depending on elevation and prevailing wind patterns. The average temperature of the city is 15.9^{0}c.The warmest average maximum or high temperature is 25^{0}c recorded in the month of March and May. The range of average monthly temperature is 3^{0}c.The coolest average minimum or low temperature is 7^{0}c occurs in January, November and December (NMA, 2010). The average annual rainfall is 1089mm and month with the driest weather is November where as the month with the wettest weather is August. The mean relative humidity for an average year is recorded as 60.7%.

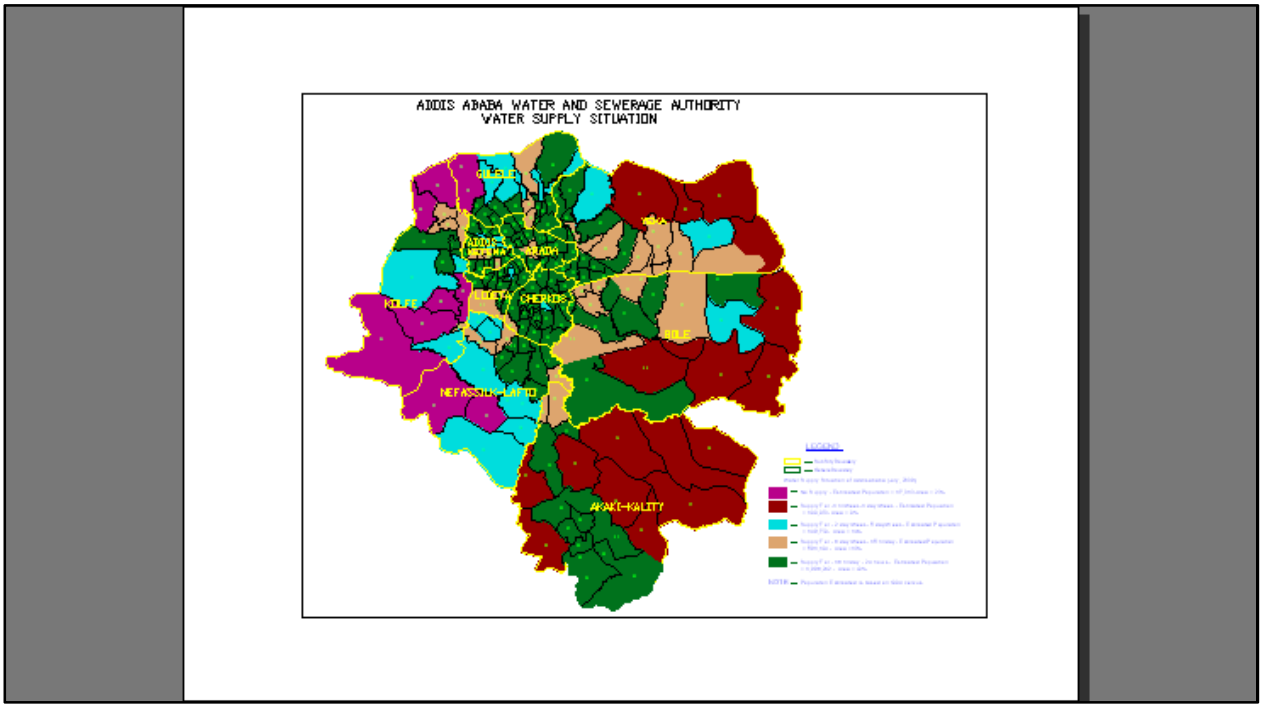

Figure 1: Map of Addis Ababa City, Source: Addis Ababa Water Sewerage Authority

3. Status qua Analysis

3.1. Current Climate Variability and Trend of Addis Ababa City

Average annual maximum temperature and Average annual maximum rainfall variability and trend observed over the City in the period 1981-2010 is shown in Figures 3 and 4, respectively. Annual maximum temperature is expressed in terms of temperature differences from the averaged for 2 Stations. Figure 3 clearly reveals that there has been a variation trend in the annual maximum temperature over the past 30 years. The City has also experienced both dry and wet years over the same period as indicated in Figure 4. The trend analysis shows that, the variation of rainfall has been increasing in the current years.

3.2. Temperature Variability and Trend

The year to year variation of annual minimum and maximum temperatures is expressed in terms of temperature differences from the averaged over 2 stations (Figure2 and 3). As it can be seen from the Figure 3, the city has experienced both warm and cool years over the last 30 years. However, the recent years are the warmest as compared to the early years. Figure 3 clearly reveals that there has been increasing warming trend in the annual maximum temperature over the past 30 years. The annual minimum temperature almost had shown constant average temperature and constant trend of coefficient of determination (r^2). However, the trend of year 1985 had shown too much variation below the average annual minimum temperature (Figure 2). This may be due to increase of cloud cover and surface evaporative cooling from precipitation in that year.

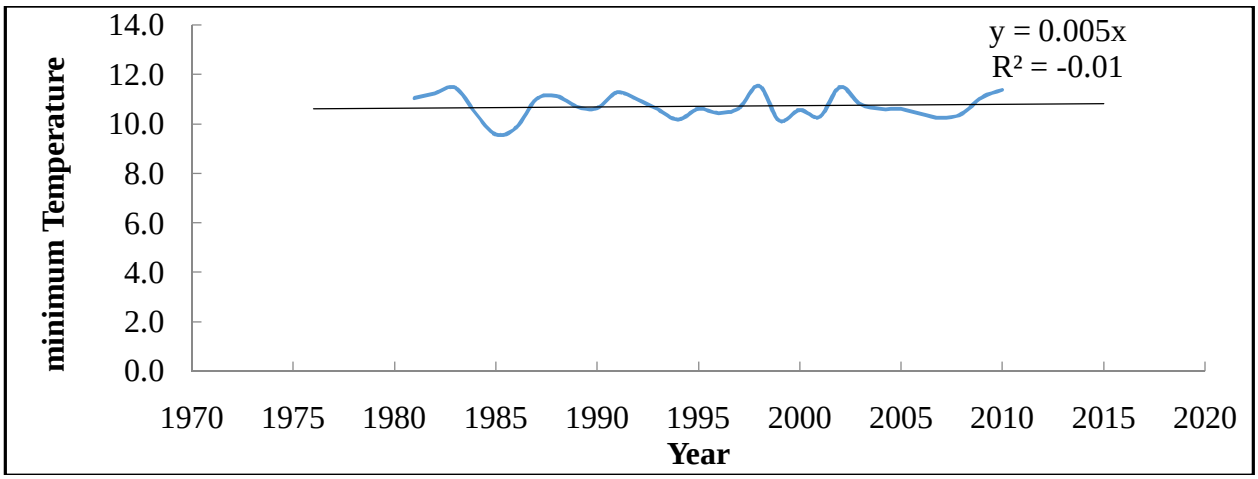

Figure 2: Average Minimum Temperature of Addis Ababa (1981-2010)

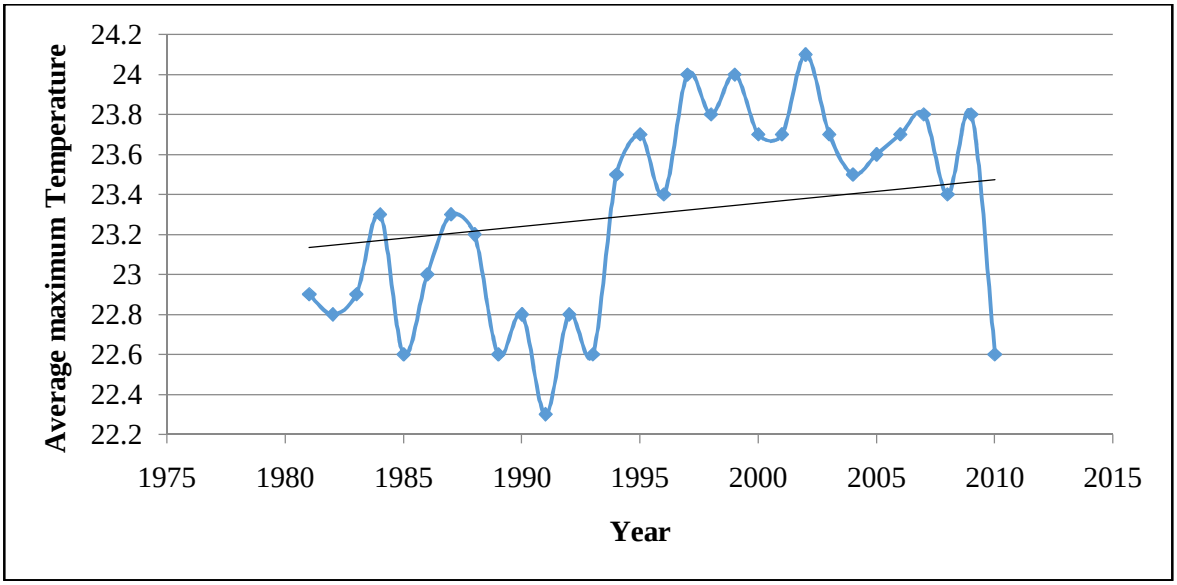

Figure 3: Average Maximum Temperature of Addis Ababa (1981-2010

3.3. Rainfall Variability and Trend

The data of average annual rainfall from 1981- 2010 for Addis Ababa stations has shown that, there is variation of rainfall from year to year over the city. This variation is expressed in terms of normalized rainfall irregularity averaged for 2 stations. As it can be seen from the figures 4, the city has experienced both dry and wet years over the last 30 years. Years like 1982, 1984, 1991, 1994, 1995 and

1999 were dry while 1987, 1989, 1999, 2006, 2007, 2008 and 2010 were wet years (Figure 4). It also indicated that, the years 1981 to 1990 has small variation but the years like 1999 to 2010 has shown huge fluctuation of rainfall (Figure 4and Annex Table 3). This may be due to the result of current climate change that affects trade winds which are the source of rainfall of the city.

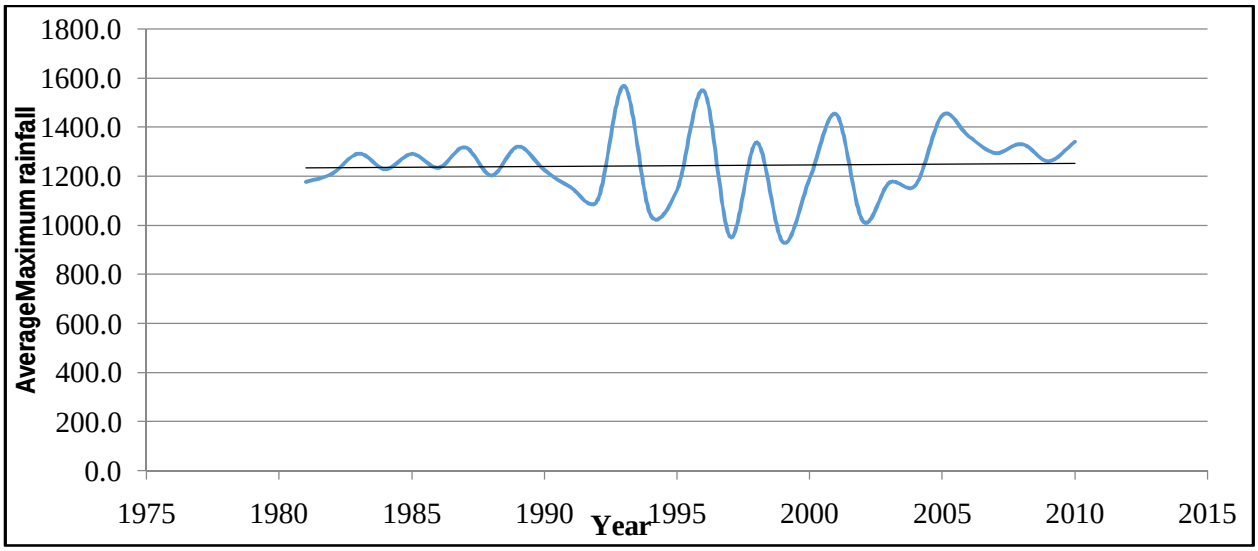

Figure 4: Average Maximum Rainfall of Addis Ababa (1981-2010)

3.4. The Vulnerability Sectors of Addis Ababa City

Vulnerability assessment based on existing secondary information and rapid assessments carried out for this seminar study in city has indicated that the most vulnerable sectors to climate variability and change are Agriculture, Water and Human health. The causes for vulnerability of Addis Ababa city to climate variability and change may be due to very high dependence on rain fed agricultural products which are very sensitive to climate variability and change, inadequate water supply, lack of capability for those who have encounter health problems, high population growth rate, low economic status which might result to low adaptive capacity and lack of awareness, etc.

Other vulnerable elements and population in the city are: residents in traditional an informal settlements, which are often located in the most vulnerable locations; industrial and informal service sector workers, whose occupations place them at significant risk to natural hazards; buildings, especially traditional and informal housing that is especially vulnerable to wind, water and natural hazards; lifeline public infrastructure, which includes roads, bridges, railways, airports and other transportation systems; water, sewage and drainage, flood, power and telecommunication infrastructure; and critical social infrastructure such as hospitals, schools, fire and police stations and ecosystems and the natural environment, especially river.

3.5. Impacts and Cause of Current Climate Variability

3.5.1. Drought

Drought has typical impacts on Addis Ababa city, shortages power or electricity, increases in food and biomass fuel prices, inadequate water supply and increasing migration from rural areas to Addis Ababa City. Continuing severe climate change-induced drought that makes subsistence agriculture uneconomical in the surrounding areas of the city (Personal Information, 2011).

3.5.2. Agriculture

Agriculture as cause of climate change and climate change also has an impacts on agricultural productivity. Therefore, in order to prepare the land for the next growing cycle, the residues left in the field are usually burned in open conditions. Emissions of non-CO2 trace gases (CH4, CO, N2O, NOx) and CO2 release from burning of above ground biomass on-site and off-site are considered as potential emission sources in Addis Ababa(Amare,2007). Poor agricultural land management and application of artificial fertilizers contribute as cause of greenhouse gas emission. The climate change shortening maturity period of agricultural crops hence, reduce the crop productivity.

3.5.3. Water

The potential impact of climate change on extreme hydrological events in Akaki River catchment of the Addis Ababa area had shown that the maximum river flows in the Akaki was variable in terms of magnitude, and indicated irregular of occurrence (Abayneh, 2010). In general, it also indicated the decreased of the both volume and energy production of the river of city. The climate change had also caused floods in the years of 1978 and 1994, which had caused much impact on the residents of the city (Table 1).

Damage	Time	
	1978	1994
People killed	12	3
House Damage	1255	954
Affected people	6000	7655
Made homeless	Many	2880
Cost of damage	N/A	15.4 million Birr

Table 1: Impact of flood on Addis Ababa city (1978 and 1994)
Source: M.J. Dyer 1994 .Damage of 1978 and 1994 Foods

3.5.4. Human Health

Although the 2007 national census indicated that, 98.64% of the housing units of Addis Ababa had access to safe drinking water, while 14.9% had flush toilets, 70.7% pit toilets (both ventilated and unventilated), and 14.3% had no toilet facilities, but still there are many infectious and chronic diseases which are either directly or indirectly sensitive to the climate change. According to information obtained from Black Lion hospital, climate change has an impact on health of the communities of the city and there is a current trend increase of case for water-washed diseases such as diarrhea, cholera, typhoid and malaria. Malaria is expected to expand from its currently endemic range (Personal Information, 2011).

3.5.5. Transport

According to city BOFED (2002), of the total 2.2 million transport users, about 69% uses taxi, 19% uses city bus, 8% use medium bus and the rest 4% uses public transport. Based on the 2002 statistical data, a total of 10,500 vehicles (10,000 minibuses and 500 taxies) are registered to give transportation services in the city. It provides a transportation services for 1.5 million passengers daily through 114 lines. In addition to this, 6,500 salon taxies are providing transport services (80% in contract basis and 20% short trip services).Transport has significant negative impacts on the environment and human health. The impacts are associated with air pollutions and overcrowding in city. It is source of greenhouse emission and there is rapidly increasing motorized mean of transportation (Personal observation, 2012).The impact of climate change is flood damage on the roads, bridge and other transportation structures in the city.

3.5.6. Energy

Energy in city had large contributed to the emission of C02. The fossil fuels in Addis Ababa are an important source of CO2 emission (Amare, 2007). The main emitters are transportation sector and industries. The industries in Addis Ababa are highly dependent on fossil fuel or petroleum products for their energy supply. Other types of fossils fuel such as secondary fuels are also contributed to the release C02 emission.

3.5.7. Building

One of the fundamental components that set a city apart from its rural surroundings is the climate that prevails over urban environment. In Addis Ababa areas, buildings and paved surfaces have gradually replaced preexisting natural land escapes as a result; solar energy is absorbed into roads and rooftops, causing the surface temperature of city or urban structures to become up to 11°C higher than the ambient air temperature (Bisrat, 2002).The buildings such as traditional and informal houses are susceptible to wind, water and other natural hazards. These natural hazards are caused by the climate change.

3.5.8. Waste

The data for methane gas emissions from Municipal solid and liquid waste and Industrial liquid waste for Addis Ababa had shown that 1992 to 1993 have higher amount of methane emission than rest of the years (Table 2).This may be due to the increasing of size of the city which resulted higher amount of solid and liquid waste. The years of 1990 and 1991 had the lowest amount of methane emission. This may probably due to the peak of Ethiopian civil war and the change of the government in 1991 in which some of the industries had stopped to give services. The methane emissions from Addis Ababa city municipal solid waste for the year 1989/90-1992/93 have been presented by table 2 based on the amount of solid waste collected annually from the city (Amare, 2007).

CH4	Source	1989/90 1990	1990/91 1991	1991/92 1992	1992/93 1993
	Landfill AA	6.72	5	4.8	14.29
	Landfill (Ext AA)	20.5 9	21.35	22.12	68.2
	Waste W.(AA)	1.05	1.08	1.12	1.15
	Fugitive	25.5 2	16.87	10.96	18.36
Total		**64.77**	**44.3**	**37.88**	**102**

Table 2: Methane Gas Emission from Solid and Liquid Waste of Addis Ababa City
Source: Inventory of Greenhouse gas in the period of 1989/90-1992/93

3.5.9. Industry

Carbon dioxide Emission from Addis Ababa and Mugar cement Factories for the years 1989/90-1992/93 has been inventoried (Amare, 2007). The yearly production figure of these factories is available and well compiled table 3.The 1991 has the lowest of carbon dioxide emission. This could be probably due to the change of the government in which some industry might stop their services because of instability.

CH4	Source		1990	1991	1992
	Waste	Industrial waste water (AA)	1.07	1.10	1.14
		Landfill	27.31	26.35	26.92
	Total		**28.38**	**27.45**	**28.06**

Table 3: Carbon Dioxide Emission from Addis Ababa and Mugar Cement Factories
Source: Inventory of Greenhouse gas in the period of 1989/90-1992/93

3.5.10. Livestock

The estimated livestock population of the city is 58,568 cattle, 28,244 sheep and goats, 5,531 equines, 539 beehives, 39,000 poultry, and 36,684 other domestic animals (CSA, 2007). The livestock, manure management, savanna burning and open burning are considered as potential emission sources for C02 in Addis Ababa city. The emission was higher for livestock followed by savanna while the year of 1990 and 1991 had higher amount of emission. This may be due to the result migration of some rural communities to Addis Ababa and its surrounding during the war time.

CH4	Source	1989/90 1990	1990/91 1991	1991/92 1992	1992/93 1993
	Dung	28.86	29.6	30.4	31.2
	Savanna	171.09	165.1	159.33	153.75
	Livestock	957.59	990.58	980.36	984.81
Total		**1157.54**	**1185.28**	**1170.09**	**1169.76**

Table 4: Carbon dioxide emission by Livestock, Dung and Savanna burning
Source: Inventory of Greenhouse gas in the period of 1989/90-1992/93

Sectors	Potential Impacts
Agriculture	Shortening of maturity period and decrease in crop yield
Pasture land and Livestock	Change in livestock feed availability Effects of climate change on animal health, growth and reproduction Impacts on forage crops quality and quantity Change in distribution of diseases Changes in decomposition rate Change in income and prices
Forests	disappearance of Plantation and Natural forests of city and its surrounding areas Expansion of land degradation
Water Resources	Decrease volume of river of the city Decrease in energy production Flood and drought impacts
Human Health	Expansion of malaria to entire areas of the city
Wildlife	Shift in physiological responses of individual organisms

Table 5: Summary of Potential Impact of Climate Change

3.6. Plan

3.6.1. Climate Change Mitigation Plan

Wilbanks etal (2003) point out that, urban areas have many linkages with climate change: urban centers concentrate industries, transportation, households and many of the emitters of greenhouse gases (GHG); they are affected by climate change; and they are sources of initiatives, policies and measures aimed at reducing emissions and adapting to climate change is needed.

Molina (2002) also state that, most of the total pollution of cities comes from the combustion of fossil fuels (coal, oils and natural gas) for heating and electricity generation for consumption by commercial and residential buildings, for running motor vehicles and in industrial processes. Other sources are households consuming fuels in heaters and cookers, or indirectly in air conditioning. It is also usual to find carbon emissions resulting from land use changes and aggravated by poor land management and many unpaved roads. Landfill sites taking urban wastes are another key source of methane. The manufacturing process used in the production of cement needed for the development of our urban areas can also account for as much as 5% of global emissions of GHG. Finally, many activities undertaken outside the boundaries of urban centers such as agriculture and cattle, aimed at satisfying urban requirements of food and raw materials. Although least developed nations cities like Addis Ababa has limited number of industry but their contribution for Greenhouse gases emission is also significant therefore, mitigation measure for climate change of Addis Ababa is proposed. The following table provides a measure of mitigation plan relevant to city.

Sector	Proposed Mitigation Plan
Energy Supply	More fuel efficiency: fuel switching, renewable (hydropower, solar, wind, geothermal and bio energy), combined heat and power, early applications of CO2 Capture and Storage
Transport	fuel efficient vehicles: hybrid vehicles, bio fuels, modal shifts from road transport to rail and public transport systems, cycling, walking, land-use planning
Building	Efficient lighting: efficient appliances and air conditioner, improved insulation, solar heating and cooling, alternatives for fluorinated gases in insulation and aplliances
Industry	More efficient electrical equipment: heat and power recovery, material recycling, control of CO2gas emissions
Agriculture	Land management to increase soil carbon storage: restoration of degraded lands, improved crops cultivation techniques, improved nitrogen fertilizer application, dedicated energy crops
Forests	Afforestation, reforestation, forest management, reduced deforestation and use of commercial forest products
Waste	Landfill methane recovery, waste burning with energy recovery, composting and recycling and waste minimization

Table 6: Mitigation Plan for Climate Change

3.6.2. Climate Change Adaptation Plan

Adaptation has a short history mostly related to climate-change research and action. It is defined as the realization of adaptive capacity, understood the potential of a city, its populations and its decision makers to modify cities' features and people's behavior so as to better cope with existing and anticipated climate impacts. Therefore, adaptation is about enhancing resilience or reducing cities', infrastructures', and people's vulnerabilities to observed or expected changes in climate (Wilbanks et al, 2007). The proposed adaptation plan for Addis Ababa city has diverse actions that would increase the resilience of vulnerability sectors such as urban agriculture, forest, water resources, health, electricity and reduction of the emission of solid wastes (Table 7).

Sectors	Proposed adaptation Plan
Agriculture: Crop	Proper use of climate information to adjust the planting date and early warning systems Grow crops which requires less water Selection of crops and cropping systems that maximize biomass production and therefore, N2 fixation Engagement in obtaining food from other sources and income generating activities in times of crises Initiate micro-finance to fund the low income communities to use irrigation scheme
livestock	Improve animal genotype and better disease parasite control to take advantage of the improved management Use of multipurpose cattle that work and provide milk and meat and also breed to provide suitable draught animals, in addition to supplying fuel and fertilizer from their dung
Water resources and Forestry	Allocation of water supply through market based systems Conservation of water and use multipurpose plantation forests at river basin in the city and its surrounding areas. Flood control by construction small damp Combating drought by establishing more than100 nursery to enrich city plantation forests Promotion of water resources saving techniques in drought and climate change vulnerable areas of the city Introduction of integrated watershed management for the management of the vegetation cover and abatement of erosion and siltation of water bodies
Waste	Regulation and prevention of discharged of domestic and industrial organic wastes as well as toxic chemical pollutants that cause hazards from entering into water bodies
Human health	Encouraging utilization of climate and meteorological information in the planning of malaria control, diarrhea, cholera and typhoid Establish climate and health data base for analysis of climate and health information and make available for city communities Establish early warning surveillance system program that will enable communities to adapt to potential out breaks of diseases Establish and strengthen surveillance system Promote integrated vector control approach and Develop effective malaria drugs Improve ecosystem management, which are sensitive to malaria invasion Educating the public about malaria and its control and encourage the use of malaria bed nests
Electricity	Use of alternative energy such as Solar and wind energy

Table 7: Climate Change Adaptation Planning

4. Conclusion

It can be concluded that, the city has experienced both warm and cool years over the last 30 years. There has been increasing warming trend in the annual maximum temperature over the past 30 years. However, the trend analysis had shown almost the constant average annual minimum temperature of the city. The most vulnerable sectors to climate variability and change are agriculture, water and human health. It could also be concluded that, the sources of emission for carbon dioxide of Addis Ababa city are energy, transport, waste, industry, livestock and agriculture.

5. Recommendation

- Agro-forestry practices should be encourage to the farmers in the surrounding areas of the city
- Drainage channel should be established in the flood vulnerable areas of the city
- Public should be aware of water-washed disease and encourage the use of mosquito net during the wet season
- The city government must increase the public transportations and reduce the other means of land transportation in the city in order to minimize emission from this sector.
- Since the fossil fuel is more polluters, other alternative energy such as solar and wind energy need to be developed
- Fire control mechanism should be developed for the open and savanna of the surrounding areas of the city.
- Environmental friendly technology should be developed for the management of waste produce in both industries and the city
- Further research for climate change mitigation and adaptation plan Addis Ababa city is needed

6. Acknowledgements

Thanks are specially, to Dr. Hailu Worku for his instructions and comments during this seminar study and Ethiopian National Metrological Agency for allowing me to get raw temperature and rainfall data of main stations of Addis Ababa city. I am also very grateful to Ethiopian Wildlife Conservation Authority for their materials assistant such as internet and printings of this seminar. Thanks are also goes to some individuals Colleague like Ato Aramde, Ato Yilikal Anteneh and Ato Hailu Tadess for their comments.

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