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**Review Article**

# The Role of Climate–Forest–Agriculture Interface in Climate Resilient Green Economy of Ethiopia

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**Abstract:** Though the problem of climate change is global its effect on the developing countries like Ethiopia are very significant, because of less capacity to reduce and reverse the problem. Ethiopia has always suffered from great climatic variability; that causes for various socio-economic and environmental problems. This review paper examines why and how climate, forest, and agriculture interfaces matters to the climate resilient green economy of Ethiopia. Different researchers explain that, Ethiopia has lost accumulative level of over 13% of its agricultural output between 1991 and 2010. And if no adaptation measures are taken, climate change may reduce Ethiopia's GDP by up to 10% by 2045. Considering this the government of Ethiopia is working to build green economy development policies with a view to climate change, which is considered as necessity as well as an opportunity ,but there are controversies among the risk in a changing climate, demand for economic development, reduction of agricultural productivity, and natural resource. So, Climate Resilient Green Economy (CRGE) approach needs to follows the principle of harmonizing these controversies. The highest bases of Ethiopian economy and source of energy are agriculture and forests respectively, plus to this both sectors are source of more than 80% Green House Gas (GHG) emission in the country. Therefore CRGE strategy which based mainly on agriculture and forest developmental policy is very important but the efforts so far have done on the two sectors are facing some challenges due to the strong interferences among Climate-Forest-Agriculture and related factors such as population growth, high dependency of national energy on fuel wood, lack of good governance, changing growing seasons, lack of real public policy discussion and policy contradiction like investment and settlement. Therefore taking in to account the role of climate, forest and agriculture interfaces in the effort to build Climate Resilient Green Economy and solving the related challenges is very important to achieve the CRGE strategy of Ethiopia.

**Keywords:** Agriculture, Climate, Climate Resilient, Forestry, Green Economy

## 1. Introduction

### *1.1. Threat of Global Warming / Climate Change and the Role of Soil and Forest*

The global climate change has occurred because the equilibrium of the world carbon cycle has been troubled. In the year from 1956 to 2005 the mean global atmospheric temperature is increasing from 0.10 to 0.16 and over the next 100 years the increment is estimated to raise from 1.1to6.4°C (UNDP, 2011). The recent data shows that global surface temperature in 2012 were increased by 0.56°C/1°F(Hansen, M *et al,* 2013). But precipitation decrease most likely in tropic and subtropical region and increase in a thigh latitude (IPCC2007). However the research conducted by different scholars' shows various result, most of the finding reveals the increment of temperature.

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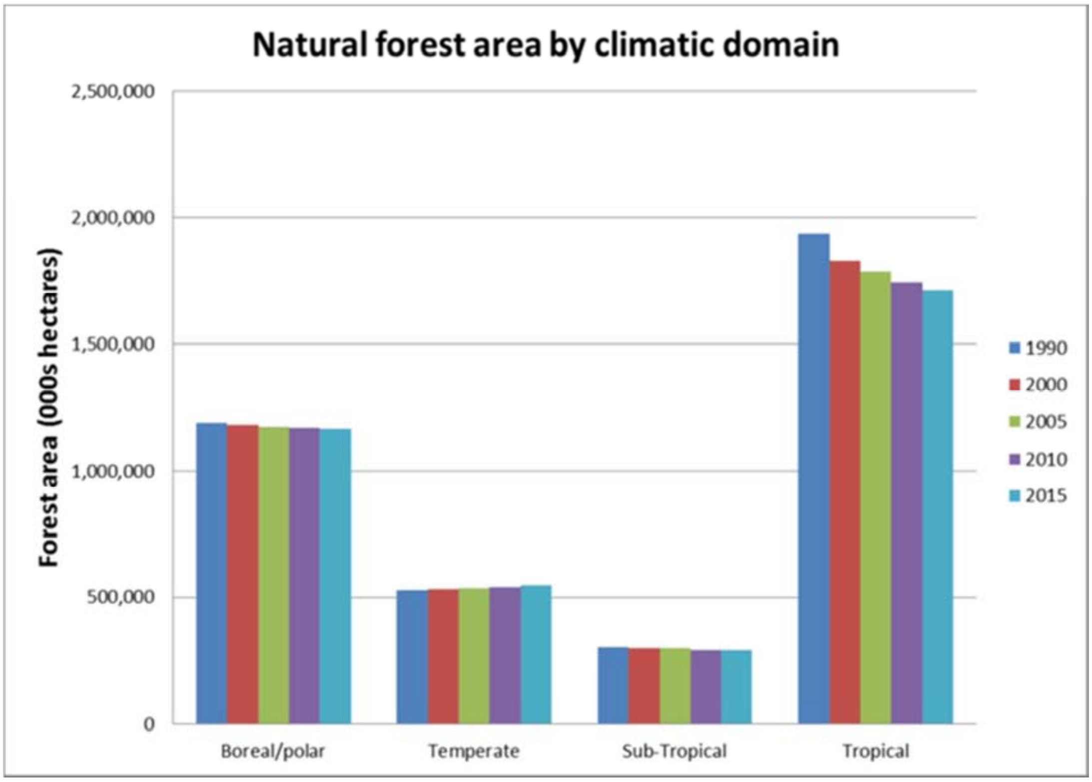
***Table 1.*** *Globalforestareachange 1900-2015.*

| Year | Forest(000ha) | Annualchange(000ha) |
|---|---|---|
| 1990 | 4128269 | |
| 2000 | 4055602 | -7267 |
| 2005 | 4032743 | -4572 |
| 2010 | 4015673 | -3414 |
| 2015 | 3999134 | -3308 |

Source: United Nations, 2015.

Table 1 shows the areal change of global forest for 25 years, here in the table no year have shown the increment of global forest coverage, but the good and encouraging change is observed, which means the rate of forest loss is reducing from time to time this may be due to the global effort to combat climate change through integrated forest management. But still both forest and land/soil resource are severely affecting by anthropogenic and natural factors.

In Ethiopia the forest minimized from 65% to 2.2% and the 90% of the highlands forest has dropped to5.6% (World Bank, 2001). According to Berry, (2003) forests cover of Ethiopia a century ago has been approximately 40% of the land, but now have reduced to only 3%. Other report from FAO, (2010) shows the forest cover of Ethiopia is 12.2millionha (11%). Similar to the global nature this is better improvement on the forest coverage of Ethiopia this may be because of the effort made on soil and water conservation for the last two decades.




Source: Global Forest Resources Assessment (2015)

***Figure 1.*** *Annual forest area change by climatic domain ( 000ha per year).*

The figure 1 above reveal that the reduction of tropical forests and little difference among the temperate, boreal and sub tropical climate forest.

The drivers of deforestation and degradation vary and higher across the tropics and include commercial and small holder agriculture, mining, roads and infrastructure, legal and illegal logging, and climate change (drought) that compared with other region (ISU, 2015). The global loss of forest has been the cause of 20% of annual green house gas emissions in the1990s (IPPC2007). In Africa in the year from 2000 to 2005, about 4million hectares of forest were lost annually, due to conversion to small-scale permanent agriculture. The major causes for wide spread deforestation in Ethiopia is cutting forest for agriculture, forest fuel, fodder and constructing materials, (Bishew, 2001). It is results to release almost 500 tera grams of carbon.

According to WBISPP's(2005) in Ethiopia conversion of forest to agricultural land causes for 55Mt $CO_2$ to the atmosphere in 2010. At 2% deforestation, about 700,000 ha of' forests' will be removed every year and releasing nearly 110 million/tons of similar gas to the atmosphere (FAO, 2005 and IPPC 2007).

If we do not prevent the process of carbon emission, global warming and climate change will treat to the existence of all life on earth. Burnett (2013) reported that Ethiopia has been identified as one of the most vulnerable countries to climate variability and change, commonly drought and floods. The major factors for vulnerability of the country are the type of agriculture which is dependent of rain-fed, poor population (low adaptive capacity), low access to (education, new information, technology, modern health services) as well as its geographical location and topography. Thus, reducing the vulnerability through mitigating and adapting to climate change can maintain growth and reduce poverty (Emerta. A, 2013). In 2011 Ethiopia has formulated the policy of CRGE, with three goals, these are economic growth, net-zero emission, and building climate resilient green economy, which targeted to take the financial opportunities and co-benefits of low emissions development. Building green economy is important policy of the time, because it improves thee economic growth, create employment opportunity, and offer extra socio-economic benefits**.** In a business term an increase in production will make a corresponding increase in emissions of the same proportion. To complement the difference, it is vital to make sure projects capacities to confront climate change and the same projects do not lead to excessive emissions of green house gases.

This shows the need to prepare appropriate environmental mitigation and adaptation policy and financial mechanisms (FAO, 2011 and Temesgen. G, *etal, 2014*). The climate change adaptation strategies of Ethiopia in the forest and agriculture sector are related with protecting and reestablishing forests for their economic and ecosystem services and agricultural technology development and promotion, disaster risk reduction, community based adaptation, governance and policy (Bashir. A, 2009). The two sectors which are forest and agriculture are the major drivers of climate change with GHGe. If this scenario is not controlled with effective implementation of CRGE policy, the country socio-economic and environmental problems will continue, because there is a strong integration among climate change, forest, agricultural activities and socio-economic issues (MoARD & WB, 200 7 and IPCC, 2007).

### *1.2. Objective of the Paper*

*I. To assess the interfaces among climate, forest, and agriculture*

*II. To review the role of the interface of climate, forest and agriculture to the CRGE policy of Ethiopia*

III. To give constructive comment and suggestion about the CRGE policy of Ethiopia.

## 2. Result and Discussion

### *2.1. Climate and Forest Interface*

The relationship between climate change and forests is intricate. On the one hand forests can mitigate climate change by absorbing carbon, while on the other they can contribute to climate change if they are degraded or destroyed. In turn climatic changes may lead to forest degradation or loss which exacerbates climate change further. Globally forests in 1990 covered about one-fourth of the Earth's land surface (FAO, 1993) although estimates differ due to the exact definition of forests. The world's climate changes are having notable impacts on the world's forests and the forest sector through longer growing seasons, expansion of insect species ranges, and increased frequency of forest fires (Beverly A. M and Gallian. B., 2008). The known impacts of climate change on forest are alterations in tree growth and productivity, alterations in forest area and competition between species, and damage caused by natural disturbances, such as fire, drought, introduced species, insect, pathogen, hurricanes, wind storms and ice (WRI2008b). Because forests are mostly susceptible to climate change, due to the long life-span of trees which does not let for rapid adaptation to environmental change (Shankar. P, 2010).

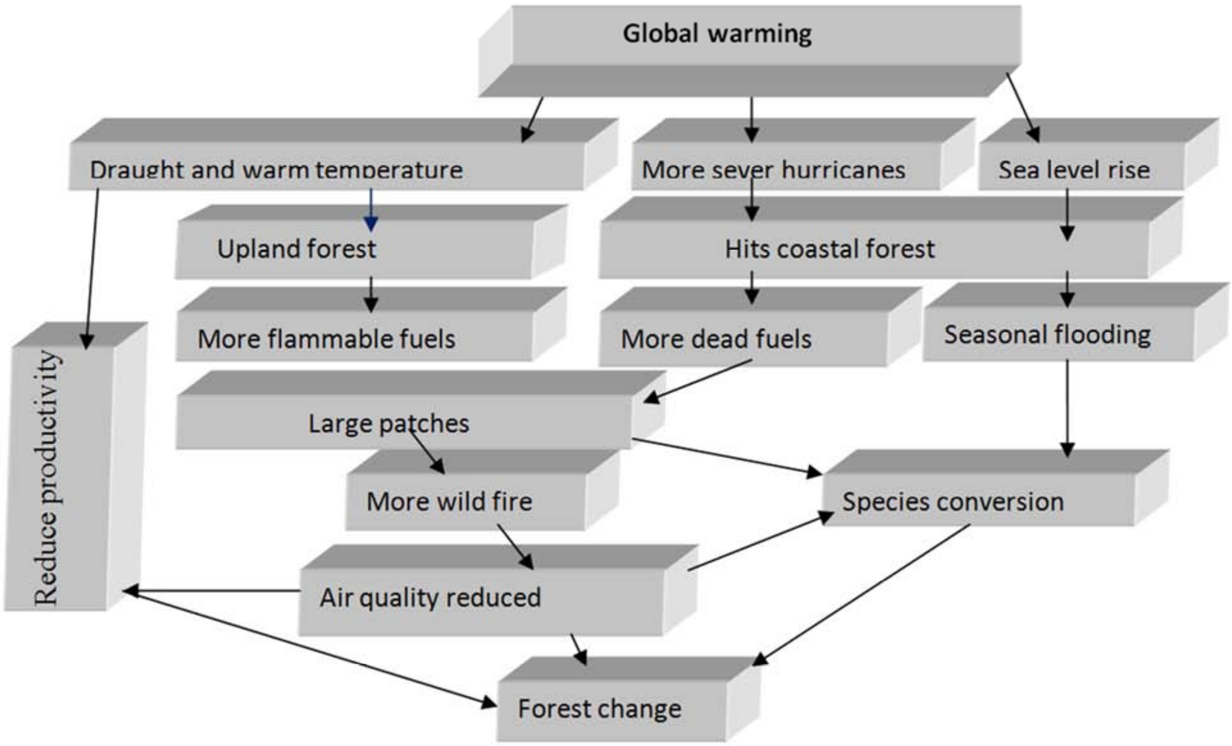
***Table 2.*** *Climate facto rand its level of effect.*

| Climate factor | Cell level | Organism level | Species level | Ecosystem level |
|---|---|---|---|---|
| $CO_2$ Increment | Increase photosynthetic | Growth rate increase | Seed mortality decrease | Biomass production increase |
| | Stomata conductance reduction | Water use efficiency increase | Recruitment increased | Change in Species competitiveness |
| | | Increase Seed production | Change in individual density | Change in Species composition |
| Temperature increment | Increase or decrease photosynthesis | +ve/-ve change in the primary production. | Change on regeneration rate | Change in Species competitiveness |
| | Increase Photosynthetic period | Seed production change | Increase tree mortality | Change in Species composition |
| | Transpiration increase | | -Negative effect for temperature change sensitive species | Increase soil mineralization |
| Rain fall reduction | Decrease growth rate | Rate of seed mortality increase | Increase mortality of matured individuals | Change in Species competitiveness/composition |

Source:-, Robledo,, C. and Forner, C. (2005)

The above table1illustrates the climate factors such as $CO_2$, temperature and rain fall and the change observed in the plants at the level of cell, organism, species and ecosystem. Here in the table the increment of $CO_2$ led to increment of photosynthesis, rate of plant growth, biomass productivity and reduction of seed mortality. But the $CO_2$ that increased photosynthesis exacerbates the water use efficiency of the plants which lead to the change of plant density and compositions. Also it not means that always high $CO_2$ is necessary for the plant growth or productivity. Carbon dioxide enhanced the plants need for extra water both to maintain their larger growth as well as to compensate for greater moisture evaporation as the heat increases, especially in the area such as tropical region where is shortage of water plant will face drought and desertification. The other adverse effect of high $CO_2$ and warming temperatures is it increases the vulnerability of plants to insects and reduces the capacity of Plant defense mechanism which affects plant productivity. Also too high concentration of $CO_2$ causes are reduction of photosynthesis in certain plants i.e. Soybeans (Villabolo, 2011).

Whereas the increment of temperature causes for the change of regenerations, change of plant species, and increment of plant mortality. One of the more susceptible phonological stages to high temperatures is the pollination stage, i.e. maize pollen productivity decreases with exposure to temperatures above 35°C (Jerry. L. Hand John, H. P, 2015). Similarly the variation of train fall affect plants growth rate, maturity, and competitiveness, compositions and seed mortality. In general the present environmental situation heavily influenced by climate change could lead to a massive destruction of forests and the extinction of countless species.




Source US States Department of Agriculture, (2012)

***Figure 2.*** *Global warming and its effect on forest.*

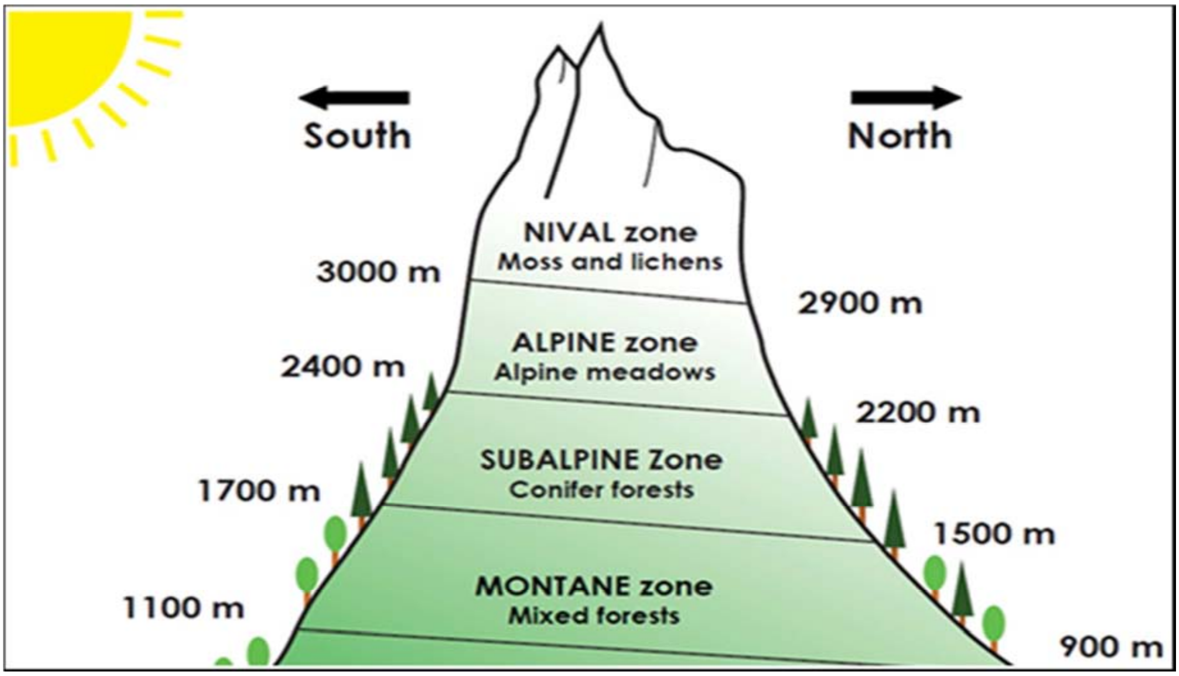
Also figure 2 shows increase of global warming/climate change cause for warmer temperature; sever hurricane, sea level rise, flooding, wild fire, species conversion and change of forest. According to the table the global warming that caused by climate change leading to the outbreak of natural fire, large, reduction of forest productivity, barren land, change of air quality and forest compositions. Global warming is likely to increase the extent of forest fires, a recent study of various forest conditions in Russia suggests that at 2°C rise in temperature could increase the area affected by forest fires by a factor of between 1.5 to 2 (Mollicone *et al.* 2006). According to Nepstad *et al*, (2008) an increasing temperatures, longer dry seasons and increasing $CO_2$ concentrations in the atmosphere in the long term are expected to reduce the capacity of forests to store and sequester carbon, and possibly alter forests from carbon sinks to carbon sources. In general climate change significantly determines, distribution, composition, structure, vegetation patterns and ecology either directly or indirectly (Fischlin *et al*., 2009 and Burton *et al*., 2010). The direct physical effects on forests caused by climate change are droughts, storms, fires and insect infestations, could also hurt the productivity of managed forests (WRI, 2008).

Climate change and alteration of plants boundary and composition

According to UNEP (2002), Lucier *et al*., (2009) and Fishlin *et al*., (2009) the rising temperatures or rain fall shortage enforces many plants and living organisms to move to higher altitude/pole wards. Other researcher explain that not all plant species shift their area because some species will be able to adapt better to changing conditions than others, resulting in changes of composition of forest types, rather than geographic shifts of forest types (Breshears *et al*., 2008 and Lucier *et al*., 2009).

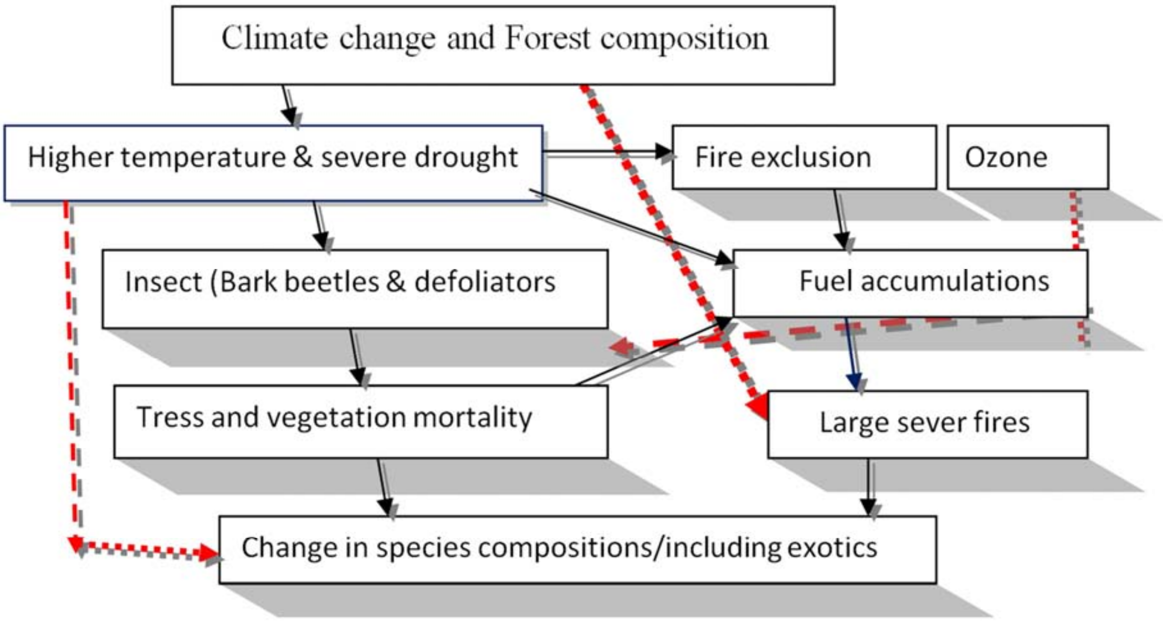
The figure 3 shows the change of climate element like precipitation and temperatures causes for the shift of boundary for the vegetation to the higher altitude and disturbance of plant composition and species. Especially most living organisms which found in the mountain area are moving to the tip of the mountain to adopt the climate change, this condition is affecting the compositions and density of plants.

In the last few decades scientists have observed that rising temperatures force many living organisms to migrate to cooler areas, while new organisms arrive. Such movements involve most species, including plants, some species will seek higher altitudes, and others will move further pole wards. The past changes have estimated natural rates of migrations of trees ranging from 40 to 500 m per year (Davis, 1986). In Britain some reports indicate that the species, such as white spruce, much faster dispersal rates of up to 1–2 km yr-1 (Ritchie and MacDonald, 1986). Other studies have noted that a number of birds, tree, scrub and herb species have migrated by an average of six kilometers every ten years (Parmesan 2003).




Sources: Benitson, (1994) and Watson,*et,al, (*1995) UNEP, (2008).

***Figure 3.*** *Impact of climate change on mountain vegetation zones.*




Source Mc Kenzie *etal*,2007 cited in USDA,(2010)

***Figure 4.*** *The effect of climate change on forest composition.*

Also Fig 4 illustrates the effects of climate change on forest composition. Fires and drought induced mortality contribute to plant species and composition changes and exotic invasions. Not only these many species and ecosystems may not be able to adapt as the effects of global warming and associated disturbances, which are floods, drought, wildfire and insect outbreaks, are compounded by other stresses such as land use change, overexploitation of resources, pollution and fragmentation of natural systems. If the global average temperature increases more than 1.5-2.5°C, it is believed likely that approximately 20-30 percent of plant and animal species assessed so far will be at an increased risk of extinction (IPCC, 2007).

In Africa the natural attempt of plant to migrate to the higher altitude has no security for the plants, because the plant species found at the border of the continent and at the tip of the Mountain will have no alternative for migration (Desanker 2003). Therefore, Africa will face comparatively higher risks from climatic change due to lack of migration paths for mountain species (Desanker, *et al,* 2001). In general climate change is held to increase biodiversity risks in Africa especially in Ethiopia (Fischlin, *et al,* 2007).

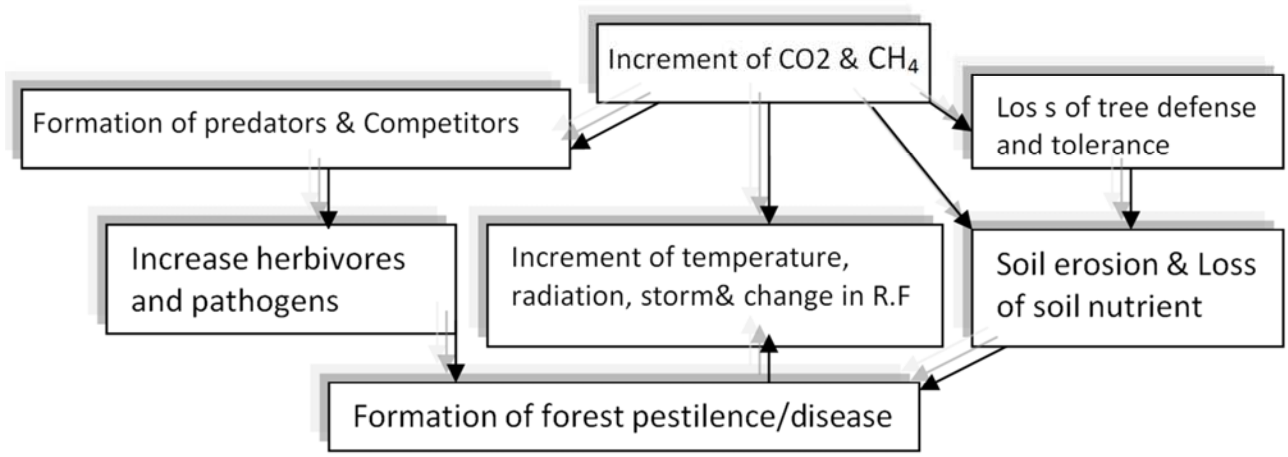
Climate change and forest productivity

As stated above to some extent an increase in atmospheric $CO_2$ may speed up photosynthesis and provide $CO_2$ fertilization to the temperate forest areas (WRI 2008). Doubling of Carbon dioxide lead to increase in plant growth by10-25 percent (Nowak *et al* 2004 and Norbay, *et al,* 2005). Climate variability may also cause plant productivity to drop because warmer temperatures lead to increased water losses from evaporation and evapo-transpiration and can result in reduced water availability for the plants (Mortsch, 2006). During the 2003 heat wave in Europe, there was a 30 per cent fall in plant productivity in continental Europe as a whole.

In contrasts other researches indicate that forests in temperate regions have seen a 15 % productivity gain since the beginning of the 20$^{th}$ century (Medlyn, *et al,* 2000). Whereas the production increases in tropical forests will be temporal and will decrease once $CO_2$ saturation levels have been reached. Especially the growth of old forest will be reduced because of high mortality caused by low soil moisture and high food competition (Feeley, *et al*, 2007). The other productive impact of climate change were shifting time for flowering and bud break, altering hydrological process, such as precipitation, evaporation, run off, infiltration, soil moisture and other which are necessary for the growth and production of plant (Reinder., B.2010).

Climate change- forest health and strength

A deeper understanding of the complex relationships between a changing climate, forests and forest pests is vital to enable those in forest health protection and management to expect and prepare for changes in pest behaviors, outbreaks and invasions (Beverly A.M and Gallian B.A 2008). For many forest types, forest health questions are of great fear with pest and disease outbreaks as major sources of natural disturbance. Increasing $CO_2$ and temperatures initiate the formation and expansion of insect/pests populations to the higher elevation or latitude to modify tree physiology and tree defense mechanisms, especially the host trees are more susceptible to pathogen infection (Herrington,*et al* 2001 and Lucier,*et al*., 2009).




Source USDA, (2012)

***Figure 5.*** *The effect of climate change on insects and pathogens.*

The figure 5 depicts the rise of greenhouse gases which are Carbon dioxide and Methane causes for the increment of element of climate such as temperature, irradiance, and storm and in some area precipitation. The above green house gas also affect both the soil nutrient as well as the tree defense and tolerance capacity. The other problem of the increment of $CO_2$ and CH4 is the effect on predators, competitors, herbivores, pathogens predators which causes for the formation of forest pestilence/disease. In general the climate change causes for existence of general pathways by which atmospheric changes associated with increasing greenhouse gases can influence forest disturbance from insects and pathogens. Global climatic changes are expected to impact insect-plant interactions in several ways. Insects play important roles in ecosystem services, acting as herbivores, pollinators, predators and parasitism, and changes in their abundance and diversity have the potential to alter the services they provide (Hillstrom & Lindroth 2008).

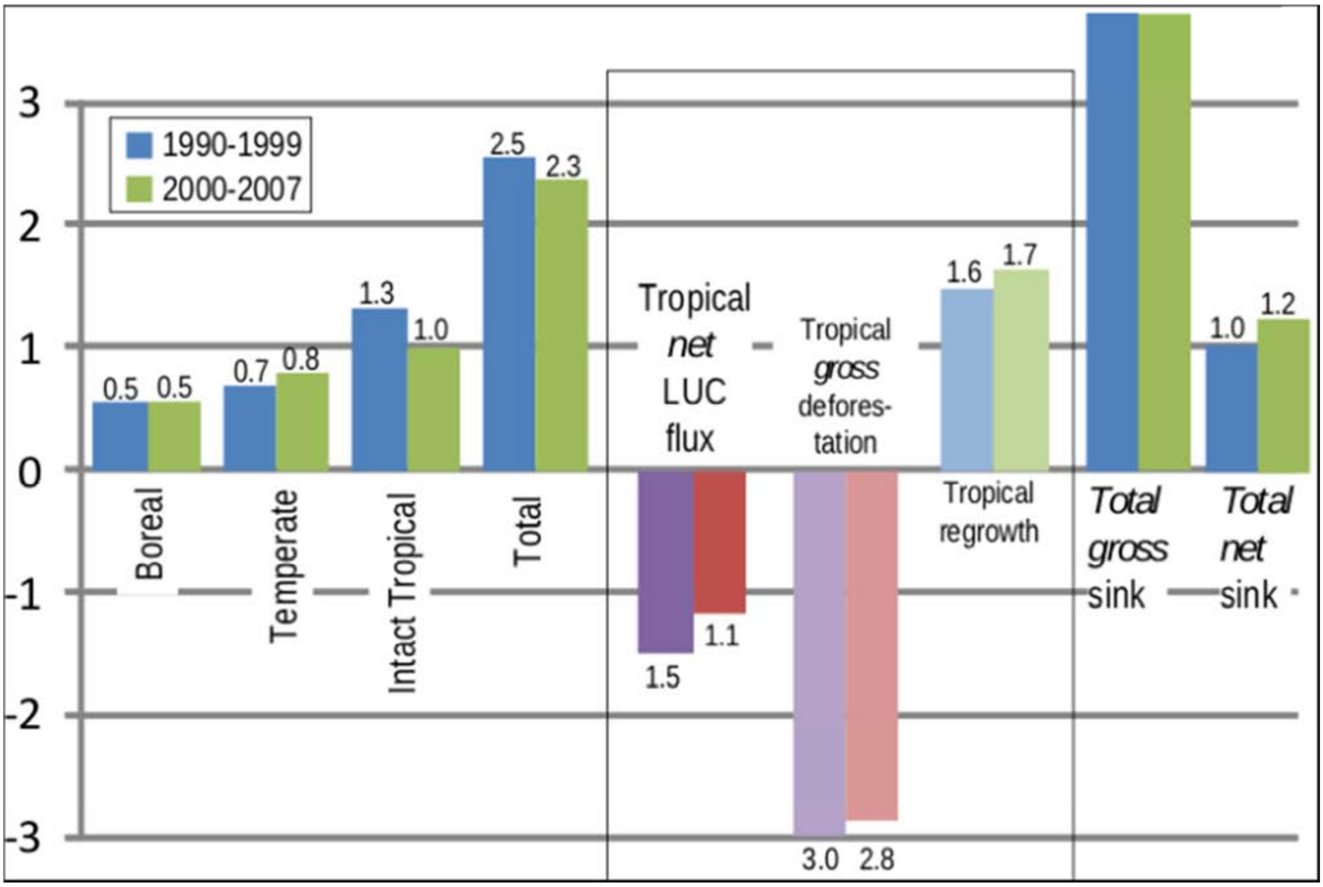
Forests are subjected to a variety of disturbances that are themselves strongly influenced by climate. Disturbances such as fire, drought, landslides, species invasions, insect and disease outbreaks, storms (hurricanes, windstorms and ice storms) influence the composition, structure and function of forests.. A changing climate will also alter the disturbance dynamics of native forest insect pests and pathogens, as well as facilitating the establishment and spread of non indigenous species. For example, pine forests in Central America became infected with bark beetles, which causes for extensive tree mortality thereby increasing fuel loads in the region's forests which severely increased the risk of wildfires The environmental conditions required by some species such as those in alpine regions may disappear altogether and the result lead to the change of structure and function of ecosystem and this change is likely causes to a rapid increase the outbreak of insect and extinction of species (Dale et al. 2001).

*The role of Forest in Climate Change*

The interaction between forests and climate change is significant and often little understood, climate change is having and will continue to have higher impact on the forests through increased drought, heat waves, and wildfires. On the contrary forest ecosystems play decisive roles in climate regulation; it has greatest gifts in terms of their ability to trap polluting carbon from the atmosphere. Forest store about 80% of all aboveground and 40% of all belowground terrestrial organic carbon (Melillo *et al*., 1990). It also important to protect from natural disasters, for example, during the Indian Ocean tsunami in 2004, vegetation-covered coastal sand dunes at Yala and Bundala National Parks in Sri Lanka completely stopped the waves and protected the land behind them (Caldecott and Wickremasinghe, 2005).

Trees help to protect soil and regulate water on farms. Crops grown in agro forestry systems are often more resilient to drought, excess rain and changes in temperatures. Woodland has a huge role to play in regulating water supplies – decreasing storm runoff and reducing the pollutants in rainfall before it reaches local water sources. It also acts as a sponge, soaking up rainfall and releasing it at times of drought regulating water flow. Recent research has linked deforestation with changes in regional rainfall patterns (Tierney Smith, 2012).

Forests accounts for almost half the terrestrial carbon pool and act both as sources and sinks of greenhouse gases through which they exert significant influence on the earth's climate (Fischlin, *et al,* 2007). They are also one of the world's largest carbon sinks, absorbing 2.4 billion tonnes of carbon dioxide each year and storing billions more. According to FAO (2006), Africa forest is estimated to contain over 100 Gt of carbon (including in soils).




Sourcepan, *etal* (2011)

***Figure 6.*** *Global forest carbon budget (Pg Cy²).*

Figure 6 reveal that the role of different type of forest in the carbon stocks. According to the figure Tropical forest are major forest type which are plying significant role in the carbon sequestration, the second is any king of forest which are contributing for the climate regulations, the third important forest type which are plying viral role in the climate regulation through carbon sequestration is temperate forest which followed by non forest type of vegetation and boreal forest. The largest share of carbon stock potential of tropical forests is because it represent about 40% of the world's forested area, containing about 60% of the global forest biomass and one-quarter of total soil carbon (210 Gt C in biomass and 220 Gt C in soils and litter) (FAO, 1982; Longman and Jenik, 1987). In general the role of forest in the climate regulation is vary from other regions to region or from one ecosystem to the other.

***Table 3.*** *Carbon density and stock of vegetation and soil in different ecosystem.*

| Ecosystem | Country/region | Vegetation carbon density(tons /ha) | Soil carbon density tons /ha | Vegetation carbon stock (Gt) | Soil carbon stock (Gt) | Total Carbon stock (Gt) |
|---|---|---|---|---|---|---|
| Boral | Russia | 83 | 281 | 74 | 249 | 323 |
| | Canada | 28 | 484 | 12 | 211 | 223 |
| | Alaska | 39 | 212 | 2 | 11 | 13 |
| Temperate | United State | 62 | 108 | 15 | 26 | 41 |
| | Europe | 32 | 90 | 9 | 25 | 34 |
| | China | 114 | 136 | 17 | 16 | 33 |
| | Australia | 45 | 83 | 18 | 33 | 51 |
| Tropical | Asia | 132-174 | 139 | 41-54 | 43 | 84-97 |
| | Africa | 99 | 120 | 52 | 63 | 115 |
| | America | 130 | 120 | 119 | 110 | 229 |

Source: Dixon*et et al,* (1994).

In the above table there are, however, considerable variations among ecosystem and forest types. In tropical forests the carbon is fairly equally distributed between vegetation and soil, whereas between 80 and 90 percent of the carbon in boreal ecosystems is stored in the form of soil organic matter. The primary reason for this difference is the influence of temperature on the relative rates of production and decay of organic matter. At high latitudes (i.e. in cooler climates), soil organic matter accumulates because it is produced faster than it can be decomposed. At low latitudes, however, warmer temperatures encourage the rapid decomposition of soil organic matter and subsequent recycling of nutrients.

But deforestation is responsible for approximately 20% of total human-caused carbon dioxide emissions each year (FAO, 2005, Barker, et al, 2007and IPPC 2007). Protecting tropical forests alone contribute to store about 25% of the carbon in the terrestrial biosphere, because it cover about 15% of the world's land surface (CIFOR, 2009). The use of forest in climate change is multidimensional; besides the direct sinks and storage of carbon, forests have been playing important role in the climate change by water regulation and soil conservation which are a huge warehouse of carbon.

### *2.2. The Climate and Agriculture Interface*

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Climate affects agriculture in a number of ways, because agriculture is highly exposed to climate change in relation with the farming activities that directly depend on climatic conditions. Including through changes in average temperatures, rainfall, and climate extremes (e.g., heat waves); changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations; changes in the nutritional quality of some foods; and changes in level. But climate change impacts can be roughly divided into two groups, biophysical impacts and socio-economic impacts. Scientific evidence shows the effect of extreme climate events on agriculture natural systems and functioning via flooding and drought (WBISPP, 2005, Olesen 2006, Africa Partnership Forum, 2007, World Bank 2007 and Alvaro. C,*et al*, 2013).

Climate change is already affecting agriculture, with effects unevenly distributed across the world. Future climate change will likely negatively affect crop production in low latitude countries, while effects in northern latitudes may be positive or negative. Climate change will probably increase the risk of food insecurity for some vulnerable groups, such as the poor.

***Table 4.*** *Total vegetative biomass and grain weight for maize exposed to extreme temperature and oil water differences in controlled chambers/ container.*

| Chamber/Container | Soil water treatment | Total vegetation matter(gm-$^2$) | Grain yield (gm-$^2$) |
|---|---|---|---|
| Normal temperature | Normal precipitation | 3739.5 | 1572.5 |
| Normal temperature | 0.75 Normal precipitation | 3000.7 | 707.0 |
| Normal temperature | 1.25 Normal precipitation | 2708.1 | 944.1 |
| Extreme temperature | Normal precipitation | 1744.8 | 823.4 |
| Extreme temperature | 0.75 Normal precipitation | 1282.6 | 805.6 |
| Extreme temperature | 1.25 Normal precipitation | 1081.8 | 353.9 |

Source Jerry. Land John, H, (2015)

The table 4 shows the maize with extreme temperatures imposed at different stages, there was no difference in phonological development and leaf area was the same among water level treatments and chambers where extreme events were imposed. However, there was a significant difference in the total vegetative dry weights between extreme temperature events. The normal precipitation soil water treatment produced the highest biomass and grain yield in both temperature treatments and either deficit water or excess soil water. In the chamber with exposure to extreme temperature events there was a significant reduction in biomass and grain yield for any comparable soil water regime. In the above table largest effect of the temperature extremes was found under the conditions of excess water in which biomass and yield were reduced by nearly two-thirds. There was no effect of temperature treatment on phonological development and all plants were at the same stage of development through the pollination stage. Increased night temperatures significantly increased the rate of deterioration of maturity productivity.

In general the effects of increased temperature exhibit a larger impact on grain yield than on vegetative growth because of the increased minimum temperatures. Temperature effects interact with the soil water status which would suggest that variation in precipitation coupled with warm temperatures would increase the negative effects on grain production.

In developing countries, 11 % of arable land could be affected by climate change, including a reduction of cereal production in up to 65 countries, and about 16 % of agricultural GDP (FAO 2005). Rising temperatures would be expected to increase soil respiration rates and lead to a decline in soil carbon content (Shankar. P, 2010). The impact of climate change is not uniform because it varies among regions or continents. This means in some area it has positive role or lesser impact but in the other area it has higher negative impacts.

For instance, in United Kingdom the yields of wheat declined by 5–8% per 1 °C rise in mean seasonal temperature (Mitchell. R, et al, 1993). Especially the African agriculture is highly vulnerable to the negative impact of climate change than other developed countries, because of its overdependence on rain-fed agriculture (CEEPA, 2006).

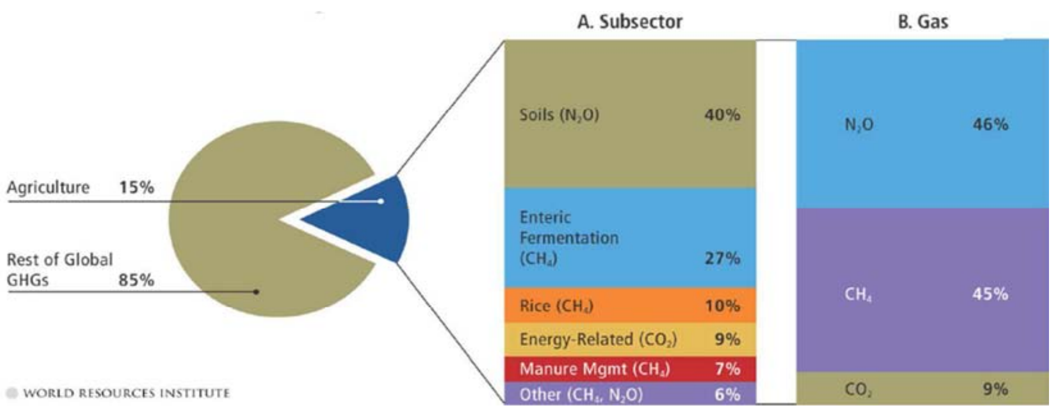
***Table 5.*** *Impact of climate change on forest, agriculture and ecosystem.*

| Phenomenon & trend in weather & climate event | Possible impacts on agriculture, forestry, water & ecosystem |
|---|---|
| Frequent warm and cold day and night over most land | In colder environment yield Increase but in the warmer environment yield decrease & increase insect pest |
| Warm Spells and heat waves increasing infrequency over most land areas | In warmer region yield reduced due to heat stress, and wild fire threat increased |
| Frequent and Heavy precipitation over most area | Soil erosion, land degradation and loss of soil fertility |
| Increasing drought affected area | Lower yields, increase livestock death & risk of wild fire |
| Increases intense tropical cyclone activities | Damage to crops, uprooting of trees & damage coral reefs |
| Increases extreme sea level rise | Salinization of fresh water, loss of arable land, out migration. |

Source IPCC, (2007)

The table 5 indicate that the positive and negative impact of weather and climate on forest, agriculture, fisheries and ecosystem. Here colder environment increase yield but in the warmer area there is a possibility of decreasing yield due to heat stress and increase of insect pest and danger of fire. The area which has heavy precipitation causes for soil erosion, damage crops and lower yields.

In other hand agriculture plays both positive and negative role to the climate. The positive roles of agriculture to the climate take place either by storing carbon in the soil or enabling the availability of water and plant, which have great role in sequestering and storing carbon. I.e. Agro forestry (intercropping trees with row crops), perennial crops, minimal tillage, rotational grazing systems and adding biochar (partly burned biomass) serve to store $CO_2$ and regulate climate (Scher and Sthapit 2009). The negative roles of agriculture to the climate are the contribution to the emissions of greenhouse gases by the conversion of forests into agricultural land. In 2010, world total annual GHG emissions from net forest to agricultural land conversion were 3,738 Mt $CO_2$ e (FAO, 2014).




Source: World Resource Institute, 2011cited in Global Development and Environment Institute(2011).

***Figure 7.*** *Global Green house Gas Emissions from agriculture.*

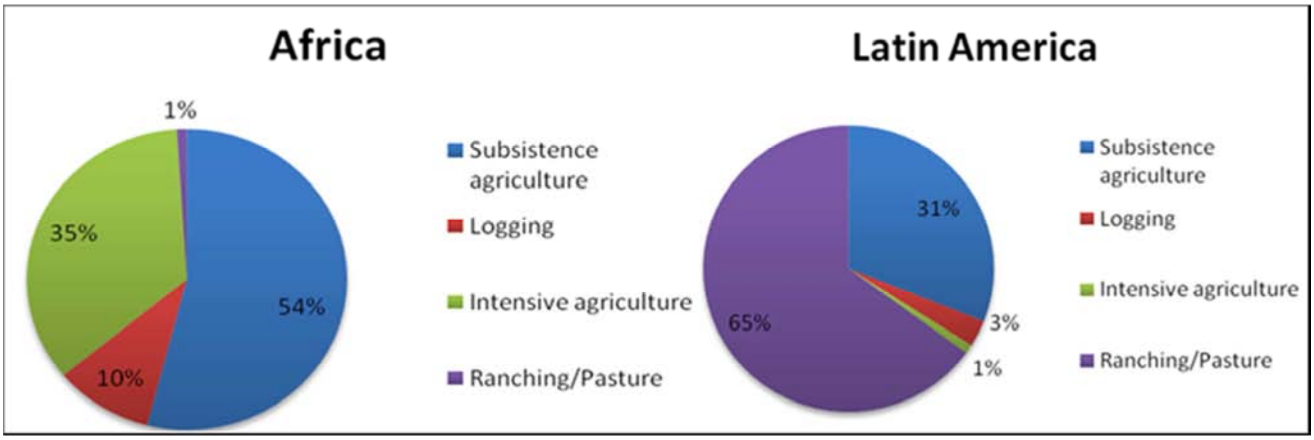



***Figure 8.*** *Factors of deforestation in Africa and Latin America.*

Source: Jonathan. M. *et al* (2011).
Source: World Resource Institute, 2011 cited in Global Development and Environment Institute (2011).

The figure 7 shows the share of agriculture to the climate change via releasing different gases $N_2O$ *(*Nitrous oxide*),* CH4 (methane) and $CO_2$ (Carbon Dioxide) that increase the global warming. A large portion of methane emission, a particularly potent source of global warming, comes from agriculture. In short agriculture currently accounts for about 13-15% of greenhouse gas emissions. Especially developing countries have the largest share of global agricultural greenhouse gas emissions and the largest expected rates of increase in emissions (WRI, 2011).

According to (FAO, 2015) in addition of land farming the animal agriculture sector is responsible for approximately 18%, or nearly one-fifth, of human-induced greenhouse gas (GHG) emissions or it emit 2.4 billion tonnes of $CO_2$ into the atmosphere each year. Expanding farm animal production plays a major role in deforestation, turning wooded areas into grazing land and cropland for the production of feed, which are contributing for the emission of carbon. Animal agriculture‘s role in deforestation has been especially devastating in South America, where expansion of pasture and arable land at the expense of forests has been the most prevalent.

In 2005 the FAO found that a cattle ranching is one of the main causes of forest destruction and contributor of climate change in Latin America. According to FAO prediction that by 2010, more than 1.2 million hectares of forest will be lost in Central America, while 18 million hectares of South American forest will disappear, in large part, because of clearing land for grazing cattle, i.e. Soybean and corn production for animal feed is the leading factors for rapid clearance of tropical forests especially in Brazil. In 2011 total annual emissions from agriculture were, 5,335 Mt $CO_2$ the highest level in history, and almost 9% higher than the decadal average of 2001-2010 (FAO 2014). Globally, it is estimated that about half of agricultural lands contain only 10 percent tree cover (Buttoud, 2013).

### *2.3. Forest and Agriculture Interface*

There is a cause-consequence relationship between forest and agriculture. Forest areas help to conserve ecosystems that provide habitat, shelter, food, raw materials, genetic materials, barrier against disasters, a stable source of resources and many other ecosystem goods and services and thus can have an important role in helping species, people and countries adapt to climate change. But the most recent estimates of the rates of deforestation indicate that 75% of forest losses are attributable to different type of agricultural expansion, which causes for the increment of $CO_2$, severe drought and flood (McKee, 2007, Mulugeta. L, and Zenebe. M, 2011).

The figure 8 above shows about 90% of the cause of deforestation in Africa is related with subsistence and intensive type of agriculture. Subsistence agriculture is self-sufficiency farming in which the farmers focus on growing enough food to feed themselves and their families i.e. cultivation, primitive agriculture ('slash and burn), nomadic herding, and intensive subsistence farming. But pastoral/ranching farming and subsistence agriculture take more than 95% drivers of deforestation in Latin America because the livestock production or grazing land is hampering natural regeneration of plant. In Africa in the period from 2000–05 an average of 4 million hectares of forest land were lost per year, mainly due to conversion to small-scale permanent agriculture and resulting in the release of almost 500 teragrams of carbon to atmosphere (FAO 2009). Historically, forests have been very important for the livelihoods of the people of Ethiopia. The Ethiopian people used trees for lumber for construction, and to fuel their cooking fires. They also made traditional medicines from trees and other forest plants. Forests were also important in Ethiopian religious beliefs; the people believed in holy spirits in the forest that they treat in the same way as human beings. Similar to the African case small scale agriculture and the need for fuel wood are the major factor for the loss of forest, especially in the high wood land area of Ethiopia.

***Table 6.*** *Deforestation rate in Ethiopia.*

| Type of land cover | Areas in hectares | |
|---|---|---|
| | 2000 | 2005 |
| Forest land | 3,651,935 | 3,337,988 |
| High wood land areas | 10,049,079 | 9,632,616 |
| Plantations land | 509,422 | 509,422 |
| Low wood land & shrub land | 46,297,530 | 46,297,530 |
| Other land | 53,169,093 | 53,899,503 |
| Inland water | 828,277 | 828,277 |
| Total | 114,505,336 | 114,505,336 |

Source: McKee (2007)

Deforestation is the process of removing the forest ecosystem by cutting the trees and changing the shape of the land to suit different uses. Table 6 above shows the rate of deforestation in different land cover, in the five years the rate of deforestation is higher in the forest land and high wood land areas, which may be related with the high demand for fuel wood and fertile soil of the area, but the change in the rest area except other land use type are insignificant. The main causes of deforestation in Ethiopia are shifting agriculture, livestock production and fuel in drier areas. Compared to other East African countries Ethiopia's deforestation rate is about average, however, the deforestation rates in East Africa are second highest of the continent (FAO, 2007). According to FAO (2007) estimation deforestation rate of Ethiopia is 1,410 km² per year.

Globally, forest and soil contain some 1.2 trillion tonnes of carbon. According to WBISPP's (2005) carbon stock in woody biomass of Ethiopia only estimated about 2,683,127 tons of carbon. But conversion of forest to agricultural land causes for 55 Mt $CO_2$ to the atmosphere in 2010.

At 2% deforestation for crop land nearly 110 million tons of $CO_2$ is releasing in every year to the atmosphere. Because forests sequester about 20 times more greenhouse gases than crop lands (Lewi s Thomas, 2010). The problem of deforestation is not only left on climate change, it is also affecting the social and health condition of the people, i.e. large number of traditional medicinal plants are disappearing with deforestation.

Whereas afforestation and re-afforestation have significant impact on agricultural productivity via protecting soil erosion, control flooding and regulate the surface and ground water, which has positive role for the increment of vegetation cover. Forest also contributes for livestock production with providing fodder particularly in the winter season (Zenebe, *et al,* 2015). Whereas deforestation negatively affect agriculture by aggravating soil erosion, flooding, deterioration of the water quality and quantity, further drought, reduction of agricultural productivity, high carbon emission, and aggravate the climate change(Mekonnen and Köhlin 2008).

### *2.4. Climate-Forest and Agriculture Interface*

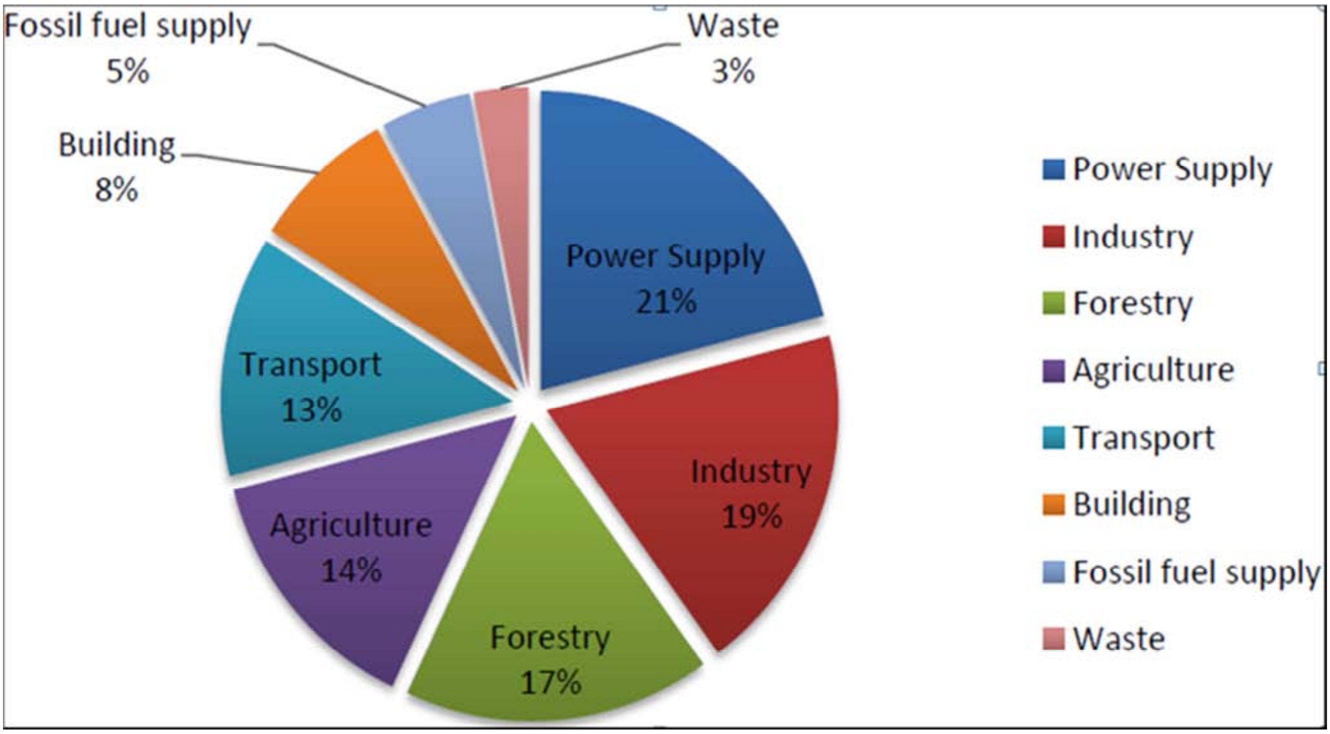
The world's climate system, forest ecosystems and agricultural activities are highly integrated and as a result changes in either one of these systems visibly trigger the change in the other. This linkage is posing challenges for the management of development, adaptation and mitigation policies. As stated above climate change which is extreme drought and flood are negatively affecting the production and ecosystem services of forest and agriculture. For instance climate change causes for the loss of vegetation, then the area without vegetation expose the soil for the agent of erosion; the areas which have lost its fertile soil can't provide any agricultural productivity as well as vegetation growth.

Whereas, properly managed forest and agricultural sector has significant role to have good climate or environment and the vice versa. In other word successful afforestation and reforestation programmes positively affect the productivity of agriculture by protecting soil erosion, soil fertility, soil moisture, and flooding. In result fertile soil with good soil moisture is suitable for both carbon storage as well as the growth of crops and plants, which use to sequester or store carbon and regulate the climate. If this scenario is not balanced both agriculture and forestry can be a major source of GHG emission rather than carbon sink or pool.

***Table 7.*** *Carbon Stock in Vegetation and Top1Meter of Soil of World Biomes.*

| Biomes | Area/million km | Carbon stocks (Gt C) and proportion in the ecosystem | | | | |
|---|---|---|---|---|---|---|
| | | Vegetation | Proportion | Soil | Proportion | Total |
| Tropical forest | 17.6 | 212 | 49.5 | 216 | 50.5 | 428 |
| Temperate forest | 10.4 | 59 | 37.1 | 100 | 62.9 | 159 |
| Boreal forest | 13.7 | 88 | 15.7 | 471 | 84.3 | 559 |
| Tropical savannas | 22.5 | 66 | 20.0 | 264 | 80.0 | 330 |
| Temperate grassland | 12.5 | 9 | 3.0 | 295 | 97.0 | 304 |
| Desert | 45.5 | 8 | 4.0 | 191 | 96.0 | 199 |
| Tundra | 9.5 | 6 | 4.7 | 121 | 95.3 | 127 |
| Wetland | 3.5 | 15 | 6.3 | 225 | 93.8 | 240 |
| Cropland | 16 | 3 | 2.3 | 128 | 97.7 | 131 |
| Total | 151.2 | 466 | - | 2,011 | - | 2,477 |
| Proportion | - | 19 | - | 81 | - | 100 |

Source: Watson *et al.* (2000) and Ravind, Rand Ostwald (2008) cited in WB (2012).




Source figure adapted from UNFCCC (2007)

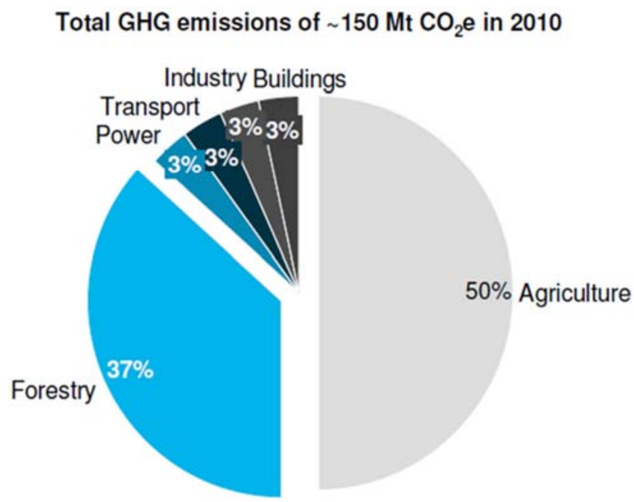
***Figure 9.*** *Forestry and agriculture as percentage of GHG emission.*

Among the biomes, vegetation carbon stocks range from 3 Gt for croplands to 212 Gt for tropical forests, while soil carbon stocks range from 100 Gt for temperate forests to 47 Gt for boreal forests. Soils generally hold more carbon than vegetation across biomes and account for 81 percent of terrestrial carbon stock at the global level (WB, 2015).

When forests are replaced by pasture or crops land, a large amount of $CO_2$ enters to the atmosphere. Because a lot of carbon is stored in the tree stems, but in addition the remaining tree roots die and are decomposed to $CO_2$ by soil organisms. Since crops and grasses do not have stems, and have less root biomass than trees (Almut. A, 2015). According to UNFCC,(2007), WRI, (2014) and FAO, (2014) in the global level forest and agriculture sector accounts about 31% of GHG emission and in Africa the two sectors takes the more than 80 % of the GHGe.

Figure 9 reveals the high contribution of agriculture and forestry to the Emissions of $CO_2$ and the climate change next from energy/industrial sources. However this figure shows how much it is higher the global carbon contribution of deforestation and agriculture, but their contribution in most developing countries take the first rank in contributing of GHG except in China, India, Brazil, and South Africa. In Africa in 1990deforestationcontributed an estimated at 5.8 Gt $CO_2$/yr and 2011 the total annual emissions from agriculture were 5,335 Mt $CO_2$ eq, the highest level in history, and almost 9% higher than the decadal average 2001-2010. In 2010 Agriculture, Forestry, and Other Land Use accounts 24% of global greenhouse gas emissions (The International Bank, 1999).

In most developing countries, agriculture and forestry represent an essential part of the economy, at the same time; it represents an important part of green house gases emissions. In Ethiopia more than 80% of GHGe come from forestry and agriculture (EPA, 2011 and UNDP, 2011).




Source EPA, (2011)

***Figure 10.*** *GHGe of Ethiopia in 2010.*

Most of the emissions from deforestation are in the form of $CO_2$, while emissions from agriculture, primarily methane ($CH_4$) and nitrous oxide ($NO_2$). Figures 11 confirm the use of reducing the emissions from deforestation and agriculture that could be a significant part of global efforts to combat the causes of GHGe and climate change, mainly in developing countries. The possibility of mitigating climate change by reducing carbon emissions caused by deforestation and forest degradation, and by increasing carbon uptake through a forestation, sustainable forest and soil management via application of environmental protection policies, has become a significant feature of global discussions on responses to climate change.

### *2.5. The role of Climate – Forest – Agriculture Interface on Green Economy of Ethiopia*

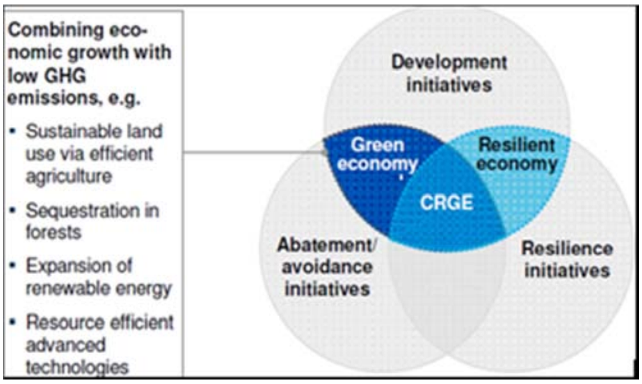
Climate risk comes from complex interactions among climate, environment, social and economic systems, and they represent combinations of the possibility of climate events and their consequences for socio-economic and the environment (Fuhrer. J *et al*, 2006). As stated above the interaction of climate-forest and agriculture is very strong, which means the disturbance of any of the three causes to the disturbance of the other. Due to high deforestation and failure of agriculture Ethiopia is experiencing the effects of climate change which are creating various kinds of threats that would hold back economic progress (UNDP, 2011).

It is encouraging that Ethiopia is one of the countries found in leading stage with fast economic growth from the sub-Saharan countries with agricultural products. But there is threat to the sustainability of this economic growth due to the challenge of climate change. Because economic growth always has a price tag in terms of ecological and environmental degradation since economy is a subsystem of the limited biosphere that supports it.

The report from OXFAM, (2010) shows that, Ethiopia has always suffered from great climatic variability, that causes for the outbreak of drought, famine, flooding, diseases, land degradation; damage to communication, declining of forest product and productivity, poor social infrastructure, and biodiversity loss (Zenebe ,G, et al 2012 and Adugnaw. B, 2014).

Ethiopian government stated in the CRGE policy that though climate change has such disadvantage for a while it will have opportunity to use the country's huge potential in renewable energy and a necessity so as to control agro-ecological degradation. According to the government the more rain of a changed climate facilitate the growth of crops, increase water source for hydroelectric power and pave the way to acquire financial support from industrialized countries for low carbon and climate resilient development.

Over the past two decades the FDRE has formulated various development strategies and policies with the aim of solving the socio-economic and environmental problem and to reduce the negative impact of climate change. Among different programs and policies the most recent and timely are the 2011 to2015 growth and transformation plan (GTP) and the 2011 CRGE strategies. The goal of GTP is to realize a double digit growth that will lift up the country to middle income country level by 2025 via climate-neutral, improved agricultural productivity, strengthening the industrial base, and promoting export growth. To achieve the goal of GTP setting strategy and designing policy such as CRGE is important step of the government.




Source:-FDRE CRGES (2011).

***Figure 11.*** *CRGE strategy of Ethiopia.*

The CRGE policy of Ethiopia has four pillars but the focus of this paper is only the first two strategies, because these sectors account more than 85% of GHG emissions in the country. The first is agriculture, improving crop and livestock production practices for higher food security and farmer income while reducing emissions. And the second is protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks (Yitebitu. M, *et al,* 2010).

Pressure from agriculture on forests can be reduced by application or implementation of climate resilient green economy and agriculture intensification on existing land or unlocking degraded land (CRGES, 2011).

It is obvious that building a green economy offers cost-efficient abatement potential while promoting GTP targets. It is not an easy job; it requires the integration of economic development and GHG abatement/avoidance. It is essential to apply the policies and strategies through enhance the adaptive and mitigation capacity and reduce the vulnerability of the country to climate variability (Wondwossen .S, 2011 and Zenebe. G, *et al,* 2012).

According to Lakew, *et al,* (2005) watershed development in Ethiopia started in the 1980's was generally unsuccessful due to lack of community participation, less responsibility of stack holders, and unmanageable planning units. However climate resilient green economy of Ethiopia is one of the models environmental policies which help to sustain the GTP of the country. But the country has several challenges to achieve the green economy policy and sustain the development. Because there is lack of financial source, conflicting investment and settlement policy, lack of good governance, lack of expertise in the coordination and implementation of the policy, high population growth and high demand for limited natural resources, high dependency to the natural resources etc.

## 3. Conclusion and Recommendations

### *3.1. Conclusion*

Though climate change become serious challenge the overall economic development and social wellbeing of the country is in a promising socio-economic track that the international organizations and development partners witnessed. But to adverse the negative impact of climate setting adaptation and mitigation plan such as CRGE is very important. As stated above the strong interfaces among agriculture, forest, and climate are very challenging for Ethiopian effort to build CRGE and to realize the GTP, because the Ethiopian economy is highly dependent of rain fed agriculture which are highly vulnerable to the impact of climate change. So the development effort needs to harmonize the high demand for natural resource and the changing climate. In this regard the government is setting sound policies and strategies to build CRGE but it is not an end by itself, so the policy need to get acceptance by the people, there should be a suitable ground to implement the policy of natural resource conservations, avoid controversial policies, control population pressure to the natural resources and reduce other socio-economic.

### *3.2. Recommendations*

Different researches conducted on climate change in the tropical region specially in the Sahel region shows continuous rise of temperature and reduction of rainfall, which has negative effect on the water resources, hydro electric energy supply and the CRGE policy of Ethiopia, unless different adaptation, mitigation and correction measures are extensively used. These are,

- Financial need to building CRGE which is 150 billion USD for 20 years need to be available from both active involvement of the Ethiopian people and support from developed countries.
- Natural resource conservation activities and controlling population pressure to the natural resource should be extensively practiced.
- Alternative energy source should be available with cheap price.
- The impact of land tenure policy on the CRGE policy should be assessed.
- The government should work hardly on good governance and capacity building.
- Environmental friendly investment and settlement policy should be formulated.
- From 25% to over 30% of disease in sub-Saharan Africa including Ethiopia is associated with environmental/ climate derived factors, such as malaria, Nipha encephalitis and Ebola, therefore further study need to be conducted about the impact of climate on the outbreak of disease and its socio-economic.

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