Ethiopian Academy of Sciences
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EPCC
ETHIOPIAN PANEL ON CLIMATE CHANGE

ETHIOPIAN PANEL ON CLIMATE CHANGE

FIRST ASSESSMENT REPORT

WORKING GROUP II- CLIMATE CHANGE IMPACT, VULNERABILITY, ADAPTATION AND MITIGATION

V

HEALTH AND SETTLEMENT

Human Health: Impacts, Adaptation and Co-Benefits of Climate Change in Ethiopia

ETHIOPIAN ACADEMY OF SCIENCES

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About the Ethiopian Academy of Sciences

The Ethiopian Academy of Sciences (EAS) was launched in April 2010 and recognized by an act of parliament (Proclamation No. 783/2013) as an independent institution mandated to provide, inter alia, evidence-based policy advice to the Government of Ethiopia and other stakeholders. Its major activities include undertaking consensus studies, conducting convening activities such as public lectures, conferences, workshops and symposia on issues of national priority; as well as promoting science, technology and innovation.

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Masresha Fetene (Prof.)
Executive Director, Ethiopian Academy of Sciences

Table of Contents

ABBREVIATIONS

°C	Degree Celsius
An. Arabiensis	Anopheles arabiensis
An. Funestus	Anopheles funestus
An. Gambiae	Anopheles gambie
ANC	Ante Natal Care
AOR	Adjusted Odds Ratio
ART	Antiretrovirus Therapy
AWG-LCA	Ad-Hoc Working Group on Long-Term Cooperative Action under the Convention
CCOHS	Canadian Centre for Occupational Health and Safety
CDC	Centers for Disease Control and Prevention
CFS	Committee on World Food Security
CHWG	Climate and Health Working Group
CO2	Carbon dioxide
DPT3	Diphtheria, Pertusis and Tetanus
EDHS	Ethiopian Demographic and Health Surveys
EMDHS	Ethiopian Mini Demographic and Health Surveys
EOS	Enhanced Outreach Strategy
EPI	Extended Programme on Immunization
FAO	Food and Agriculture Organization of the United Nations
FMOH	Federal Ministry of Health of Ethiopia
HEP	Health Extension Programmes
HMIS	Health Management Information System
HSTP	Health Sector Transformation Plan
ICCM	Integrated Community Case Management
IPCC	Intergovernmental Panel on Climate Change
IRS	Indoor Residual Spray

ITN	Insecticide Treated Nets
LDT	Lower development threshold
MOFED	Ministry of Finance and Economic Development
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
OHS	Occupational Health and Safety
OTP	Outpatient Therapeutic Program
PAHS	Polycyclic Aromatic Hydrocarbons
R&D	Research and Development
SNNPR	Southern Nations Nationalities and People Region
SUN	Scaling Up Nutrition
TFP	Therapeutic Feeding Programme
Topt	Optimum temperature
TSF	Targeted Supplementary Food
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children’s Fund
UNIGME	United Nations Inter-agency Group for Child Mortality Estimation
UNSCN	United Nations Standing Committee on Nutrition
UV	Ultra Violet
µmax	Development rate at this temperature

Executive Summary

There is a strong and growing, global, scientific consensus that warming of the climate system is a fact and is affecting human health.

The Health sector is affected by weather variability and climate change. This includes morbidity and mortality due to climate sensitive diseases, health infrastructure damage and shift of resources to respond to health crisis related to weather variability and climate change. The most common climate change related effects on health in Ethiopia are morbidity and mortality due to vector-borne infectious diseases. However, new conditions may emerge under climate change [low confidence], and existing diseases (e.g. food-borne infections) may extend their range into areas that are presently unaffected. But the largest risks will apply to populations that are currently most affected by climate-related diseases.

It is a well established fact that climate change has great impact on the health of the nation in three different ways, which include:

- Direct impacts, which relate primarily to changes in the frequency of extreme weather including heat, drought, and heavy rain
- Effects mediated through natural systems, for example, etiologic agents, animal reservoirs of disease vectors, water-borne diseases, and air pollution
- Effects heavily mediated by human systems, for example, occupational impacts, under nutrition, and mental stress.

If climate change continues as projected until mid-century, the major increases of ill-health compared to no climate change will occur through:

- Greater risk of injury, disease, and death due to more intense heat waves and fires,
- Increased risk of under-nutrition resulting from diminished food production in poor regions,
- Consequences for health of lost work capacity and reduced labor productivity in vulnerable populations,
- Increased risks of food- and water-borne diseases and vector-borne diseases,
- Modest improvements in cold-related mortality and morbidity in some areas due to fewer cold extremes geographical shifts in food production, and reduced capacity of disease-carrying vectors due to exceedence of thermal thresholds. These positive effects will be

out-weighed by the magnitude and severity of the negative effects of climate change.

Strategies to respond to climate change through adaptation, mitigation, finance, technology, and capacity-building, should be devised and properly take into account the impact of climate change on health. The most effective adaptation measures for health in the near-term are programs that implement basic public health measures such as provision of clean water and sanitation, secure essential health care including vaccination and child health services, increase capacity for disaster preparedness and response, and alleviate poverty.

1. Introduction

Ecosystems are the planet's life-support systems - for human species and all other forms of life. The needs of human beings for food, water, clean air, shelter and relatively constant climatic conditions are basic. Ecosystems are essential to human well-being and especially to human health – defined by the World Health Organization as a state of complete physical, mental and social well-being. Those who live in materially comfortable, urban environments commonly take for granted ecosystem services to health. They assume that good health derives from prudent consumer choices and behaviors, with access to good health care services. But that ignores the role of the natural environment: of the array of ecosystems that allow people to enjoy good health, social organization, economic activity, a built environment and life itself (IPCC, 2007).

Health risks from climate change are expected to increase. Human activities are responsible for an annual emission of an estimated 7.9 billion tons of carbon dioxide to the atmosphere. Reforestation and changes in agricultural practices in temperate regions in the past few decades have enhanced global capacity to absorb this carbon, but not sufficiently to halt climate change. Reducing anthropogenic carbon emissions is critical to the mitigation of climate change. Enhancing or maintaining the capacity of ecosystems to weather and climate has affected human health for millennia. Scientists tell us that the evidence the earth is warming is "unequivocal". Now, climate change is altering weather and climate patterns that previously have been relatively stable. Climate experts are particularly confident that climate change will bring increasingly frequent and severe heat waves and extreme weather events, as well as a rise in sea levels. These changes have the potential to affect human health in several direct and indirect ways, some of them severe (IPCC, 2007).

Global Green House Gases (GHG) emissions due to human activities have grown since pre-industrial times, with an increase of 70% between1970 and 2004 (IPCC, 2007). Continued GHG emissions at, or above, the current rates would cause further warming and induce many changes in the global climate system during the 21st century, that would very likely be larger than those observed during the 20th century. For the next two decades a warming of about 0.2°C per decade is projected for a range of Special Report on Emissions Scenarios (SRES). Even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected (Sambo , 2011).

This document presents what is known about the effects of climate change on human health and, the direct impacts of Climate-Altering Pollutants (CAPs) on health. We reviewed diseases and other aspects of poor health that are sensitive to weather and climate change. We examined factors that influence the vulnerability of populations and individuals to ill-health due to variations in weather and climate, and described steps that may be taken to reduce the impacts of climate change on human health. The document also includes a section on health "co-benefits." Co-benefits are positive effects on human health that arise from interventions to reduce emissions of CAPs or vice versa. This is a scientific assessment based on best available evidence according to the judgment of the authors.

1.1. Current State of Global Health

In general, in our Globe, people have started enjoying the fruit of development in terms of having good health status even though the issue of inequality remains as it is. The following is the excerpt from IPCC 2014 regarding this topic:

The Fourth Assessment Report pointed to dramatic improvement in life expectancy in most parts of the world in the 20th Century, and this trend has continued through the first decade of the 21st century (Wang, 2012). Rapid progress in a few countries (especially China) has dominated global averages, but most countries have benefited from substantial reductions in mortality. There remain, sizable and avoidable inequalities in life expectancy within- and between-nations in terms of education, income and ethnicity (Beaglehole and Bonita, 2008) and in some countries, official statistics are so patchy in quality and coverage that it is difficult to draw firm conclusions about health trends (Byass, 2010). Years lived with disability have tended to increase in most countries (Salomon et al., 2012).

If economic development continues as forecasted, it is expected that mortality rates will continue to fall in most countries; WHO estimates the global burden *of disease (measured in Disability Adjusted Life Years per capita) will decrease by 30% by 2030, compared with 2004 (World Health Organization, 2008a; World Health Organization, 2008b). The underlying causes of global poor health are expected to change substantially, with much greater prominence of chronic diseases and injury, nevertheless the major infectious diseases of adults and children will remain important in some regions, particularly Sub-Saharan Africa and South Asia (Hughes et al., 2011). (Source: IPCC 2014)*

1.2. Past and Present Health Trend in Ethiopia

Ethiopia has 9 Regional States and two city administrations, further divided into 817 woredas (districts). The estimated population is more than 85 million of which more than 84 percent live in rural areas.

The potential primary health service coverage is 93% with 127 hospitals, 3,245 health centers, 16,048 health posts and more than 4,000 private for profit and not for profit clinics. The health system is a four-tier system where a primary health care unit (PHCU) comprising of five satellite health posts, one health center and primary hospital to serve 5,000, 25,000, and 100,000 population, respectively; then secondary level general hospital to serve 1 million population and tertiary or specialized hospital which is expected to serve 5 million people. (Health and Health Related indicators, 2005 EFY, MOH, Ethiopia 2014).

1.2.1. Access to Health Services

The flagship health program of the Ministry of Health, the Health Extension Program (HEP), an innovative community-based strategy to deliver preventive and promotive services and selected high impact curative interventions at community level, is being implemented in a better way since it was started. The program also improves access to essential health services by bridging the gap between the community and health facilities through the deployment of Health Extension Workers (HEW).

Access to a health facility is critical component of equity. In Ethiopia, access to primary health care units (primary hospitals, health centers and health posts) has increased in a significant manner.

Health Development Army (HDA) is the main strategy that is being used to engage the community so that they own their own health. HDA refers to an organized movement of the community through participatory learning and action meetings. Organizing a functional HDA requires the establishment of health development teams (HDA groups) that comprise of up to 30 households residing in the same neighborhood. The health development team is further sub-divided into smaller groups of six members, commonly referred as one-to-five networks. The leaders of the health development teams and the one-to-five networks are selected by the team members. The essential function of the HAD, health development teams and one-to-five networks is promoting for the health of the households and the community.

Since 2000, almost all the health and socio-economic indicators of the country showed significant improvement as indicated in table below.

Table: Levels and trends of health and socio-economic indicators in Ethiopia, 2000-2011

Indicators	Unit	Survey Years			2013 UNIGME (HMIS)
		2000	2005	2011	
Health indicators					
Potential health service coverage	%	51	72	92	
Proportion of children stunted	%	52	47	44	
Proportion of children wasted	%	11	11	10	
Proportion of children underweight	%	47	38	29	
Previous birth interval (median no of months)	months	34	34	34	
Proportion of women 15-49 using Contraception (any method)	%	8	15	29	
Antenatal care coverage (1 visit)	%	6	29	43	97
Antenatal care coverage (4 visits)	%	10	12	19	No data
Protection against tetanus	%	17	32	48	
Delivery at health institution	%	6	5	10	
Skilled delivery	%	5	6	10	23
Early initiation of breastfeeding	%	52	69	52	

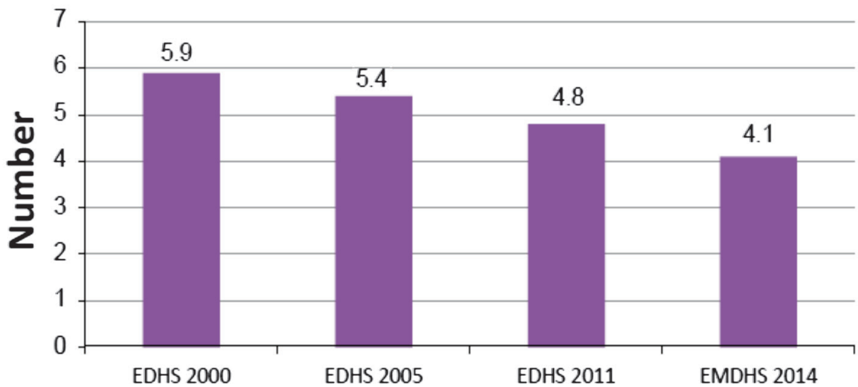
Exclusive breastfeeding until six months	%	4	49	52	
DPT3 vaccination	%	22	32	37	88
Measles vaccination	%	22	35	56	83
Fully Immunized children	%	14	20	24	78
Vitamin A supplementation	%	56	46	53	
Seeking care for pneumonia	%	16	19	27	
Seeking care for fever	%	19	18	24	
ORS during diarrhoea	%	13	20	26	
Received antibiotics for pneumonia	%	69	58	74	
Received anti-malaria's for fever	%	39	38	44	
Socio-economic indicators					
Households with Access to safe drinking water	%	25	34	54	
Households with access to toilet facilities	%	18	38	62	
Women 15-49 Primary education attainment	%	18	26	41	
Women 15-49 Secondary education attainment	%	5	6	4	
Proportion of women in union	%	64	65	62	
Proportion of women with access to mass media	%	1	1	2	
Women's median age at first birth	Years	19	19	19	

Source: Central Statistics Authority, Ethiopian Demographic and Health Surveys (EDHS) and Ministry of health (2000, 2005, 2011)
EMDHS = Ethiopia Mini Demographic Health Survey (2014)

1.2.2. Reproductive Health and Family Planning

According to EDHS, the total fertility rate for Ethiopian women was reduced from 5.4 to 4.8 children in the five years between 2005 and 2011. The Ethiopia Mini Demographic Health Survey (EMDHS) was carried out in 2014 and it showed that the total Fertility Rate further decreased from 4.8 to 4.1 between 2011 and 2014. The contraceptive prevalence rate almost doubled from 15% to 28.6% in the period between 2005 and 2011,while there was a steep increase between 2011 and 2014 which increased from 28.6% to 41.8%. (Annual Performance Report 2013/14, FMOH)

Fig. Trend in Total Fertility Rate (EDHS 2000-2011 and EMDHS 2014)



1.2.3. Improve Maternal and Newborn Health

EDHS 2011 reported the ANC follow up with at least one visit and four plus visits as 43% and 19%, respectively. Whereas, according to FMOH report of 2013/14 proportion of pregnant women who received ANC (at least one visit) was 98.1%.

The percentage of HIV-positive pregnant women who received ART to prevent Maternal to Child Transmission (MTCT) of HIV has been estimated at 60.6% in 2013/14, and according to the 2013 UNAIDS Report, Ethiopia is one of the few “rapid decline” sub-Saharan African countries, with a reduction by 50% of new HIV infections among children between 2009 and 2012.

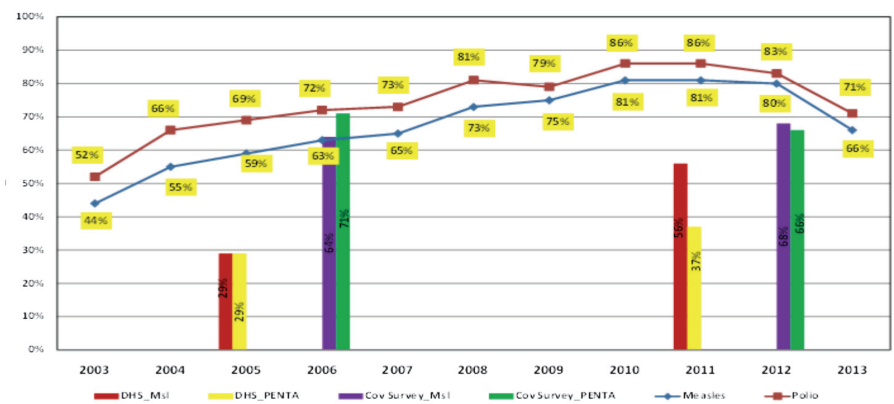
The Essential new-born care interventions also show significant changes over time. EDHS 2011 reported the Neonatal Mortality Rate (NMR) as 37/1000 live births, which has not shown significant declines from the earlier report.

Table: Trends in child mortality rate

category	**EDHS 2000**	**EDHS 2005**	**EDHS2011**	**2012 UN IGME**
U5	165	123	88	68
child	76	50	31	
infant	97	77	59	47
post neonatal	48	38	22	
Neonatal	49	39	37	29

Ethiopia is among the few countries in the world that are recognized to achieve MDG 4 targets three years ahead of the due date. Among the important interventions that have been successfully implemented and contributed to the achievement are IMNCI (currently being provided in 71% of health facilities) and ICCM (with a national coverage of 79%), prevention and management of malaria (with 65% of under 5 children sleeping under ITN with IRS reaching 47% of houses in endemic areas in 2011), and community based nutrition programs. However, the coverage of some other essential interventions like proper case management of Acute Respiratory Illness (ARI) and diarrhoea is still low.   EPI, another important intervention, is not performing to the expectation in recent years. Immunization program in many areas is now suffering from high dropout rates, supply shortage, vaccine stock out and poor follow up.

Routine EPI coverage and Surveys (Penta 3 and Measles) 2003 to 2013



Source: FMOH 2005, 2008, 2011/2012, vaccine coverage survey 2012

1.2.4. Prevention and Control of Major Communicable Diseases

In past decades, Ethiopia has made significant strides in expanding coverage of key interventions towards major communicable diseases prevention and control throughout the country. As a result, there is a significant decrease in the burden of the diseases such as malaria, TB and HIV/AIDS. For instance, the adult HIV prevalence is estimated at 1.2% (0.8% in males and 1.6% in females) and the adult HIV incidence at 0.03% in 2014 (HIV related estimates and projections for Ethiopia-2012, FMOH and Ethiopian Health and Nutrition Research Institute (EHNRI), 2014).

1.3. Non-Climate Health Effects of Climate-Altering Pollutants (CAPs)

IPCC 2014 report indicated that CAPs such as CO_2 affect the health in other ways than through climate change. CO_2 creates non-climate effects such as ocean acidification and calcifying marine species. There are potential implications for human health, such as under-nutrition in coastal populations that depend on local fish stocks, but, so far, links between health and ocean acidification have not been closely studied. CAPs such as black carbon and tropospheric ozone have substantial, direct, negative effects on human health. Although CO_2 is not considered a health-damaging air pollutant at levels experienced outside particular occupational and health-care settings, one study has reported a reduction in mental performance at 1000 ppm and above, within the range that all of humanity would experience in some extreme climate scenarios by 2100.

2. How Climate Change Affects Health

2.1. General Facts

It is a well-established fact that climate change has great impact on the health of the nation in three different ways, which include:

- Direct impacts, which relate primarily to changes in the frequency of extreme weather including heat, drought, and heavy rain
- Effects mediated through natural systems, for example, etiologic agents, animal reservoirs of disease vectors, water-borne diseases, and air pollution
- Effects heavily mediated by human systems, for example, occupational impacts, under nutrition, and mental stress (Figure below).

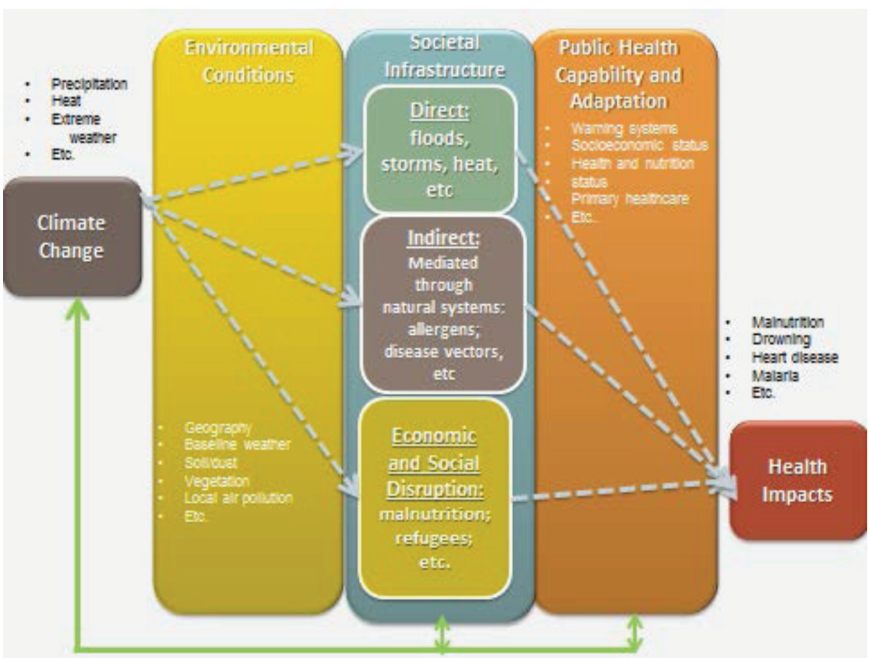


Figure xx: Conceptual diagram showing three primary exposure pathways by which climate change affects health: directly through weather variables such as heat and storms; indirectly through natural systems such as disease vectors; and pathways heavily mediated through human systems such as undernutrition. The yellow box indicates the moderating influences of local environmental conditions on how climate change exposure pathways are manifest in a particular population. The orange box indicates that the extent to which the three categories of exposure translate to actual health burden is moderated by such factors as background public health and socioeconomic conditions, and adaptation measures. The green arrows at the bottom indicate that there may be feedback mechanisms, positive or negative, between societal infrastructure, public health, and adaptation measures and climate change itself. Some measures to improve health also reduce emissions of climate-altering pollutants, thus reducing the extent and/or pace of climate change as well as improving local health. (Source: IPCC 2014)

These potential health impacts were considered for increases in extreme events, increases in temperature, decreases in rainfall and increases in sea-level.

Potential climate change health effects include: heat-related morbidity and mortality; weather-related morbidity and mortality; asthma, respiratory allergies, and airway diseases; food borne, waterborne, vector-borne and zoonotic diseases; cardiovascular disease and stroke; nutrition diseases and human developmental effects; mental health and stress-related disorders; neurological diseases and disorders; and cancer.

In 2010 there were an estimated 216 million cases of malaria and 655,000 deaths, the vast majority in Africa. The Sub-Saharan Africa (SSA) has contributed the least of any world region to the global accumulation of greenhouse gas emissions; yet the highest regional burden of climate change is likely to be borne by SSA, with 34% of the global Disability Adjusted Life Years attributable to the effects of climate change in the region. The tropical African climate is favorable to most major vector-borne diseases, including malaria, schistosomiasis, onchocerciasis, trypanosomiasis, filariasis, leishmaniasis, plague, Rift Valley fever, yellow fever and tick-borne hemorrhagic fevers. The continent has a high diversity of vector-species complexes that have the potential to redistribute themselves to new climate-driven habitats leading to new disease patterns. These organisms have different sensitivities to temperature and precipitation.

2.2. Ethiopian Situation

Climate related hazards in Ethiopia include drought, floods, heavy rains, strong winds, frost, heat waves (high temperatures), lightning, etc. Though the historical social and economic impacts of all of these hazards are not systematically well documented, the impacts of the most important ones; namely, droughts and floods are discussed. Understanding how social systems respond to climate change and variability requires knowledge of how they are affected by those conditions today and how they might respond in the future if those conditions change. Historical analogs give us some insight into climate changes and corresponding social responses (National Meteorological Services Agency (NMSA), 1996).

According to this document, the major adverse impacts of climate variability in Ethiopia include:-

- Food insecurity arising from occurrences of droughts and floods;
- Outbreak of diseases such as malaria, dengue fever, water borne diseases (such as cholera, dysentery) associated with floods and respiratory diseases associated with droughts;
- Land degradation due to heavy rainfall;
- Damage to communication, road and other infrastructure by floods;
- Droughts and Floods

Ethiopia is highly vulnerable to drought (Degefu, W., 1987). It is also indicated that drought is the single most important climate related natural hazard impacting the country from time to time. Drought occurs anywhere in the world, but its damage is not as severe as in Africa in general and in Ethiopia in particular, due to low adaptive capacity. Recurrent drought events in the past have resulted in huge loss of life and property as well as migration of people. The other climate related hazards that affect Ethiopia from time to time are flash and seasonal river floods. Areas in the Afar Region along the Awash River, in the Somali Region along the Wabi Shebele River and in the Gambela Region along the Baro-Akobo River, in the Southern Region along the Omo-Gibe River, Bahirdar Zuria and Fogera areas along the Abbay River in the Amhara Region are prone to seasonal river floods (Endalkachew, B, etal, 2004).

Major floods which caused loss of life and property occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006. For example, in the 2006 main rainy season (June-September), flood caused the following disasters (National Meteorology Agency (NMA), 2006).

- Due to the Diredawa Flood, more than 364 people died, and more than 6000 people were displaced due to flooding of about 14 villages in South Omo.
- More than 16,000 people were displaced in West Shewa.
- Similar situations also occurred over Afar, Western Tigray, Gambella Zuria and the low lying areas of Lake Tana.
- In terms of loss in property and livestock
    - ✓ It is estimated about 199,000 critically affected people due to flood in the country.
    - ✓ More than 900 livestock drowned over South Omo. 2700 heads of cattle and 760 traditional silos were washed away (World Food Program).
    - ✓ About 10,000 livestock were encircled by river floods in Afar.
    - ✓ In Diredawa, the loss in property is estimated in the order of tenth of millions of dollars.

Other impacts of flood include human health such as spread of Acute Watery Diarrhea and malaria outbreak, impacts on the country's infrastructure and damages to field crops.

Globally, the issue of global warming or climate change has emerged as a major developmental and political issue in the past two decades. It is a global phenomenon the impacts of which will affect all countries, but more so the poorer and vulnerable countries of Africa that are least responsible for it. In this respect, the Federal Democratic Government of Ethiopia has been officially attending different international technical, scientific, political, and Intergovernmental Panel meetings on Climate Change (IPCC). Ethiopia is the signatory for the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. It also fully supports initiatives by the African Partnership Forum in 2007, the WHA resolution 2008 & others. As part of the efforts to implement the conventions, numerous activities are being undertaken by MOFED & the National Metrologic Services Agency including other sectors (National Metrological Agency, 2007).

Climate change could jeopardize achievements of the Millennium Development Goals, including the health-related Goals, and undermine the efforts of the health sector to improve public health and reduce health inequalities. Some of the effects of climate change are related to more variable weather, heat waves, heavy precipitation events, flooding, droughts, and more intense storms such as hurricanes, sea level rise, and air pollution. Each of these changes has the potential to negatively affect health. The likely direct and indirect health effects of increased temperatures and extreme weather conditions such as acute heat stress that could be followed by exhaustion and heat stroke; trauma; air quality/pollution, increase vector-borne and zoonotic diseases, water- and food-borne diseases and mental health and compromise others. It is worth noting that while climate change is recognized as a global issue, its effects will vary across geographic regions and populations. To this effect, the FMOH should raise community awareness, initiate trainings to health professionals and researchers on the effects of climate change on health, ensure that systems are in place to detect and track climate change-induced health problems, make the necessary preparations to respond to, and manage climate change associated risks. The FMOH should as well be engaged in such activities in collaboration with the Ministry of Environmental and Forest. Responding to the health impacts of climate change through tracking of up-to-date information is also one of the strategies of the health sector to overcome such encounters (Ministry of Health, Ethiopia, 2010).

3. Vulnerability to Disease and Injury due to Climate Variability and Climate Change

The impact of injuries due to climate variability and climate change depends on the degree of vulnerability of the society. Vulnerability is a function both of exposure to changes in climate and on the ability to adapt to the impacts associated with that exposure. Vulnerability includes a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. (Ref: WHO 2000 and IPCC 2014)

The IPCC reports four types of population vulnerability to health impacts: social, economic, technological and demographic. Causes of population vulnerability to ill-health in the face of environmental stress also include the level of dependency (such as reliance on others for information, resources and expertise) and geographical isolation. The attainment of good public health depends on a responsive social order. Dependency causes vulnerability because support is not always provided when needed. Deprived communities, lacking wealth, social institutions, environmental security and robust health, are likely to be at greatest risk of adverse health effects from climate and other environmental changes. By stretching limited social resources across a broader range of health and other problems, climate change may affect the implementation of public health and nutrition programs.

Criteria for Identifying Key Vulnerability

According to the Report of IPCC 2014 criteria for identifying key vulnerabilities, key risks, and emergent risks are set.

The following five criteria are used to judge whether vulnerabilities are key:

1. *Exposure of a society, community, or social-ecological system to climatic stressors.* While exposure is distinct from vulnerability, exposure is an important precondition for considering a specific vulnerability as key. Exposure can be assessed based on spatial and temporal dimensions.
2. *Importance of the vulnerable system(s).* Defining key vulnerabilities in the context of particular societal groups or ecosystem services also takes into account the conditions that make these population groups or ecosystems highly vulnerable, such as processes of social marginalization or the degradation of ecosystems (Leichenko and O'Brien, 2008; O'Brien et al., 2008; IPCC, 2012a).

3. *Limited ability of societies, communities or social-ecological systems to cope with and to build adaptive capacities to reduce or limit the adverse consequences of climate-related hazard.* While coping describes actions taken within existing constraints to protect the current system and institutional settings, adaptation is a continuous process which encompasses learning and change of the system exposed – including changes of rule systems or modes of governance.
4. *Persistence of vulnerable conditions and degree of irreversibility of consequences.* Vulnerabilities are considered key when they are persistent and difficult to alter. This is particularly the case when the susceptibility is high and coping and adaptive capacities are very low due to conditions that are hard to change. Irreversible degradation of ecosystems chronic poverty and marginalization, and insecure land tenure arrangements are drivers of vulnerability that in combination with climatic hazards determine risks which often persist over decades. In this way, communities or social-ecological systems may reach a tipping critical threshold that would cause a partial or full collapse of the system, including displacement.
5. *Presence of conditions that make societies highly susceptible to cumulative stressors in complex and multiple-interacting systems.* Conditions that make communities or social-ecological systems highly susceptible to the imposition of additional climatic hazards or that impinge upon their ability to cope and adapt, such as violent conflicts are considered under this criteria. Also, the critical dependence of societies on highly interdependent infrastructures (e.g. energy/power supply, transport and health care) leads to key vulnerabilities regarding multiple-interacting systems where capacity to cope or adapt to their failure is low.

Criteria for Identifying Key Risks

The IPCC 2014 report also identified key risks. Risks are considered “key” due to high hazard or high vulnerability (“key vulnerability”) of societies and systems exposed, or both.

Criteria for determining key risks build on the criteria for key vulnerabilities, since vulnerability is a component of risk. As such, risk is strongly determined by coping and adaptive capacities. However, the criteria for identifying key risks also take into account the magnitude, frequency and intensity of hazardous events and trends linked to climate change to which vulnerable systems are exposed.

Accordingly, the following four additional criteria are used to judge whether risks are key:

1) *Magnitude:* Risks are key if associated harmful consequences have a large magnitude, determined by a variety of metrics including, human mortality and morbidity, economic loss, losses of cultural importance, and distributional consequences. Magnitude and frequency of the hazard as well as socioeconomic factors that determine vulnerability and exposure contribute.
2) *Probability that significant risks will materialize and their timing.* Risks are considered key when there is a high probability that the hazard due to climate change will occur under circumstances where societies or social-ecological systems exposed are highly susceptible and have very limited capacities to cope or adapt and consequently potential consequences are severe. Both the timing of the hazard and the dynamics of vulnerability and exposure contribute. Risks which materialize in the near term may be evaluated differently than risks which materialize in the distant future, since the time available for building up adaptive capacities is different.
3) *Irreversibility and persistence of conditions that determine risks.* Persistence of risks refers to the fact that underlying drivers and root causes of those risks, either socioeconomic (e.g. chronic poverty) or physical, cannot be rapidly reduced. The criteria for assessing key vulnerabilities include, the persistence of socioeconomic conditions contributing to vulnerability that also apply here. In addition, some hazards are associated with the potential for persistent physical impacts, such as loss of an ice sheet causing irreversible sea level rise or release of methane clathrates from the seabed.
4) *Limited ability to reduce the magnitude and frequency or other characteristics of hazardous climatic events and trends and the vulnerability of societies and social-ecological systems exposed.* Criterion 3 pertaining to key vulnerabilities discusses limited ability of societies to improve coping and adaptive capacities in order to manage risk. This criterion also applies here. In addition, risks are also considered to be key when societies together have very limited prospects for reducing the magnitude, frequency or intensity of the associated climate hazards. For example, risks that may be reduced or limited by greenhouse gas reductions which reduce the probability of the associated hazard are less threatening than those for which the likelihood of the hazard cannot

be effectively altered. For example, risks which are already projected to be large during the next few decades under a range of Representative Concentration Pathways (RCPs) are much more difficult to influence by reducing emissions than those projected to become large late in this century.

Criteria for Identifying Emergent Risks

A risk that arises from the interaction of phenomena in a complex system is defined here as an *emergent risk*. For example, feedback processes between climatic change, human interventions involving mitigation and adaptation, and processes in natural systems can be classified as emergent risks if they pose a threat to human security. Emergent risks could arise from unprecedented situations, such as the increasing urbanization of low lying coastal areas that are exposed to sea-level rise or where new pluvial flooding risk emerges due to urbanization of vulnerable areas not historically populated. Some emergent risks have been identified or discussed only recently in the scientific literature and as a result, our ability to assess whether they are key risks is limited. In this chapter, the only emergent risks discussed are those which have the potential to become key risks once sufficient understanding accumulates.

Some of the emergent risks involving health effects include changes in the prevalence and distribution of diseases that are climate and weather sensitive. These effects will differ substantially depending on baseline epidemiologic profiles, reflecting the level of development and access to clean and plentiful water, food and adequate sanitation and health care resources. Furthermore, the impact of climate change will differ within and between regions, depending upon the adaptive capacity of public health and medical services and key infrastructure that ensures access to clean food and water.

A principal emergent global public health risk is malnutrition secondary to ecological changes and disruptions in food production as a result of changing rainfall patterns, increases in extreme temperatures and increased atmospheric CO2.

3.1. Geographic Causes of Vulnerability

Urbanization

According to IPCC 2007, urbanization and climate change may work synergistically to increase disease burdens when it is rapid and urbanization is unplanned. Problems associated with rapid and unplanned urbanization are expected to increase over the next few decades, especially in low-income countries. Populations in high-density urban areas with poor housing will be at increased risk with increases in the frequency and intensity of heat waves, partly due to the interaction between increasing temperatures and urban heat-island effects. Adaptation will require diverse strategies which could include physical modification to the built environment and improved housing and building standards.

Rural populations

Climate change could have a range of adverse effects on some rural populations and regions, including increased food insecurity due to geographical shifts in optimum crop-growing conditions and yield changes in crops, reduced water resources for agriculture and human consumption, flood and storm damage, loss of cropping land through floods, droughts, a rise in sea level, and increased rates of climate-sensitive health outcomes. Water scarcity itself is associated with multiple adverse health outcomes, including diseases associated with water contaminated with faecal and other hazardous substances (including parasites), vector-borne diseases associated with water-storage systems, and malnutrition. Water scarcity constitutes a serious constraint to sustainable development particularly in savanna regions: those regions cover approximately 40% of the world land area.
As 84% of the population of Ethiopia resides in rural areas, those effects have a significant impact in our situation.

Population in low-lying areas

Densely populated regions in low-lying areas are vulnerable to climate change. In Ethiopia, especially people living in eastern and south eastern parts of the country, could face inundation by a water depth of 30 to 90 cm based on assumptions of a 2°C temperature increase, an 18% increase in monsoon precipitation, and a 5% increase in monsoon discharge into major rivers (BCAS/RA/Approtech,

1994).

Populations in mountain regions

Little published information is available on the possible health consequences of climate change in mountain regions. However, it is likely that vector-borne pathogens could take advantage of new habitats at altitudes that were formerly unsuitable. In Ethiopia malaria is one of the communicable diseases where evidences show that it is crawling up the mountains (Woyessa et al, 2004). In mountain regions diarrhoeal diseases could also become more prevalent with changes in freshwater quality and availability. More extreme rainfall events are likely to increase the number of floods and landslides. Glacier lake outburst floods are a risk unique to mountain regions; these are associated with high morbidity and mortality and are projected to increase as the rate of glacier melting increases.

3.2. Current Health Status

Ethiopia has made great improvements in many health indicators. One of its flagships which contributed to this achievement is the implementation of the Health Extension Program and expansion of PHC units. The number of health facilities has significantly increased and the potential health service coverage dramatically changed. These changes will definitely decrease the vulnerability of its population to climate change and variability. It is the priority of the Ministry of Health to expand and sustain this progress by envisioning a system that will be equitable, sustainable, adaptive and efficient, and will meet the health needs of a changing population. Universal health coverage (UHC) is a goal for Ethiopia's health sector development and the six priority strategic areas of focus set are as follows:

- Empower the community to play a significant role in the health sector
- Strengthen primary health care units (PHCU) within the larger health sector
- Ensure a robust Human Resources Development system that commensurate with socio economic development of the country
- Engage the private sector in support of the FMOH's vision
- Develop sustainable financing mechanisms to fund health
- Develop institutional capacity to be responsive to changing economic, social, environmental, technical, and epidemiologic context. (Draft HSTP, FMOH, 2014).

3.3. Age and Gender

Children, young people, and the elderly are at increased risk of climate-related injury and illness (Perera, 2008). Children are generally at greater risk when food supplies are restricted: households with children tend to have lower than average incomes, and food insecurity is associated with a range of adverse health outcomes amongst young children (Cook and Frank, 2008). Older people are at greater risk from storms, floods, heat-waves and other extreme events (Brunkard *et al*., 2008). Older people are also more likely to suffer from health conditions that limit the body's ability to respond to stressors such as heat and air pollution (Gamble et al., 2013).

One of the studies carried out in pastoralist areas of Ethiopia indicated that women are more vulnerable to climate change than men as they are the sole bearer of most of the household activities which worsens during drought (Aklilu and Alebachew, 2009). This will definitely make them vulnerable to injury and infectious diseases, as they will easily be exposed, they will not have enough time to seek for health care, they lack property to pay for health care etc.

Pregnancy is a period of increased vulnerability to a wide range of environmental hazards, including extreme heat (Strand et al., 2012) and infectious diseases such as malaria, foodborne infections and influenza (Van Kerkhove *et al*., 2011).

3.4. Socioeconomic Status

IPCC 2014 report indicated that poverty is a critical factor determining vulnerability of societies to climate change and extreme events. Regions such as sub-Sahara Africa, where 47% of the population resides, lives in poverty (poverty headcount ration at $1.25 per day) and hence the area is the most vulnerable.

Income distribution trends to show significant increases in inequality in some countries in Africa, and in Asia, such as in China, India, Indonesia and Bangladesh (World Bank, 2012). In South East Asia, this trend overlaps with areas of compound climate risk (19.3.2.4) in terms of people currently exposed to floods and tropical cyclones as well as sea-level rise (Förster et al., 2011; Peduzzi et al., 2012; IPCC, 2012a). Assessing vulnerability (and risk) in these countries requires in-depth analysis of trends and distribution patterns of poverty, income disparities and exposure of people to changing climatic hazards.

3.5. Public Health and Other Infrastructure

Populations that do not have access to good quality health care and essential public health services are more likely to be adversely affected by climate variability and climate change (Frumkin and McMichael, 2008). Harsh economic conditions in Europe since 2008 led to cutbacks in health services in some countries, followed by a resurgence of climate-sensitive infectious diseases including malaria (Karanikolos *et al*., 2013). The condition of the physical infrastructure that supports human settlements also influences health risks (this includes supply of power, provision of water for drinking and washing, waste management and sanitation). In Cuba, a country with a well-developed public health system, dengue fever has been a persistent problem in the larger cities, due in part to the lack of a constant supply of drinking water in many neighbourhoods (leading to people storing water in containers that are suitable breeding sites for the disease vector, A. aegypti) (Bulto *et al*., 2006). In New York, daily mortality spiked after a city-wide power failure in August 2003, due in part to increased exposure to heat (Weis, 2011).

3.6. Projections for Vulnerability

(Source IPCC report) Population growth is linked to climate change vulnerability. If nothing else changes, increasing numbers of people in locations that are already resource-poor and are affected by climate risks will magnify harmful impacts. Virtually all the projected growth in populations will occur in urban agglomerations, mostly in large, low latitude hot countries in which a high proportion of the workforce is deployed outdoors with little protection from heat.

The age structure of the population also has implications for vulnerability. The proportion aged over 60, world-wide, is projected to increase from about 10% presently to about 32% by the end of the century (Lutz *et al.*, 2008). The prevalence of overweight and obesity, which is associated with relatively poor heat tolerance, has increased almost everywhere in the last 20 years, and in many countries the trend continues upwards (Finucane *et al.*, 2011). It has been pointed out that the Sahel Region of Africa may be particularly vulnerable to climate change because it already suffers so much stress from population pressure, chronic drought, and governmental instability (Diffenbaugh and Giorgi, 2012; Potts and Henderson, 2012).

Future trends in social and economic development are critically important to vulnerability. For instance, countries with a higher Human Development Index (HDI) (a composite of life expectancy, education, literacy and GDP per capita) are less affected by floods, droughts and cyclones that take place (Patt *et al.*, 2010). Therefore, policies that boost health, education, and economic development should reduce future vulnerability. Overall, there have been substantial improvements in HDI in the last 30 years, but this has been accompanied by increasing inequalities between and within countries, and has come at the cost of high consumption of environmental resources (UNDP, 2011)

Institutional vulnerability refers, among other issues, to the role of governance. Governance is increasingly recognized as a key factor that influences vulnerability and adaptive capacity of societies and communities exposed to extreme events and gradual climate change (Kahn, 2005; Nordås and Gleditsch, 2007; Welle et al., 2011). People in countries or places that are facing severe failure of governance, such as violent conflicts are particularly vulnerable to extreme events and climate change, since they are already exposed to complex emergency situations and hence have limited capacities to cope or undertake effective risk management (see Ahrens and Rudolph, 2006; Menkhaus 2010). The Failed State Index (Fund for Peace, 2012; Foreign Policy, 2012) as well as the Corruption Perception Index (Transparency International, 2012) are used to characterize institutional vulnerability and governance failure. Trends in the Failed State Index from 2006 to 2011 show that countries with severe problems in the functioning of the state cannot easily shift or change their situation (persistence of institutional vulnerability). Studies at the global level also confirm that countries classified as failed states and affected e.g. by violence are not able to effectively reduce poverty compared to countries without violence (World Bank, 2011). In addition, climate change is also likely to undermine the capacity of some states to provide the services and support that help people to sustain their livelihoods in a changing climate (Barnett and Adger, 2007). Governance failure and violence as characteristics of institutional vulnerability have significant influence on socio-economic, and therefore climatic vulnerability. Furthermore, corruption has been identified as an important factor that hinders effective adaptation policies and crisis response strategies (Birkmann et al., 2011b; Welle et al., 2012). At the local level, various aspects of governance in developing and developed countries, particularly institutional capacities and self-organization as well as political and cultural factors, are critical for social-learning, innovations and actions that can improve risk management and adaptation to climate related risks and for empowering highly vulnerable groups (IPCC, 2012a).

4. Direct Impacts of Climate and Weather on Health

4.1. Heat and Cold – Related Impacts

Evidences have shown that climate change is likely to cause increased heat-related mortality. Extremes of temperatures, both hot and cold, can cause physiological disturbance and organ damage leading to illness or death. A recent Intergovernmental Panel on Climate Change (IPCC) report indicated that anthropogenic climate change is likely to cause a range of direct and indirect effects on human health (IPCC, 2014). Heat-related morbidity and mortality is highly likely outcome of climate change. This is particularly in response to episodes of stressful weather, such as heat waves. Excessive heat is a well-known cause of heat stress, and exacerbates illness and mortality. The impacts of heat-related mortality vary with age and socio economic status. Thus, the elderly, the very young, persons with impaired mobility, and persons suffering from cardiovascular disease, appear to be disproportionately affected by such weather extremes. Probably, this might be because of the lesser physiological coping ability of these groups of population. In addition, socioeconomically deprived segments of urban populations are also relatively more vulnerable to the impact of heat waves, which is considered to be due to poor housing conditions, lack of access to air-conditioning, and greater response to the urban "heat island effect" (McMichael *et al*., 1996). Consequently, heat-related mortality is a matter of great public health concern, especially in the context of climate change (Huang *et al*., 2011). Climate change is expected to exacerbate the health impacts of heat through rising temperatures and higher frequency and severity of heat waves. An increase in heat-related mortality and morbidity in many parts of the world are some of the effects observed (Haines *et al*., 2006; McMichael *et al*., 2012). For example, in the UK and Australia, annual and seasonal mean temperatures are generally projected to increase significantly over the 21st century.

In addition, climate models also predict that extreme cold weather events are still likely to occur over European continental areas, and other middle and high latitude regions (Kodra *et al*., 2011). The magnitude of climate change related impacts will vary substantially between countries and population groups. For example, the elderly are much more vulnerable to heat and cold compared with younger age groups (Hajat *et al*., 2007; Hajat *et al*., 2014). Heat and cold related health risks can also vary considerably across or within countries (Analitis *et al*., 2008; McMichael *et al*., 2008).

In general, the extent of heat-related mortality varies according to geography. Thus, mortality data for many cities in temperate regions show a sharp rise in total mortality during unusually hot weather conditions. Daily mortality can be more than twice the long-term mortality mean in some cases. Conversely, populations in more tropical regions seem to be less affected by temperature extremes. Such differences between regions in the pattern of heat-related mortality may reflect differences in the variability of summer temperatures (McMichael *et al*., 1996).

Furthermore, temperate regions are more affected by higher temperature compared to tropical ones. In temperature regions, the very hot episodes occur within periods of generally milder weather, and presumably, the physiological "shock value" of a very high temperature is considerable. In tropical cities, the hottest periods usually do not greatly exceed the mean temperature. Similarly, cold-related morbidity and mortality are also very important as health outcomes due to extreme weather event. In temperate climate countries, there is a clear-cut seasonal variation in mortality. In the past, death rates of 10-25% higher in the winter season than those in the summer season have been recorded in temperate climate countries (McMichael *et al*., 1996). However, the rate of increase appears to be considerably less steep than those accompanying increasing temperature in summer. Possibly, behavioural responses such as cold avoidance are important thermoregulatory processes at very low temperatures in populations well-accustomed to extreme cold.

4.1.1. Mechanisms

The onset of heat exhaustion or heat stroke is the most direct impact of heat stress on the human body. But an increase in mortality that is associated with hot weather occurs via a number of mechanisms. For example, deaths from cardiovascular and respiratory disorders, and from some types of accident, typically increase during stressful conditions, which explain why heat stroke and heat exhaustion represent only a small proportion of the mortality increase. Because of this diversity of causes of death, the number of heat-related deaths is considered to be the number of deaths occurring in excess of the number of that would have been expected for the population in the absence of a heat wave. So far, the causal mechanisms underlying heat mortality are not well known. However, reports showed that in the older population, the excess heat mortality is mainly caused by cardiovascular and respiratory deaths, but in younger age groups, traffic accidents and drowning play more important roles as causes of mortality (McMichael *et al*., 1996).

On the one hand, in extreme climates, stormy rather than very cold weather is responsible for some wintertime excess mortality. In the USA, heart attack related to overexertion may be a major cause of wintertime death. The increased risk of mortality in persons with cardiovascular disease in winter may simply reflect a cold-induced tendency for blood to clot, perhaps exacerbated by the effect of wintertime respiratory infections (McMichael *et al*., 1996). In fact, the number of deaths from influenza, pneumonia and accidents also increases during winter. As respiratory infections depend upon aerosol transmission, usually in confined poorly-ventilated places, a small rise in winter temperatures should reduce this risk since people usually spend less time indoors during warmer weather. On the other hand, the excess cardiovascular deaths during heat spells have been attributed to the loss of water and salt by sweating and perspiration that result in haemo-concentration. Consequently, a decline in blood pressure would increase the risk of vascular thrombosis, and heat stress that may lead to fatal heart failure among frail individuals (Keatinge *et al.*, 1986).

4.1.2. Near-Term Future

Climate change is a real situation that will be expected to continue until sometimes in the future. Most of the evidences come from developed countries and there is limited information from developing countries. It was estimated that by 2050, climate change could increase several fold such as the frequency of extremely hot days and the occurrence of extraordinarily hot summers (McMichael *et al*., 1996). In addition, another study projected that mortality impact of temperature-related health burdens in UK and Australia during the 2020s, 2050s, and 2080s. In the absence of any planned, spontaneous behavioural or physiological adaptation of the population to climate change, heat-related mortality is projected to rise steeply by approximately 90% and 70% between the 2020s and 2050s in the UK and Australia due to rising mean temperatures, as well as due to population growth and ageing, respectively (Vardoulaksi *et al*., 2014). The same author showed that over the same period, cold-related mortality estimates show a relatively smaller decline (e.g. by approximately 16% and 17% between 2020s and 2050s in the UK and Australia, respectively. Nevertheless, the absolute number of cold-related deaths is projected to remain higher than that of heat-related deaths in UK regions and Australian cities over the assessment period (Vardoulaksi *et al*., 2014).

In order to overcome such a huge heat-and cold-related burden, there is a need for carefully designed adaptation plan. A study suggested that improved general health and wellbeing of the elderly, particularly of those living in large cities, as well as planned adaptation measures may help to curb these large mortality burdens (Marmot Review Team, 2011). Accordingly, the adaptation measures could be temperature-health warning systems, targeted public health messages and improved home insulation. A study also projected future heat-related mortality burdens in the UK. Hames and Vardoulakis (2012) estimated an increase in annual heat-related mortality over the periods 2020s-2050s (74%) and 2050s-2080s (57%), and a decline of cold-related mortality over the periods 2020s-2050s (24%) and2050s-2080s (26%) in the UK. In addition, another study by Hajat *et al*. (2014) based on model led by daily temperature projections for the whole of the UK estimated that increases of 115% and 78% in annual heat-related deaths over the periods 2020s-2050s and 2050s-2080s, and corresponding decreases of 6% and 10% in cold- related deaths, when future population projections were taken into account. In addition, other studies have also shown that heat-related mortality will rise by half of the century (Bambrick *et al*., 2008), and that could be by about 15% by 2070 (Armstrong *et al*., 2011).

4.2. Floods and Storms

Climate change is expected to manifest itself partly as change in weather variability. Relatively small changes in climate variability or mean climate could produce relatively large changes in the frequency of “extreme” weather

events. Probably, climate change could also affect the frequency of the El Nino/Southern Oscillation (ENSO) which amplifies climate variability around much of the world. Extreme weather events can be defined as infrequent meteorological events that have a significant impact upon the society or ecosystem at a particular location. Examples of extreme weather events include floods, wind storms, landslides and forest fires (McMichael *et al.*, 1996).
Some studies have observed an increase in the frequency of extreme weather events in recent decades, and the number of people affected (Noin, 1994). But data on the impacts of extreme weather events are often approximate or simply underestimated. Moreover, measuring such impacts is difficult because of problems related to definition and accuracy (Noin, 1994).

The 1997/98 El Niño dramatically illustrated the global character of the phenomenon. The El Niño was associated with anomalous patterns of rainfall and cloudiness over most of the global tropics. Thus, El Niño impacts were felt in the tropics and subtropics and across the eastern South Pacific and central South America (Kovats *et al.*, 1999). The same authors found there was a dramatic decrease in tropical storm and hurricane activity across the subtropical north Atlantic and an extensive area of favourable conditions for tropical cyclone activity in the North Pacific. Moreover, Kenya was particularly affected by flooding, and rainfall surpluses between October 97and February 98 exceeded 1000mm in some parts. On the one hand, very heavy rain fall was also experienced along the coastal regions of Ecuador and Northern Peru. Similarly, Guyana, Indonesia and Papua New Guinea were severely affected by drought. The sea level in the Colombian Pacific coast rose by 20cm (Kovats *et al.*, 1999). The human impacts of climate-related disasters have been considerable during the past two decades (IFRC, 1998). Thus, floods are the second most frequent cause of a natural disaster after wind storms. However, the highest numbers of persons killed or affected by natural disaster are due to drought and famine. There is a widely held perception that El Niño and La Niña herald disaster and weather chaos. There is good evidence that ENSO events are associated with increased risk of natural disasters in certain regions.

Regional analyses by Kovats *et al.* (1999) showed that the impact of ENSO on the number of persons affected by natural disasters is strongest in South Asia.

This Region contributes more than 50% of all disaster victims due to its high population density and high absolute population. El Niño is important because it is associated with drought in many vulnerable regions at the same time. The most effected populations were in Ethiopia, the Sahel and in parts of India and China (Kovats *et al.*, 1999). The world food crisis of 1982–83 was also linked to the El Niño, when famines struck populations in Ethiopia and the Sahel, which were also badly affected by the civil war (Kovats *et al.*, 1999).

In Ethiopia, evidence has shown that flooding is one of the principal and frequent outcomes of climate change that inflicts human health. It is considered as the most frequent and devastating type of natural disaster worldwide, accounting for 40% of all natural disasters (CRED, 2008). Most the floods occur in developing and tropical regions. For example, East Africa has experienced many episodes of flooding between the years 2000 and 2008 (CRED, 2008). According to a study in the Gambella Region, three critically important weaknesses such as lack of flood-specific policy, absence of risk assessment, and weak institutional capacity were identified (Samson *et al*., 2009). The Gambella flooding during 2008 was an aspect of increased frequency and magnitude of flooding in other parts of the country over the past decade. Nevertheless, the floods in Gambella were attributed to land-use change (deforestation and over cultivation) and also to climate change. However, the role of rivers such as Baro, Akobo, Gilo, and Alwero and low lying homogeneous topography of the area is known to be vital in aggravating the impact of floods. On the other hand, unplanned resettlement and population increase in the Region are the main causes of land-use change. Consequently, intensive forest clearance and large scale farming have takenplace. Thus, deforestation leads to higher run-off volumes which can result in flooding in low plain areas.

In addition, Samson and his colleagues (2009) suggested climate change as the major causes of flooding in Gambella Region. The onset of the rainy season had been erratic and also the amount of rainfall had become unusually high. This is in line with findings (NMSA, 2001), which show increases in the precipitation patterns for Gambella Region and the surrounding regions. In addition, the IPCC projection indicated an increase in precipitation and run-off in eastern African countries including, Ethiopia (IPCC, 2008), during the same year.

Regarding the major health impacts the 2006 flooding in the Gambella, death was recorded by regional health authorities. Local Health Bureau report indicated the rapidly rising of flood-related deaths for consecutive five years before that survey. The number of flood-related deaths in Ethiopia has increased steadily from 199 in 2003 to 932 in 2006 (Samson *et al*., 2009). Diarrhoea and malaria incidence were other health impacts that followed floods in the area. The occurrence of diarrhoea and its aggravation is related to overcrowding and inadequate water and sanitation in temporary resettlement camps. Rise of the risks of diarrhoeal outbreak were high when displaced people returned to their villages. This was because the floods contaminated the local water sources. High malaria incidence was reported after floods, which was associated with increases in favorable mosquito breeding sites (Samson *et al*., 2009). The same authors cited other studies that also reported a positive correlation between floods and the incidence of malaria.

In addition, Samson and his co-workers (2009) reported the destruction of crops caused by flooding in the Gambella Region. Floods damage crops and inundate farm land, which can lead to food shortages that may lead to malnutrition. It was estimated that the 2006 flood in the Gambella Region caused damage to 1,650 ha of maize crops (Samson *et al*., 2009). From local reports, there was also a 20% reduction in production, mainly resulting from water logging on the farmlands. Most of the people affected by this flood were very poor and considered highly vulnerable in terms of food security. Though it is difficult to relate flooding to nutritional status without undertaking prior surveys, it is likely that shortages of food caused by flooding in Ethiopia exacerbated existing malnutrition in the country.

Unlike the setting of Ethiopia, there is ample evidence on flooding for other countries. For instance, ample evidence exists related to the association of El Niño and drought in many countries such as Papua New Guinea and Indonesia (Kovats *et al.*, 1999). The same authors showed that some droughts in the Philippines are related to ENSO. The 1997/98 El Niño was associated with the most serious drought in 50 years in Papua New Guinea and the government declared a state of emergency. Many small island states in the Pacific were also seriously affected, such as the Marshall Islands. While floods are much localized in time and space, droughts are long-term events that usually affect a greater area. Floods are also much more frequent than droughts. Thus, floods and flood disasters have high natural variability in time and space (Kovats *et al.*, 1999).

4.2.1. Mechanisms

El Niño is associated with changes in local temperature and rainfall patterns in selected regions around the Pacific and beyond. Several mechanisms can explain the association between rainfall anomalies (drought, heavy rain, floods) and disease incidence. Outbreaks of infectious disease are often associated with catastrophic events, not only due to the initial cause (e.g. flooding), but also due to population displacement and overcrowding (Kovats *et al.*, 1999). Previous global analysis has shown no association between ENSO and the number of flood disasters or ENSO and the number of persons affected by floods and landslides. However, the number of persons affected by landslides, particularly in South America, increases in the year after the onset of El Niño (year+1). While floods are much localized in time and space, droughts are long-term events that usually affect a greater area (Kovats *et al.*, 1999).

Floods are also much more frequent than droughts. Thus, floods and flood disasters have high natural variability in time and space. The geographical aggregation of data may have been inappropriate in studies described above. Moreover, during El Niño, countries in eastern equatorial Africa experience wetter-than-normal conditions in the winter period. The impact of 1997/98 El Niño was very severe and catastrophic flooding occurred in East Africa (Kovats *et al.*, 1999). Flooding was caused by exceptionally heavy rainfall in Somalia, northern Kenya, Ethiopia and Tanzania. Severe flooding in China in 1998, killing more than 5,500 and leaving atleast21 million homeless, was possibly associated with El Niño (Kovats *et al.*, 1999).

Overall, extremes of weather have the most devastating impacts on human health and well-being. Thus, storms, hurricanes, and floods kill many thousands of people every year. However, non-catastrophic weather can also have varied and significant impacts on human health. On the other hand, natural disaster can also severely affect the local infrastructure. In some of the situations, El Niño-related damage may include: flood damage to buildings and equipment, including materials, and supplies; flood damage to roads and transport systems; problems with drainage and sewerage systems; damage to water supply system.

4.2.2. Near-Term Future

Predicting the effects of climate change on the frequency, timing and duration of extreme weather events is very difficult. Climate models are unable to describe extreme weather events adequately because the models are unable to describe extreme weather events adequately since they lack spatial and temporal resolution. Thus, climate change models indicate major regional differences in changes in future precipitation patterns. Still the tools are not sophisticated enough to predict with certainty the impact of climate change.

If the frequency of extreme weather events increases, deaths, injuries, stress-related disorders and many adverse health effects associated with social disruption, enforced migration and settlement that those events entail, would also increase. The impacts of extreme weather events would be greatest on communities with limited technical and social resources (McMichael *et al*., 1996).

4.3. Ultraviolet Radiation

Stratospheric ozone (O_3) accounts for about 90% of all atmospheric ozone. It absorbs significant quantities of incoming solar radiation, thereby providing protection from UVR at Earth's surface (WHO, 1994). Normally, of the solar radiation that reaches Earth's surface, approximately 5% is ultraviolet (UV), a further 55% is infrared and 44% is visible (McMichael *et al*., 1996). However, GHG accumulation increases the effect of radiative forcing on climate, while destruction of stratospheric ozone by chlorine radicals leads to increased ultraviolet radiation (UVR) at ground level.

4.3.1. Mechanisms

A study showed that strong interactions exist between stratospheric ozone depletion and changes in climate-induced by increasing GHGs (McKenzie *et al.*, 2011). Thus, stratospheric ozone depletion impacts on climate and climate change impacts on the ozone. McKenzie *et al.* (2011), further point out that these changes are likely to decrease total stratospheric ozone in the tropics and increase total ozone at mid-and high-latitudes. Exposure to UVR is increasing as stratospheric ozone depletion and global climate changes influence surface radiation levels (WHO, 2003; Zepp *et al.*, 2007; McKenzie *et al.*, 2003).

The primary source of radiation that reaches the eye is from sunlight (Oliva and Taylor, 2005).The spectrum for solar radiation ranges from short-wave length (100nanometers, nm) UVR to long wave length (1 mm or100, 000nm) far-infrared radiation. The physical spectrum of UVR ranges from 100 to 400 nm. Thus, the UV wavelength band ranges 200-400 nm and is conventionally subdivides into three, consisting of UV-A (315-400 nm), UV-B (280-315 nm) and UV-C (100-280). Stratospheric O3 absorbs essentially all of the highest-energy, shortest wave length radiation (i.e. UV-C), approximately 75% of the next highest energy band (i.e. UV-B), but only a small part of the lowest energy radiation (i.e. UV-A). Subsequently, UVR is absorbed in the troposphere (*lower* atmosphere) via clouds, dusts and gaseous and particulate air pollutants. According to McMichael *et al*. (1996), the total proportion of UVR absorbed in the atmosphere is a function of the time taken by incoming solar radiation to reach Earth's surface. Therefore, the intensity of UVR at ground level varies significantly with the angle of incoming solar radiation, and hence, with the time of day, season, and altitude. Clear-sky UVR reaches its highest levels at low altitudes. Conversely, its levels are lowest at the north and south poles (McMichael *et al*., 1996).

Direct UV exposure has both harmful and beneficial effects on humans. In this regard, a summary of the main effects of solar UVR on health of human beings is well described (McMichael *et al*., 1996). The nature of the effects are categorized into effects on immunity and infection, the eye, the skin and other direct and indirect effects. The same author identified some of the harmful effects, with sufficient evidence that include suppression of cell mediated immunity, acute photokeratitis and photoconjuctivitis, acute solar retinopathy, malignant melanoma, non-melanotic skin cancer, sunburn, and photodermatoses (McMichael *et al*., 1996). Moreover, there are also various harmful effects with inadequate and limited evidence such as increased susceptibility to infection, impairment of prophylactic immunization, activation of latent virus infections, climatic droplet keratopathy, cancer of the conjunctiva, lens opacity (or cataract), and macular degeneration. However, a few beneficial effects including, vitamin D production and general well-being were considered (McMichael *et al*., 1996).

In addition, another study also showed some of the human health impacts caused directly from UVR exposure including, skin cancer and sun-burns, immune system suppression, and eye damage, such as cataracts and photokeratitis. Evidences identified that various categories of UVR have different human health impacts. For instance, UVR coming from sunlight with category of UV-A (315 to 400nm) causes tanning, aging of the skin and skin cancer; while UV-B (280 to 315nm) causes sun burn and skin cancer and UVC (280-100nm) which is almost completely absorbed by the atmospheric ozone and has minimal effects on health. A high level of UVA that passes through the atmosphere remains unfiltered (Jaggernath *et al*., 2013).

Many geographical and environmental factors are known to influence high levels of UVR. The high position of the sun, close proximity to the equator, increased altitude, depletion of the ozone layer, and by surfaces that reflect the sun's rays, such as water bodies, sea foam and snow influence high levels of UVR (Jaggernath *et al*., 2013). For example, increase by 5% of UVR is suggested with every1000meters altitude rise. Thus, the geographical variation of stratospheric O_3 exists and showed that human-induced depletion of stratospheric O_3 is much greater at high latitudes (Jaggernath *et al*., 2013). The same authors showed that increases in ground-level UVR are anticipated to be greatest in the southern parts of Africa, Australia and South America, and mid-latitudes (30-60^{o}N) in Europe, Asia and North America. Earlier estimate indicated that UVR reaching the lower atmosphere has increased by approximately 3% per decade at 30^{o}N and at 30^{o}S. Thus, the estimate is considered to be observed in cities like New Orleans, Delhi and Shanghai in the North, and in Sydney, Buenos Aires and Durban in the South (Jaggernath *et al*., 2013).

The mechanisms and detailed interaction of UVR with skin, eye and immune system is considered on the basis of previous evidence. On the one hand, many epidemiological studies have implicated solar radiation as a cause of skin cancer in fair-skinned humans (WHO, 1994). A review showed that UV-specific mutations of prominent cancer-associated genes have been identified in several skin cancers, but particularly in skin cancer occurring in UV-sensitive patients with the DNA repair-deficient disease xerodermapigmentosum (McMichael *et al*., 1996). While such mutations may directly cause malignant changes in the affected cell, other forms of UV-induced DNA damage occur indirectly via modification of cellular activities, including those that contribute to the body's immune system. On the other hand, evidence shows that UVR is harmful to the eye and vision through its profound damage to various ocular tissues (Oriowo *et al.*, 2002). Long-term/chronic exposure due to long periods of exposure or repeated exposure to high levels of UVR results in both acute and chronic effects to the eye. Solar UVR usually affects the anterior structures of the eye and those areas adjacent to the eye. The anterior structures of the eye (cornea and lens) absorb more than 99% of UV-B radiation, which has high energy, and can therefore damage the anterior structure easily.

Cataract is another eye problem with ocular damage resulting from broad band UVR. A cataract is clouding of the crystalline lens of the eye and sunlight-related eye disease (ophthalmoheliosis) with the most serious public health implications (DeGruijl*et al.*, 2003). In addition, Jaggernath *et al*. (2013) described that UVR and increased exposure to sunlight has been shown to be one of the major risk factors for cortical cataract. People who spend more than four hours per day in the sun on weekdays are known to face a significant increase in the risks for two different grades of cortical opacification, which is the process of becoming cloudy or opaque. Moreover, the same authors cited a study from Somalia that found strong association between deformations of the anterior lens capsule and the central pupillary area, climatic droplet keratopathy and reflected UV-B. Keratopathy is corneal degeneration due to prolonged climatic exposures.

Another study also indicated the risk of presbyopia may also be increased with greater exposure to UVR and higher climate temperatures (Jaggernath *et al*., 2013). Presbyopia is defined as a condition in which the natural lens of the eye loses its ability to accommodate changes in focal length and focusing on close objects becomes difficult. In fact, presbyopia is believed to be common in populations that live in close proximity to the equator, in areas that experience hot climate conditions and are exposed to high levels of sun are at a greater risk in their earlier years. This is referred to as early onset presbyopia. In addition, presbyopia has been noted to increase five years earlier in the tropics than in the northern climates as a result of increased solar radiation (Jaggernath *et al*., 2013).

Acute and chronic exposure of the eyelid to UV-A and UV-B solar radiation causes UVR related damage to the skin of the eyelids as the skin becomes more susceptible to changes in melanin pigmentation, and histopathological production (Oliva and Taylor, 2005). According to Liquis (2010) the most common types of skin lesions around the eyelids that frequently result from UVR exposure, which includes basal cell carcinoma, squamous cell carcinoma, sebaceous cell carcinoma, and malignant melanoma. Basal cell carcinoma refers to a malignant lesion that is usually found on the lower eyelid or the inner canthus (nasal part) of the eye. In Australia, a country with intense sunlight exposure, the incidence of basal cell carcinoma is the highest that reaches 823 *per* 100,000 (Marks, 1995).There is an overall lack of evidence directly linking predictions of climate change with eye health. However, available literature reviewed in this article on the links between eye health and climatic factors suggest that long-term climate changes could have adverse effects on eye health and visual impairment-related morbidity.

4.3.2. Near-Term Future

A study estimated that the relationship between cortical cataract and sun exposure indicating a more modest 10% risk (West *et al.*, 1998). Based on these data, West and her colleagues developed risk estimates for the entire US population under conditions of ozone depletion (West and Valmadrid, 1995). Accordingly, risk estimates were calculated for fixed levels of ozone depletion that ranged between 5% and 20% (West *et al.*, 1998). From this estimation, more likely, the number of cortical cataract cases would increase between 1.3% and 6.9% by the year 2050.The study also showed that cortical cataract is relatively more prevalent than other types of cataract in populations living in temperate climates and the incidence increases toward lower latitudes.

5. Ecosystem-Mediated Impacts of Climate Change on Health Outcomes

The constant warming of the Earth due to anthropogenic emission of greenhouse gases (GHGs) changes the hydrologic cycle around the globe (Bernstein *et al*., 2007), resulting in subsequent changes in long term patterns of rainfall and other weather patterns. The effects of these changes vary by region of the world (Bindoff *et al*., 2007), with implications for many ecosystems (Parmesan and Yohe, 2003) as well as for human health (Confalonieri *et al*., 2007). The Intergovernmental Panel for Climate Change (IPCC) has assessed and projected that the global mean temperature is likely to increase by 1.4-5.8^{o}C between 1990 and 2100 (McMichael *et al*., 2001). Consequently, the planet's geological, biological and ecological systems (Hales *et al.*, 2003), including human biology and health are expected to be altered. As a result of the earth's changing climate, adverse weather and climate events are anticipated to occur more frequently.

The World Health Organization(WHO) quantitative assessment concluded that the effects of the climate change that have occurred since the mid-1970s may have caused a net increase of over 150,000 deaths in 2000. Moreover, McMichael *et al*. (2004) suggested that these impacts are likely to increase in the future. Unfortunately, the largest health risks are to children in the poorest communities, who have contributed least to GHG emissions (Patz *et al*., 2005). The major components of health outcomes that could be aggravated as a result of climate changes considered in this document include vector-borne and other infectious diseases, food- and water-borne diseases and health outcomes from poor air quality. Research evidences available online were used in this document in which only open access and freely downloadable articles were retrieved.

5.1. Vector-Borne and Other Infectious Diseases

The tropical African climate is favorable for most of the vector-borne diseases. Some of these diseases are malaria, schistosomiasis, onchocerciasis, trypanosomiasis, filariasis, leishmaniasis, plague, Rift Valley fever, yellow fever and tick-borne haemorrhagic fevers. The high diversity of vector-species complexes including, *Anopheles gambiae* complex, *A. funestus*, *A. darling, Culex quinquefasciatus,* and *Aedes aegypti* are responsible for transmission of most of the vector-borne diseases. Instead of naming different species of vectors transmitting the same disease, it could be better to mention different genera of insect vectors transmitting different diseases. For instance, the genus Anopheles, Simulium, Phlebotomus, Biomphlaria, etc., are serving as vectors of malaria, Onchocerciasis, Leishmaniasis and Schistosomiasis, etc.

Climate plays a vital role in the transmission of many infectious diseases. Climate not only determines spatial and seasonal distributions but influences inter-annual variability, including epidemics and long-term trends (Kelly-Hope and Thomson, 2008). The diseases are with short and long development periods that differ in the sensitivities to climate. Those diseases with a short development period tend to be highly seasonal or epidemics in nature and usually the basis of epidemiological research. Thus, several diseases were identified as candidates for climate-based early warning systems as a means of improving preparedness for and in response to epidemics (Kuhn *et al.*, 2005). In contrast, chronic diseases with long development periods, in which the pathogen may survive for many years in the human host (e.g. lymphatic filariasis), may exhibit little or no seasonal or inter-annual variability, even though transmission may be driven by climatic factors. The former categories of diseases with epidemic nature such as malaria are the focus of this review. Other vector-borne diseases of public health significance and evidence related to association with climate change and variability including dengue, tick-borne diseases, and trypanosomiasis is considered in detail below.

The vectors are sensitive to temperature changes as immature stages in the aquatic environment and as adults. Moreover, these mosquitoes have also the potential to redistribute themselves to new climate-driven habitats leading to new disease patterns. The greatest effect of climate change on transmission is likely to be pronounced at extremes of range of temperatures at which transmission occurs. For instance, for many diseases, the lowest end range 14-18^{o}C and the upper end at 35-40^{o}C. Warming in the lower range has a significant and non-linear impact on the extrinsic incubation period of the parasite (Githeko *et al*., 2000). However, at around 30-32^{o}C, vectorial capacity can increase substantially owing to a reduction in the extrinsic incubation period, despite a reduction in the vector's survival rate.

It is well known that temperature influences development of mosquitoes both at immature and adult stages. A review showed if water temperature rises, the larvae take a shorter time to mature (Githeko *et al*., 2000), and consequently there is a greater capacity to produce more offspring during the transmission period. In warmer climates, adult female mosquitoes digest blood faster and feed more frequently, thus increasing transmission intensity. Similarly, malaria parasites and viruses complete extrinsic incubation within the female mosquito in a shorter time as temperature rises, thereby increasing the proportion of infective vectors. Warming above 34°C generally has a negative impact on the survival of vectors and parasites. In addition, increased precipitation has the potential to increase the number and quality of breeding sites for vectors such as mosquitoes, ticks and snails, and the density of vegetation, affecting the availability of resting sites (Githeko *et al*., 2000).

5.1.1. Malaria

Malaria is one of the oldest vector-borne diseases with ample evidences that its epidemiology is determined by environmental variables. Temperature is one of these variables that play a critical role in affecting both the distribution of the vector and the effectiveness of pathogen development through the vector. Temperature increase or decrease in survival of vector, changes in: rate of vector population growth, feeding behavior, susceptibility of vector to pathogens, incubation period of pathogen, seasonality of vector activity and seasonality of pathogen transmission of vector-borne diseases (Gubler *et al.*, 2001), and including malaria. Epidemiological evidences are available related to association of increased malaria risk and climate variability due to El Nino events in both South America and Asia (Bouma and van der Kaay, 1996; Bouma *et al*., 1996, 1997; Bouma and Dye, 1997). The increased malaria risk is partly due to increased temperature and partly due to increased rainfall, leading to increased mosquito breeding sites.

In addition, rainfall is another important parameter that influences malaria prevalence. Gubler *et al*. (2001) identified a range of possible mechanisms where by rainfall can impact on the risk of transmission of vector-borne diseases, including increased surface water can provide breeding sites for vectors, low rainfall can also increase breeding sites by slowing river flow, increase drain can increase vegetation and allow expansion in population of vertebrate host, flooding may eliminate habitat for both vectors and vertebrate hosts and flooding may force vertebrate hosts into closer contact with humans.

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Climate change will have short- and long-term impacts on disease transmission. For example, a short-term increase in temperature and rainfall, as was seen in the 1997-98 El Nino-an example of inter-annual climate variability-caused *Plasmodium falciparum* malaria epidemics in Kenya (Githeko *et al*., 2000). Similarly, malaria outbreak that encompassed wider geographical areas mainly the Highlands of Ethiopia occurred during similar years but only a study in Akaki Town and its environs has been documented (Woyessa *et al.*, 2004). This epidemic may have been due to accelerated parasite development and an explosion of vector populations. There is emerging evidence that, in addition to seasonal extreme climatic events, there is a general elevation of mean temperatures and, in some cases, precipitation (Conawy *et al.*, 2004). However, most of the malaria epidemics that occurred in most parts of Ethiopia during 1997-98 remained undocumented.

Moreover, in Ethiopia, malaria is altitude and climate dependent, while the latter variables such as temperature and rainfall are determined by altitude (Graves *et al*, 2009). Thus, malaria transmission is seasonal and unstable that varies in space and time (Adhanom *et al*., 2006; Tulu, 1993). Many malaria epidemiological studies showed that rise in malaria incidence including devastating epidemics overlapped with abnormal weather conditions (Fontaine *et al*, 1961; Abose *et al*, 2003; Negash *et al*., 2005).

The upper altitudinal limit of malaria transmission was known to be 2000 meters above sea level (masl) (MCP, 1983). Nevertheless, there has been ample evidence that confirmed the encroaching of endemic malaria to high altitudes above 2,000 m and as high as 2,200 masl, respectively (Tulu, 1996; Woyessa *et al*, 2004; Tesfaye *et al*, 2011; Woyessa *et al*, 2012). In support to this evidence, an average increase in the daily minimum temperature of 0.4^{o}C *per* decade for three decades has been recorded in Ethiopia (Conway *et al*, 2004). Additional evidence showed the regional climatic variability/change in the last three decades. For instance, a rise of all temperature variables by 0.2^{o}C *per* decade was observed in the Kenyan highlands since 1979 (Omumbo *et al*., 2011).

A recent study showed an intensive environmental degradation in the East African Highland areas, which presumably exacerbated environmental changes. Thus, huge deforestation and agricultural activities were documented mainly in Ethiopia for consecutive three decades (Himeidan and Kweka, 2012). The ecological changes might have accounted for the creation of favorable conditions for the principal vector to enhance malaria transmission. Studies have shown the role of ecological changes related to deforestation and agricultural activities resulting not only in the rise of malaria incidence but also establishment of malaria transmission where it was non-existent (Lindblade *et al*., 2000; Afrane *et al*., 2006). These human activities exhibited modification of the microclimate that supported malaria transmission.

Moreover, most probably, this temperature rise has favored the occurrence of malaria by keeping minimum temperatures in the highlands above the cut-off for sporogony, or development of the malaria parasite in mosquitoes (Molineaux, 1988).The relationship between global warming and malaria in the highlands has been an important concern. For instance, the resurgence of malaria incidence during the 1990s and beginning of 2000s in the Eastern African Highlands has been associated with global warming (Omumbo *et al*., 2011).

Many researchers engaged in modeling of the potential impacts of global warming on malaria transmission found almost similar findings. Martens*et al*. (2005) suggested that expansion of malaria is more pronounced at the borders of malaria endemic areas and at higher altitudes within malarious areas. Another recent study projected that highlands of Ethiopia and Zimbabwe will likely experience rise of malaria incidence closer to their upper limits of transmission cut-off (Tanser *et al*., 2003). This implies that areas free from malaria transmission due to low temperature located at high altitudes might experience endemic malaria in the future. According to projections in the past the highland areas of Ethiopia and Zimbabwe are among those with expected rise of malaria incidence in higher altitudes.

5.1.2. Dengue

Dengue is is transmitted by *Aedes aegypti* and is well adapted to the urban environment and successfully breeds in containers where water is allowed to accumulate. *Aedes* mosquitoes thrive in warmer environments, but not in dry environments. The disease mainly occurs in urban and peri-urban areas, but also occurs in rural areas. Higher ambient temperatures favor rapid development of the vector, increase the frequency of blood meals, and reduce the extrinsic incubation period (EIP).The EIP is the time taken between the vector ingesting an infective blood meal and being able to transmit the virus in a subsequent feed. A short EIP increases the opportunities for virus transmission during the life time of an infected mosquito. If the ambient temperature is too low, mosquitoes are unlikely to survive long enough to become infectious and pass on dengue (Patz *et al*., 1998).

Dengue infection causes a spectrum of disease, such as from mild flu-like symptoms to severe life threatening hemorrhage (Halstead *et al*., 2007). An estimated 2.5 billion people are at risk of dengue, in tropical and subtropical areas throughout the world (WHO, 2008). Van Kleef*et al.* (2009) indicated that dengue pandemic was identified during the19th century. The outbreak was believed to have started and ended in Tanzania in 1870, East Africa. Then it spread towards Egypt, Saudi Arabia (Jeddah, Mecca and Medina), Yemen (Aden), India, China, Indonesia, Indochina (Vietnam, Laos and Cambodia) and then back to Mauritius in 1873.

A literature has shown that dengue was relatively uncommon in East Africa before 1952. However, outbreaks were documented in several countries between1924and1950; Mozambique, Madagascar, Ethiopia, Somalia, and the Comoros. A recent study indicated that dengue was present in Ethiopia (Dire Dawa and Harrar), Somalia (Mogadishu), Madagascar (Diego Suarez) and in the Comoros Islands (Mayotte) and in other parts of Somalia (Kismayu, Berbera and Hargeisa) and Mauritius (McCarthy and Bagster, 1948). A review summarized that the Comoros, Ethiopia, Kenya, the Seychelles, Somalia, Tanzania, Réunion, Mauritius, and Mozambique were considered to be endemic from 1975 to1996 (van Kleef *et al*., 2009). The same authors showed that dengue occurs sporadically in Kenya and Somalia four major outbreaks between1982 and 1993 in various regions of Somalia. This review didn't uncover any notable outbreak for Ethiopia. There was an outbreak in Eritrea in 2005 (WHO, 2009).

As seen in malaria epidemiology, suitable climate is a necessary, but not on its own, sufficient factor for dengue transmission. A source of infection (either locally acquired or imported), a competent vector, and vector contact with a susceptible human population must all be present for dengue transmission to occur. Climatic conditions provide an absolute constraint on the geographic area suitable for transmission of dengue, but within climatically suitable areas, non-climate factors are important in determining the extent to which transmission of dengue actually occurs.

A study in Buenos Aires, Argentina, noted that the highest abundances in breeding of *Aedes* mosquitoes after several months with mean temperatures above 20^{o}C and accumulated rainfalls above150mm. A sharp decline in egg laying was observed when monthly mean temperature declined to 16.5^{o}C, and no eggs were found below14.8^{o}C (Vezzani *et al*., 2008). A dramatic increase in the incidence of dengue in the past 50 years and some geographic expansion of transmission has been documented (Nathan *et al*., 2009). Recently, local transmission of dengue has been reported for the first time in several African countries Bhutan; Nepal and France (Dorji *et al*., 2009; Pandey *et al*., 2008; La Ruche *et al*., 2010). For example, unpublished report showed the occurrence of outbreaks of dengue fever in East Ethiopia during 2013/2014.A review has demonstrated that dengue has also returned after many decades of absence in Hawaii and Florida, USA (van Kleef, 2009). The reasons for the emergence of dengue are complex and not completely understood. Probable causes include, increases in poor urban populations, breakdown in public health measures, especially vector control Programmes, increased travel and trade, and environmental disturbances (van Kleef, 2009).

In summary, dengue is endemic in urban populations in tropical countries. Large epidemics of dengue have occurred less frequently in subtropical regions, and rarely in cities in temperate regions. Although the exact boundaries of current and historical transmission are impossible to establish with certainty, we conclude that despite increases in the geographic distribution of dengue in recent decades, the current distribution of the disease is less extensive than its historical limits. This geographic contraction has occurred at the same time as increases in incidence in many countries.

An important question is "Has climate change played a role in the resurgence of dengue?" Surface temperature has increased by a global average of 0.75°C in the past century. The current understanding is that temperature increases of this magnitude are associated with substantial increases in dengue epidemic potential. Given that transmission also depends on the interaction between numerous non-climatic local factors (e.g. breeding sites, shelter, urban features, poverty, surveillance and control measures), the impact of climate change cannot be quantified, based on current evidence. On the basis of theoretical grounds, however, climate trends will have exacerbated the effects of other factors, at least in some areas (van Kleef, 2009). Wu *et al*. (2009) used regression models incorporating spatial lags to fit climate and environmental data to smoothed rates of dengue notifications (1988–2002) within Taiwanese townships. Months with temperature >18°C and urbanization were important predictors. The estimated "population at risk" (the number of people living in transmission risk zones) approximately doubled for each1°C increase in temperature.

5.1.3. Tick-Borne Diseases

Ticks transmit several rickettsial and other non-viral pathogens to humans. Since ticks are ecto-parasites, their geographical distribution depends primarily upon the distribution of suitable host species, usually mammals or birds. Additionally, the distribution of ticks is further determined by climatic factors, predators and habitat. Ticks require sufficiently high temperatures for completion of their life cycles, and low enough in winter to suspend the life cycle. However, ticks need sufficient humidity to prevent dying out of their eggs.

Currently, tick-borne diseases are becoming a serious problem. This has been associated with people increasingly build homes in formerly uninhabited wilderness areas where ticks and their animal hosts live. However, in Ethiopia, information on the transmission of human zoonotic pathogens through ixodid ticks remains scarce. An infection with *R. africae* was reported in a man in France who recently returned from Ethiopia. A 62-year French man confirmed to be *R. africae* positive after he had spent a month in southwest Ethiopia, north of Kelem near the Sudanese border, and returned to France on October 26, 2005. While in Ethiopia, the subject had been in contact with cattle in the villages related to his duties by then. A study confirmed the presence of *R. africae* in ticks collected from Ethiopia, as well as *R.aeschlimanii* (Mura *et al.*, 2008). Thus, evidence of *R. africae* in Ethiopia has been known for a long time. Another recent study conducted between 2011 and 2014 demonstrated the occurrence of spotted fever group rickettsiae in various areas of Ethiopia (Kumsa *et al.*, 2114). This implies that transmission of spotted fever group rickettsiae through ixodid ticks is a potential risk for human health in different parts of Ethiopia. Tick-borne diseases can be caused by viruses, bacteria, or parasites. Most people become infected through tick bites during the spring and summer months.

More interestingly, most of the evidence related to tick-borne diseases comes from the United States. Rocky Mountain spotted fever, tularemia, Lyme disease, human granulocytic ehrlichiosis/anaplasmosis, and human monocytic ehrlichiosis are reportable tick-borne pathogens in the country in 1998. Except for tularemia, all of these illnesses have since increased in annual incidence and many more have been added to the list (Institute of Medicine unpublished report, 2011). Lyme disease, for example, increased 101% from 9908 reported cases in 1992 to 19,931 cases in 2006 (Bacon *et al.*, 2008). According to CDC, around 300,000 Americans are diagnosed with Lyme disease each year (CDC, 2013). The exact figure of Lyme disease is approximately about 10 times greater than the number of annual reported cases in the United States. Thus, tick-borne infection is a significant public health problem (CDC, 2013).

Moreover, national and regional epidemics of tick-borne infections in Central and Eastern Europe, India, Turkey, Russia, and the US has been documented since the end of the 20th century and the beginning of the 21st century (IMC, 2011). Thus, there is a recognizable concern about the increasing prevalence of tick-borne illnesses. Climate change is suggested to have influenced the rise of tick-borne diseases. In the US, average daily temperatures since 1900 have risen by 0.4^{o}C. This change has largely occurred over the past 30 years (Githeko *et al.*, 2000). Climate change is predicted not only to cause warmer temperatures, but to increase rainfall, droughts, wildfires, and natural disasters (Greer *et al.*, 2008). The resulting environmental transformation will alter the Earth's complex ecosystems, affecting the life cycles of vectors and their hosts. An important potential consequence is the increased risk of disease transmission (Githeko *et al.*, 2000).

The mechanisms about how the climate could influence the transmission of tick-borne diseases, especially from North America, is illustrated below. As ticks spend most of their life cycle detached from their hosts, climate plays a vital role in the dispersal of tick populations across the United States (Brownstein *et al.*, 2005). Tick is an arachnid in which its life cycle begins at the egg, and then progresses to larva and nymph stages before growing to adulthood. After hatching from the egg, a tick needs to consume blood at every stage to live (CDC, 2014). Humidity of above 85% and temperatures over 7^{o}C are required for the life cycle to continue. A rise in temperature up to a certain limit can accelerate the developmental cycle, increase egg production, and increase tick population density (Süss *et al.*, 2008). Greater rainfall can also increase the amount of breeding sites for ticks (Githeko *et al.*, 2000). In fact, regions with the highest average rainfall correlate with high tick populations (Süss *et al.*, 2008).

Moreover, a rise in tick populations will result in an expansion of their geographical distribution in North America, particularly at higher latitudes where there will be an increase in minimum temperatures. The increased number of ticks may also lead to increased tick-human interactions. Currently, the close proximity of humans, tick vectors, and deer has increased the transmission of tick-borne pathogens. An earlier study indicated the geographic expansion of areas with adequate habitat suitability of *Ixodes* *scapularis*, a tick transmitting Lyme disease, in the United States between 1982 and 2000 (Estrada-Peña, 2002). Additionally, the same author found increase in winter temperatures and in vegetation vitality was a key to habitat switch from unsuitable to suitable in countries with different degrees of habitat suitability.

In addition, a link between climate change and increased transmission of tick-borne diseases is confounded with numerous variables such as socioeconomic factors, human migration and settlement, human behavior, changes in land cover, and population immunity. All these variables are known to play a role in incidence of infection. These variables are also affected by global warming, resulting in a convoluted pattern of interactions that make it difficult to identify the exact element responsible for increased disease transmission (Gray *et al.*, 2009). However, some still argue that increased awareness or better diagnostic testing caused the rise in incidence of tick-borne diseases in the US.

5.1.4. Other Vector-Borne Diseases

Trypanosomiasis is a parasitic disease which occurs in large areas of Africa, Latin America, the Middle East and Asia. It affects most species of domestic livestock, many types of wild animals and humans. Human African Trypanosomiasis (HAT), also known as ‘sleeping-sickness’, is a vector-borne parasitic disease. It is transmitted through bites from the tsetse fly. Human African trypanosomiasis takes two forms, depending on the parasite involved: *Trypanosoma brucei gambiense* found in west and central Africa, currently accounts for over 95% of reported cases of sleeping sickness and causes a chronic infection. *Trypanosoma brucei rhodesiense* found in eastern and southern Africa represents less than 5% of reported cases and causes an acute infection (WHO, 2014).

The most important trypanosomes in terms of economic loss in domestic animals are the tsetse fly-transmitted species Trypanosoma congolense, T. vivax and T. brucei. Closely related subspecies T.b.rhodesiense and T.b.gambiense cause human sleeping sickness. The distribution of African trypanosomiasis in domestic animals and humans coincides with the known distribution of tsetse fly vectors. Tsetse flies (*Glossina* species) inhabit a wide range of habitats covering over 10 million km^2, representing 37% of the African continent and affecting 38 out of a total of 55 countries. Approximately, 30% of the total cattle population in Africa and about 50 million people are exposed to bovine trypanosomiasis and human sleeping sickness, respectively (Abebe G, 2006).

The distribution of endemic human trypanosomiasis and its tsetse vectors appear to be limited to southern and southwestern Ethiopia. The human disease, based on case reports, occurs in Oromiya Region (Illubabor and Wollega), Gambella, and Southern Nations Nationalities and Peoples Region (SNNPR). The disease is caused by the protozoan parasite *Trypanosoma brucei rhodesiense* (Abebe G, 2006).

African human trypanosomiasis was first seen in Ethiopia in March 1967 (Baker and McConnell, 1969). In addition, between March 1967 and March 1968, four cases were recorded; in the following 12 months the total had risen to 95 (Baker *et al.*, 1970). The disease occurs mainly in an area of southwestern Ethiopia bounded to the north by the Baro River, to the south by the Akobo River and to the east by the escarpment leading up to the central Ethiopian plateau: its western limits are uncertain. Within this area there are centres of infection, associated mainly with the Gilo River and a low-lying moist region north of it. The disease is of the acute type, caused by *Trypanosoma brucei rhodesiense*. Two men probably acquired the infection in that region in 1967 and one in 1968. A blood film survey of 430 people in 1968 failed to reveal any further infections, and it is probable that here the disease is a zoonosis, transmitted to man sporadically by *Glossina morsitans* and, perhaps, *G. pallidipes* and *G. fuscipes*.

Although the first confirmed case of human trypanosomiasis in Ethiopia was reported in 1967, a major outbreak of the disease was not recorded until the 1969-1970 epidemics. Only sporadic cases have been reported between 1977 and 1983 (Abebe , 2006). The specific areas from where human trypanosomiasis have been reported include, Gambella during the 1969 epidemic and sporadic cases from the Gamo Gofa (Morsi-Bodi *Woreda*), Keffa (or Maji area) and Wollega (resettlement area in Anger-Didessa Valley). These three cases must be considered the tip of the iceberg, with many cases going unreported due to lack of diagnostic facilities (Abebe , 2006).

The potential area of tsetse infestation has been variously estimated. Thus, based on an estimated breeding limit of 1,500 m altitude with a total surface area of 66,000 km^2 , 1,600 m altitude with a total surface area of 97,855 km^2, and 1,700-2,000 m altitude with a total surface area of between 135,000 and 220,000 km^2 (Abebe , 2006). Evidence show that tsetse flies in Ethiopia are confined to the southern and western regions between longitudes 33^o and 38^{o}E and latitude 5^o and 12^{o}N, with an estimated area infested with flies amounting to 97,855 km^2. The infested area extends from the southern part of the Rift Valley, around the southwestern corner of the country and along the western lowlands and escarpments north of the Blue Nile Basin (Abebe , 2006).

5.1.5. Near-Term Future

In summary, vector-borne diseases will be affected by global climate change. Probably, malaria is likely to spread locally, especially into altitudes that are adjacent to current endemic areas. In fact, the highland-fringe and highland areas of Ethiopia are known to be receptive to malaria transmission that experienced outbreaks of varying intensity in the past. However, the strength and sustainability of health system and control efforts underway play an important role in the future expected distribution and intensity of malaria. Effective public health programmes, using control measures such as quarantine, vaccination, drug treatment and pesticide application, can limit the geographical distribution of vector-borne diseases (McMichael *et al*., 1996).

5.2. Food- and Water-Borne Infections

Global warming is expected to cause more variable precipitation, with an increase in the frequency and intensity of both floods and droughts. Thus, disease transmission may be enhanced through the scarcity and contamination of potable water sources. According to the World Health Organization (WHO) almost 90% of the burden of diarrheal disease is attributable to lack of access to safe and adequate water, sanitation (WHO, 2009a). Additionally, reductions in the availability and reliability of fresh water supplies are expected to amplify the disease burden. Previous estimations showed that 1.1billion people do not have access to safe and adequate supplies of safe water, and 2.4 billion people do not have access to adequate sanitation (WHO, 2009b). Thus, under global warming situation the prevailing shortage of safe water might be exacerbated mainly in developing countries. Globally, childhood diarrhea is already a major cause of premature mortality. Under deteriorating conditions of water qualities epidemics of cholera, typhoid, and similar diseases can be expected (Hunter, 2003).

A review in the past by Esrey and co-workers (1991) demonstrated that improved water supply and sanitation result in substantial reductions in morbidity from diarrhea(26%), ascariasis (29%),guinea worm infection (78%),schistosomiasis (77%), trachoma(27%) and a median reduction of 65% in diarrhea-specific mortality and 55% in general child mortality. This review compromised 144 water and sanitation interventions conducted in various developing countries and in the U.S. to assess the association of the interventions and reduction in disease burden. The authors recommended that nearby water supply and hygienic practices be integrated into water supply and health programs.

Climate change is emerging as a major threat to health and adding pressure on public health systems, especially in Africa. It causes a rise in sea levels, accelerates erosion of coastal zones, increases the intensity and frequency of natural disasters and accelerates the extinction of species (Hunter, 2003). Moreover, climate change jeopardizes the quality and availability of water and food, which are the fundamental determinants of nutrition and health. Thus, waterborne diseases and epidemics of acute diarrhea are rampant in flood situations. Malnutrition and climate-related infectious diseases will seriously affect the most vulnerable segment of the population including, small children, the elderly and the infirm. Moreover, women living in poverty also face particular risk when natural disasters and other global warming-related dangers strike (Hunter, 2003).

5.2.1. Vibrios

Cholera is an indirectly transmitted water-borne disease transmitted by water vehicle: the bacteria (*Vibrio cholerae*) reside in marine ecosystems by attaching to zooplankton. Survival of these small crustaceans in turn depend on the abundance of their food supply, phytoplankton.

The mechanisms how global warming could facilitate cholera are described as follows. The most important ways through which climate influences the epidemiology of water-borne disease are heavy rainfall events, flooding and increased temperature. First, evidence comes from developed countries and showed the linkage of heavy rainfall and occurrence of outbreaks. Most of the outbreaks were due to contamination of water sources. The presence of various organisms in water is also additional evidence to verify the impact of heavy rainfall on the epidemiology of enteric pathogen. For example, there is a correlation between rainfall and the likelihood of detecting Giardia or Cryptosporidium oocysts in river water and pathogenic enteric viruses in water (Hunter, 2003). Heavy rainfall leads to storm water runoff into surface water sources, which has high counts of indicator bacteria as well as potential pathogens. It is also associated with high counts of indicator bacteria in river waters and marine waters. Given the well described relationships between counts of indicator organisms in surface water and the subsequent risk of predominantly gastrointestinal illness, it should be expected that people swimming in untreated surface waters after heavy rain would be at increased risk of illness (Hunter, 2003).

Second, flooding is an impact factor that affects the epidemiology of water-borne diseases. Flooding could follow due to either heavy rainfall or tidal surges and rapid snowmelt. The health effects of flooding can be divided into those associated with the acute event and those arising after the flood has resolved. Drowning is the main acute health effect and occurrence of outbreaks as a result infectious diseases as the significant health effect following flooding. However, evidences are limited from developing countries. Both acute diarrheal and acute respiratory disease increased in Nicaragua. In addition, Hepatitis E, malaria and diahorreal disease have followed floods in Khartoum (Hunter, 2003).

Third, probably the most obvious link between water-borne disease and increased temperature relates to the blooms of various planktonic species that are directly or indirectly hazardous to human health. The most evidence of the effect of temperature on risk from water-borne disease is in relation to cholera. There is now good evidence that *V. cholerae* survives in marine waters in available but non-cultural form that seems to be associated with algae and plankton. Phytoplankton populations tend to increase (or bloom) when ocean temperatures are warm. Consequently, increases in sea-surface temperature as a result of El-Niño events have been shown to precede increases in cholera incidence in both Asia and South America (Lobitz *et al*., 2000; Pascual *et al*., 2000; Speelmon *et al*., 2000).

5.2.2. Other Parasites, Bacteria and Viruses

Yellow fever (YF) is one of the major infectious diseases that affects humankind. Predominantly, the disease occurs in some tropical regions of South America and Africa. It is estimated that 200,000 cases of yellow fever occur annually, resulting in about 30 000 deaths. Of these, 90% of cases occur in Africa. In East Africa, yellow fever remains as a disease of increasing epidemic risk. For example, Uganda (late 2010), Sudan (in 2003 and 2005) and Kenya (1992-1993) yellow fever outbreak was reported by the WHO (WHO, 2013). In most of the cases the epidemic occurred after several years of absence, 2-5 decades.

Over the last two decades, the number of yellow fever epidemics has risen and more countries are reporting cases. Ethiopia is also among the East African countries stricken by yellow fever outbreak in 2013 (EPHI, 2013 unpublished report). The outbreak attacked areas in southwestern Ethiopia, similar areas where it has been reported as outbreak between 1959 and 1962. Changes in the world's environment, such as deforestation and urbanization, have increased contact with the mosquito/virus. Wide spread international travel plays an important role in spreading the disease. The recent epidemics clearly indicate the vulnerability and potentiality of the yellow fever as a global public health threat in the changing environment (Karunamoorthi, 2013).

Thirty-two African countries are now considered at risk of yellow fever, with a total population of 610 million people, among which more than 219million live in urban settings (WHO, 2012). Yellow fever has shown come back during the 1980s after its declining for many years in endemic countries and the rest of the world too (WHO, 2007). The resurgence of yellow fever is also closely connected with changes in the modern world and with the interaction of various economic, climatic, social and political factors (Cardona, 2003). Gardner and Ryman (2010) suggested that the recent epidemics, especially in densely populated, poor urban settings, both in Africa and South America, has greatly increased due to: (1) reinvasion of urban set- tings by the mosquito vector of yellow fever, *Ae. aegypti*; (2) rapid urbanization, particularly in parts of Africa, with populations shifting from rural to predominantly urban; and (3) waning immunization coverage.

The disease maintains its transmission using a complex life cycle and non-human reservoirs. The virus is maintained in endemic areas of Africa and South America by enzootic transmission between mosquitoes and monkeys in which the epidemiology of the disease reflects the geographical distribution of the mosquito vectors (Galbraith and Barrett, 2009). In addition, the enzootic transmission cycle involves tree-hole-breeding mosquitoes such as *Aemagogus janthinomys* (South America) and *Ae. Africanus* (Africa) and nonhuman primates. More interestingly, there is also vertical transmission of the virus. The virus passes from the female mosquito to her progeny and from congenitally infected males to females during copulation. Virus in the egg stage provides a mechanism for virus survival over the dry season when adult mosquito activity and horizontal transmission abate. The virus is maintained over the dry season by vertical transmission in mosquitoes. Ova containing virus survive in dry tree-holes and hatch infectious progeny mosquitoes when the rains resume (Monath, 2006).

Yellow fever is the viral disease transmitted by an arthropod with potential to be prevented using vaccination. However, the disease remained the most feared and severe in the 21st Century. Karunamoorthi (2013) suggested that the major contributing factors for the resurgence of yellow fever such as global warming, land use changes, uncontrolled population growth, unchecked urbanization, rural - urban migration, international trade, conflict and civil disruption. Despite the presence of tools for diagnosis, vector con-trol, vaccine and surveillance system for yellow fever the endemic countries had extremely poor or inadequate implementation of programs. In addition, the global-warming concomitant effect immensely contributed to the high reproduction rate and the capacity of insect vectors to establish and to adapt to new environmental conditions.

5.2.3. Near-Term Future

Probably, food-and water-borne infections might become the major health outcomes with more cases and deaths following the repeated occurrence of extreme climate events such as increased temperature, heavy rainfall and associated factors. As already mentioned in previous section of this document, improvement in health system is expected to play a crucial role in counteracting the escalation of infection and diseases as well as deaths. For instance, Hunter (2003) showed that developed countries (e.g. United Kingdom) with repeated events of flooding, but with strong health system remained less affected by diahorreal cases despite encountering flooding events, unlike developing countries (e.g. Bangladesh).

5.3. Air Quality

5.3.1. Long-Term Outdoor Ozone Exposures

High temperatures also raise the levels of ozone and other air pollutants that exacerbate cardiovascular and respiratory diseases, and pollen and other aeroallergens that trigger asthma (WHO, 2009b). There are serious risks to health not only from exposure to particulate matter (PM), but also from exposure to ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) (WHO, 2009b). The long term exposure to PM and the gases are known to have health impacts. For instance, a review has shown evidence of linking long-term exposure to PM and NO_2, with the development of heart failure (WHO, 2009b). Similarly, the same document showed associations between PM and incident coronary heart disease (CHD), myocardial infarction, stroke, and arrhythmias, which were close to unity. But the association increased for heart failure and PM. Increased incidence of heart failure was also positively associated with NO_2 and SO_2. Previously, Elliot *et al*. (2007) reported positive associations between black smoke and SO_2 and subsequent mortality in Great Britain using small-area population and socioeconomic status statistics. But data on individual risk factors is lacking. More recently, a large representative study of the UK population reported on long-term effects in relation to the prevalence of CHD and found small associations with PM_{10} (Forbes *et al*., 2009).

Moreover, excessive Ozone (O_3) in the air can have a marked effect on human health. O_3 can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases. O_3 is among an important factor in asthma morbidity and mortality, while NO_2 and SO_2 also can play a role in asthma, bronchial symptoms, lung inflammation and reduced lung function (WHO, 2014). In fact, O_3 at ground level is one of the major constituents of photochemical smog and different from the ozone layer in the upper atmosphere.

Normally, O_3 is formed by the reaction with sunlight (photochemical reaction) of pollutants such as nitrogen oxides (NO_x) from vehicle and industry emissions and volatile organic compounds (VOCs) emitted by vehicles, solvents and industry. As a result, the highest levels of ozone pollution occur during periods of sunny weather. In Europe, it is currently one of the air pollutants of most concern. Several European studies have reported that the daily mortality rises by 0.3% and that for heart diseases by 0.4%, per 10 µg/m^3 increase in ozone exposure (WHO, 2014).

5.3.2. Acute Air Pollution Episodes

Extreme high air temperatures can kill directly; it has been estimated that more than 70,000 excess deaths occurred in the extreme heat of summer 2003 in Europe (WHO, 2009b). By this second half of this century, such extreme temperatures will be the norm. In addition, rising air temperatures will increase levels of important air pollutants such as, ground-level zone, particularly in areas that are already polluted. Urban air pollution currently causes about 1.2 million deaths each year (WHO, 2009b), mainly by increasing mortality from cardiovascular and respiratory diseases.

In addition, in Ethiopia, *indoor air pollution* is among the very serious environmental problems that causes acute respiratory illness (ARI), particularly in women and children (European Commission, 2007). The prevalence of ARI among children under five is 13% (European Commission, 2007). These problems are mainly associated with source of energy for cooking, heating and lighting by poor households. These sources include traditional polluting stoves and woody biomass. About 95% of Ethiopia’s energy supply comes from woody biomass, mainly fuel wood (77%), dung (8%), crop residues (9%) and charcoal (1%) (European Commission, 2007). A number of empirical studies confirm links between exposure to indoor air pollution and the incidence of respiratory diseases and a variety of peri-natal health hazards arguably due to maternal exposure during pregnancy(Ezzati and Kammen, 2002; Smith *et al*., 2004). Women and girls are also particularly vulnerable to environment-related diseases due to their increased exposure to in-door air pollution and the heavy burden of fetching water and biomass fuel on a daily basis. Consequently, girls are deprived of their right to schooling due to their responsibilities to do household roles.

In addition, urban ambient air pollution causes approximately 800,000 deaths *per* year worldwide (WHO, 2002).Other studies on indoor air pollution from solid-fuel use (Wang and Smith, 1999; Bailis *et al*., 2005) that kill over 1.5 million each year and is still widespread among the poorest populations in developing-country cities (WHO, 2006).

5.3.3. Aeroallergens

Human activities are resulting in increases in atmospheric greenhouse gases, such as carbon dioxide, and changes in global climate. There is now considerable evidence to suggest that climate change will have, and has already had, impacts on aeroallergens. These include impacts on pollen amount, pollen allergenicity, pollen season, plant and pollen distribution, and other plant attributes. There is also some evidence of impacts on other aeroallergens, such as mold spores (Beggs, 2004). Aeroallergens are sensitive to meteorological conditions such as temperature and humidity. Allergic diseases can manifest with skin or respiratory symptoms, including atopic dermatitis, commonly known as eczema; allergic rhinitis, commonly known as hay fever; and some types of asthma. Although the etiology of allergic diseases is genetic and environmental, the specific attributable risk from various environmental exposures is a topic of research (Liu *et al*., 2009). Thus, climate change is expected to result in the rise of non-communicable diseases such as respiratory and cardiac diseases. For instance, the global rise of pediatric allergic diseases, mainly in developed countries is well documented (Maziak *et al*, 2003).

It has been documented that this rise is attributed to demographic transitions in both developed and developing countries, but is not completely understood (Harper and Armelagos, 2010). However, there is limited information from developing countries, unlike developed countries.

In this paper, evidences are compiled to learn about the effect of allergen exposure in childhood on the development and symptoms of allergic diseases and burden in relationship with climate change. The seasonality of pollen, which is beginning earlier in the year, for a number of species in various parts of the globe has been reported (Clot, 2003; Emberlin *et al.*, 2002; Levetin and Van de Water, 2008; Rasmussen, 2002; Teranishi *et al.*, 2006). This implies allergic diseases induced due to pollen are indirectly associated with climatic conditions. Moreover, studies indicated a trend towards increasing annual pollen production in some European species over the last 30 years (Rasmussen, 2002; Spieksma *et al*., 2003).

Probably, therefore, future climate change could affect the timing and severity of the pollen season. On one hand, a review has shown that higher temperature and greater precipitation prior to the pollen season leads to increased production of many types of tree and grass pollen. For example, ragweed pollen production has been observed to increase in response to increased temperatures and concentrations of atmospheric carbon dioxide (Sheffield *et al*., 2011). The relation of a number of pollen types to meteorological variables has been examined. However, only a few clinically-relevant outdoor fungal species, such as *Alternaria* and *Cladosporidium*, have been similarly investigated (Sheffield *et al*., 2011). Moreover, many studies have also found that increased atmospheric concentrations of some mold spore types are associated with increased temperature and humidity (Freye *et al.,* 2001*;* Katial *et al.*, 1997; Troutt and Levetin, 2001). A study also confirmed that maximum mold concentrations occurred earlier than normal in the year following the warm, wet conditions of the 1997-1998 El Nino event (Freye *et al.,* 2001), indicating that the timing of mold counts could also be affected by climate change.

On the other hand, studies demonstrated that aeroallergens such as pollen and mold can worsen symptoms of allergic diseases in already affected individuals. For instance, a study that assessed the relationship of daily ambient pollen and fungus concentrations with the severity of childhood asthma concluded that weed pollen appeared to be associated with asthma exacerbations and use of emergency and hospital services (Schmier and Ebi, 2009). Another study also found an association between pediatric emergency department asthma visits and daily grass pollen concentrations (Heguy *et al.*, 2008). The association of damp indoor spaces and mold with respiratory symptoms and asthma symptoms was demonstrated in people who are already sensitized. However, there is only limited or suggestive evidence regarding the association of damp indoor spaces with respiratory illness in otherwise healthy children or the development of asthma in susceptible persons. Thus, while exposure to aeroallergens can exacerbate existing allergic diseases, their role in the development of allergic disease is less understood (Pedon, 2000).

Outdoor air pollution is a major environmental health problem affecting many countries. For example, in 2012, ambient (outdoor air) pollution was estimated to cause 3.7 million premature deaths worldwide in both cities and rural areas (WHO, 2014). About 80% of outdoor air pollution-related premature deaths were due to ischaemic heart disease and strokes, while 14% of deaths were due to chronic obstructive pulmonary disease or acute lower respiratory infections; and 6% of deaths were due to lung cancer. However, some deaths may be attributed to more than one risk factor at the same time. For example, both smoking and ambient air pollution affect lung cancer. Some lung cancer deaths could have been averted by improving ambient air quality, or by reducing tobacco smoking (WHO, 2014).

Moreover, outdoor air pollution is carcinogenic to humans, with the particulate matter component of air pollution most closely associated with increased cancer incidence, especially lung cancer (WHO, 2014). An association has also been observed between outdoor air pollution and increase in cancer of the urinary tract/bladder. Most of the outdoor air pollution burden (88%) was known to be accounted by low- and middle-income countries in which the greatest burden was from the WHO Western Pacific and South-East Asia regions (WHO, 2014).

Additionally, indoor smoke is also a serious health risk for some 3 billion people, who cook and heat their homes with biomass fuels and coal (WHO, 2014). Some 4.3 million premature deaths were attributable to household air pollution in 2012 (WHO, 2014). Almost that entire burden was in low-middle-income countries as well. The WHO recommended that air pollution-related deaths could be reduced by around 15% using a method that brings annual average particulate matter (PM_{10}) concentrations from levels of 70μg/m^3 to 20μg/m^3 level. However, it is estimated that average life expectancy is 8.6 months lower than it would otherwise be, due to PM even in the European Union, where PM concentrations in many cities do comply with Guideline levels (WHO, 2014).

In developing countries, indoor exposure to pollutants from household combustion of solid fuels on open fires or traditional stoves increases the risk of acute lower respiratory infections and associated mortality among young children. Moreover, indoor air pollution from solid fuel use is also a major risk factor for cardiovascular disease, chronic obstructive pulmonary disease and lung cancer among adults (WHO, 2014). There are serious risks to health not only from exposure to PM, but also from exposure to ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). As with PM, concentrations are often highest largely in the urban areas of low- and middle-income countries. Ozone is a major factor in asthma morbidity and mortality, while nitrogen dioxide and sulfur dioxide also can play a role in asthma, bronchial symptoms, lung inflammation and reduced lung function (WHO, 2014).

The major sources of anthropogenic emissions of Nitrogen dioxide (NO_2) are combustion processes (heating, power generation, and engines in vehicles and ships). Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2. Reduced lung function growth is also linked to NO_2 at concentrations currently measured (or observed) in cities of Europe and North America (WHO, 2014).

Studies indicate that a proportion of people with asthma experience changes in pulmonary function and respiratory symptoms after periods of exposure to Sulfur dioxide (SO_2) as short as 10 minutes (WHO, 2014). SO_2 is a colorless gas with a sharp odor and it is produced from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulfur. The main anthropogenic source of SO_2 is the burning of sulfur-containing fossil fuels for domestic heating, power generation and motor vehicles. SO_2 can affect the respiratory system and the functions of the lungs, and causes irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract (WHO, 2014) Hospital admissions for cardiac disease and mortality increase on days with higher SO_2 levels. When SO_2 combines with water, it forms sulfuric acid; this is the main component of acid rain which is a cause of deforestation. Although the causality of the effects of low concentrations of SO_2 is still uncertain, reducing SO_2 concentrations is likely to decrease exposure to co-pollutants (WHO, 2014).

Moreover, the effect of outdoor aeroallergen exposure in asthma may be enhanced by air pollutants, including ozone, nitrogen dioxide and particulates, and by certain weather conditions. An earlier study in UK found that rainfall and thunderstorms are important effect modifiers in the relation between grass pollen and measures of acute asthma morbidity (Lewis *et al.*, 2000). .

The increase in the prevalence of allergic respiratory diseases such as bronchial asthma in recent years, especially in industrialized countries, may be explained by changes in environmental factors, including indoor and outdoor air pollution. A body of evidence suggests that urbanization, with its high levels of vehicle emissions, and a westernized life style are linked to the rising frequency of respiratory allergic diseases observed in most industrialized countries (D´Amato *et al.,* 2005). In addition, there is considerable evidence that asthmatic persons are at increased risk of developing asthma exacerbations with exposure to O_3, NO_2, SO_2 and inhalable PM (D´Amato *et al.,* 2005). However, it is not easy to evaluate the impact of air pollution on the timing of asthma exacerbations and on the prevalence of asthma in general. As concentrations of airborne allergens and air pollutants are frequently increased contemporaneously, an enhanced IgE-mediated response to aeroallergens and enhanced airway inflammation could account for the increasing frequency of allergic respiratory allergy and bronchial asthma (D´Amato *et al.,* 2005).

5.3.4. Near-Term Future

Over last three decades, studies have shown changes in production, dispersion and allergen content of pollen and spores, which may be region- and species-specific. In addition, these changes may have been influenced by urban air pollutants interacting directly with pollen. Data suggest an increasing effect of aeroallergens on allergic patients over this period, which may also imply a greater likelihood of the development of an allergic respiratory disease in sensitized subjects and exacerbation of symptomatic patients. There are a number of limitations that make predictions uncertain, and further and specifically designed studies are needed to clarify current effects and future scenarios (Cecchi *et al*., 2010).

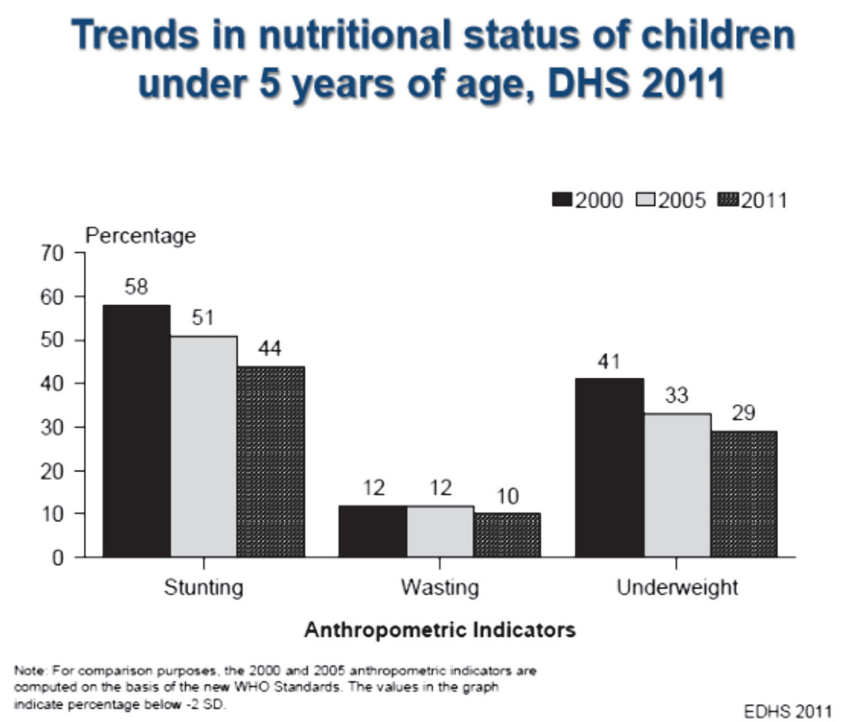
6. Health Impacts Heavily Mediated through Human Institutions

6.1. Nutrition

Undernutrition remains one of the world's most serious, but least addressed socioeconomic and health problems (Horton *et al.,* ,2009; Food and Agriculture Organization of the United Nations, 2010; Scaling Up Nutrition (SUN), 2010). The number of people suffering from hunger stood at 925 million in 2010 and maternal and child under nutrition remain pervasive (Food and Agriculture Organization of the United Nations, 2010; Black *et al.*, 2008). In developing countries nearly one-third of children are underweight or stunted (Horton *et al*., 2008). Under nutrition, including micronutrient deficiencies (also referred to as "hidden hunger") is caused by inadequate dietary intake and disease which in turn stem from food insecurity, poor maternal and child care practices and inadequate access to clean drinking water and safe food, sanitation and quality health services. The human and socioeconomic costs of under nutrition are enormous, falling hardest on the poorest, especially on women and children (Horton*et al.,,*2009; Scaling Up Nutrition (SUN), 2010). Under nutrition interacts with infectious disease, causing an estimated 3.5 million preventable maternal and child deaths annually Scaling Up Nutrition (SUN), 2010); Black, 2008 . The resulting impacts in terms of lost national productivity and economic growth are huge, and the recent food and economic crises and economic downturn have magnified the challenge of hunger and undernutrition (Horton et al., 2009; Scaling Up Nutrition (SUN), 2010 and Bloem et al., 2010).

Climate change affects food and nutrition security and further undermines current efforts to reduce hunger and protect and promote nutrition (Easterling ,2007; Confalonieri, 2007; Costello , 2009 ; Nelson , 2009 ; Food and Agriculture Organization of the United Nations (FAO), 2008; United Nations Children's Fund (UNICEF) 2007; World Health Organization 2008; Parry et al., . (2009) and United Nations Standing Committee on Nutrition, 2010). Additionally, under nutrition in turn undermines the resilience to shocks and the coping mechanisms of vulnerable populations, lessening their capacities to resist and adapt to the consequences of climate change. Climate change directly affects food and nutrition security of millions of people, undermining current efforts to address under nutrition, one of the world's most serious, but least addressed socioeconomic and health problems (United Nations Systems, 2010)

In Ethiopia, malnutrition particularly under nutrition is one of the public health problems that warrant special attention for intervention. The major problems are protein-energy malnutrition and micronutrient deficiencies such as vitamin A, iron, and Iodine. Those are responsible for the morbidity and mortality among the general community although, children and women are affected most. National Nutrition strategy has been developed to address the policy issues in relation to health and nutrition (Central Statistical Agency, 2011).



The Federal Ministry of Health of Ethiopia (FMOH) has set the following initiatives and targets to deal with nutritional problems in the country. The targets are mentioned as shown below (FMOH, Ethiopia, 2010):

- Decrease wasting prevalence among children under 5 from 11% to 3%; and stunting prevalence from 46% to 37%
- Increase the proportion of newborns breastfed within one hour of birth from 69% to 92%
- Increase the proportion of exclusive breast feeding of 0-6 months from 49% to 70 %
- Increase the proportion of infants of 6 -9 months introduced to complementary food and &continuation of breastfeeding from 54% to 65%
- Increase the proportion of under 5 children managed for severe malnutrition from 23% to 91%.
- Achieving cure rate > 75%, defaulter rate < 15% and mortality rate < 5% in Therapeutic Feeding Programmes(TFP) (both inpatient care and Outpatient Therapeutic Program (OTP). .
- Increase the proportion of children in the age group of 6-59 months given vitamin A supplements every 6 months from 94% to 96%
- Increase the proportion Children 2-5 years receiving deworming every 6 months from 86% to 96 %
- Reduce the prevalence of anemia in women of childbearing age (15-49) from 27% to 12%
- Increase the proportion pregnant women supplemented with Iron during their pregnancy from 10% to 86%
- Increase the proportion of households using iodized salt from 4% to 95%

  Initiatives
- Sustaining the Enhanced Outreach Strategy, (EOS) with Targeted Supplementary Food, (TSF) and Transitioning of EOS into (Health Extension Programme (HEP)
- Health Facility Nutrition Services
- Community Based Nutrition (CBN).
- Micronutrient Interventions
- Essential Nutrition Actions/Integrated Infant and Young Feeding counseling services
- Institutional Strengthening for nutrition policy and program implementation and monitoring.
- HEP

The targets and initiatives are not addressing climate issues in relation to nutrition.

6.1.1. Mechanisms

Strategies to respond to climate change through adaptation, mitigation, finance, technology, and capacity-building, should be devised and properly take into account the impact of climate change on nutrition security. The following are the descriptions of the mechanisms to be implemented to respond to the problems particularly in low and middle income countries for mechanisms proposed by (United Nations Systems , 2010)

1. Adaptation - Nutrition and food security need to be integrated in the enhanced action on adaptation. Nutrition security should be explicitly addressed in climate resilient development, national adaptation and disaster risk reduction plans in low and middle income countries (LMIC). A revitalized twin-track approach to ensure food and nutrition security could reduce vulnerability, build resilience and secure nutrition under a changing climate. Track one consists in the up-scaling of nutrition-specific interventions and safety nets. Track two consists in a multi-sectoral nutrition-sensitive approach to sustainable and climate-resilient agriculture, health and social protection schemes, risk reduction and risk management plans and climate resilient community-based development. It is essential to increase attention to and target the most vulnerable to suffer from under nutrition such as mothers and young children.
2. Mitigation Nutrition-sensitive climate change- mitigation interventions are urgently required, to reduce current and future impacts of climate change on food and nutrition security. Mitigation actions can favour or compromise food and nutrition security in LMIC and thus should be designed carefully. Nutrition-sensitive mitigation strategies that bring co-benefits in terms of enhanced production of and access to food, should be further explored, tested and scaled up. Investments in research are essential to obtain further evidence to determine which mitigation actions have negative effect on nutrition security, why and identify alternative nutrition-sensitive solutions.
3. Finance, technology and capacity-building - Financial mechanisms are crucial to address climate change impacts on nutrition in LMIC. The finance section of the Ad-Hoc Working Group on Long-Term Cooperative Action under the Convention (AWG-LCA) should stress that support for adaptation and mitigation should protect and improve nutrition. Climate Funds and private investments that will finance climate change adaptation and mitigation in LMIC should

be nutrition-sensitive, with national adaptation plans ensuring adequate budgetary allocations and actions to address nutrition problems. Climate Funds should finance mitigation strategies that bring co-benefits and enhance adaptive capacity for food and nutrition security and nutrition-sensitive technological innovation. It is necessary to strengthen the capacities of national governments to protect and enhance nutrition security under a changing climate, and to integrate nutrition into climate-resilient development and adaptation plans.

4. Policy coherence - It is necessary to develop coherent and coordinated nutrition-sensitive institutional and policy frameworks at local, national and international levels, to address the impacts of climate change on nutrition. Stakeholders involved in the climate change discussions should draw on support from the UNSCN and other related international institutions and initiatives, such as the Committee on World Food Security (CFS), and the Scaling Up Nutrition (SUN) movement. Mechanisms that ensure policy coherence between development, adaptation and mitigation objectives should be explored and implemented at all levels.

Case studies:

Local solutions harnessing local innovation to improve food security, nutrition and climate resilience in Ethiopia

The experience from Tigray as reported by Hunger Nutrition, climate and justice (2013) showed that a watershed rehabilitation project, followed by a collaborative 'Operational Research' programme that harnesses local knowledge, is restoring natural resources, raising agricultural yields and improving food security in Tigray, Ethiopia.

The central and eastern parts of Tigray, a mountainous region of northern Ethiopia, were highly food insecure and were badly affected by famine in 1984. About 37 per cent of households typically eat less than 2,200 kilocalories a day (MOFED, 2013). Low annual rainfall and frequent drought makes farming difficult. Plots are small and often severely degraded. Yields are low, and many farmers are only able to plant one main crop each year (Hunger Nutrition, climate and justice, 2013).

The farmers also found it difficult to access markets, making them particularly food insecure. Added to that, climate models suggest an average temperature rise of 2.2 degrees by the 2050s, increasing water stress for many crops. Rainfall patterns have changed in many parts of the region, starting later and finishing earlier, also becoming more erratic, intense and often damaging. Knowledge gaps are an important aspect of these challenges. Past agricultural research and extension projects have not met farmers' needs in marginal areas. For example the varieties promoted were usually ill-suited to local conditions. However, these situations are changing these days with collaborative efforts of local and international partners including the community itself (Hunger Nutrition, climate and justice, 2013).

Agriculture is fundamental to reducing global hunger and, along with the health and care-based approaches, is integral to improving nutrition outcomes worldwide (Black R.E. et al., 2008). Climate change instills greater urgency to find more sustainable, resilient and efficient ways of producing, trading, distributing and consuming food. Producing more food does not necessarily lead to a better access to food or to an improved nutritional status of those who need it most (Hazell Pet al., 2010).

Negative coping strategies (for instance reduction of the quality, safety and quantity of their meals, reduction of the expenditures on health and education, sale of productive assets, etc.).Intergenerational cycle of malnutrition (during the critical period i.e between conception and two years of age) is one of the undesirable consequences (Hunger Nutrition, climate and justice, 2013).

6.1.2. Near Term Future

Climate change directly affects food and nutrition security, undermining current efforts to address under-nutrition, one of the world's most serious, but least addressed socioeconomic and health problems. A combination of nutrition-sensitive adaptation and mitigation measures, nutrition-smart investments, increased policy coherence, and institutional and cross-sectoral collaboration can address the threats to food and nutrition security from climate change (United Nations Systems , 2010).

Nutrition-sensitive adaptation and mitigation measures should be integrated with development strategies and programmes. Changes in policies, institutions and governance will be needed to facilitate this intersectoral approach. Placing people and human rights at the centre of strategies to adapt to and diminish the effects of climate change can enhance the development and implementation of climate-resilient policies. A rights-based approach engages the rural, peri-urban and urban stakeholders most vulnerable and affected by climate impacts as active participants in this process. Comprehensive long-term cooperative actions in the frame of the UNFCCC are needed to formulate clear responses in order to protect and enhance nutrition from the effects of climate change. The UNFCCC negotiators have the opportunity and the responsibility to consider and address nutrition in the strategies defined in the frame of the *Ad-hoc* Working Group on Long-Term Cooperative Action under the Convention (AWG-LCA). Unless we urgently do so, it will not be possible to reduce hunger and under nutrition under a changing climate (United Nations Systems , 2010).

With increasing risks of climate-related disasters, there is a need to better protect those who are already food and nutrition insecure by developing nutrition-sensitive disaster risk reduction strategies and risk management practices. Innovative examples of climate risk management have already been developed, and could be scaled up and replicated. One example is the Livelihoods, Early Assessment and Protection (LEAP) software application developed in Ethiopia, which allows users to quantify and index the drought and excessive rainfall risk in a particular administrative unit (Hazell et al.,2010). Potential for scale and sustainability in weather index insurance for agriculture and rural livelihoods, Rome: International Fund for Agricultural Development and World Food Programme.).

Glossary

The United Nations Systems (2010) described the following terms contextually:

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life; household food security is the application of this concept to the family level, with individuals within households as the focus of concern.

Malnutrition is a broad term that refers to all forms of poor nutrition. Malnutrition is caused by a complex array of factors including dietary inadequacy (deficiencies, excesses or imbalances in energy, protein and micronutrients), infections and socio-cultural factors. Malnutrition includes undernutrition as well as overweight and obesity.

Nutrition security exists when food security is combined with a sanitary environment, adequate health services, and proper care and feeding practices to ensure a healthy life for all household members.

Undernutrition exists when insufficient food intake and repeated infections result in one or more of the following: underweight for age, short for age (stunted), thin for height (wasted), and functionally deficient in vitamins and/or minerals (micronutrient malnutrition).

6.2. Occupational Health

Occupational health is concerned with the control of occupational health hazards that arise as a result of or during work activities. Occupational health or industrial hygiene has been defined as that "science and art devoted to the anticipation, recognition, evaluation and control of those environmental factors or stresses arising in or from the work place, which may cause sickness, impaired health and well-being, or significant discomfort among workers or among the citizens of the community". It encompass the study of chronic as well as acute conditions emanating from hazards posed by physical agents, chemical agents, biological agents and stress in the occupational environment and the outdoors environment. Evaluation of the magnitude of the environmental factors and stresses arising in or from the work place is performed by the industrial hygienist, aided by training, experience and quantitative measurement of the chemical, physical, ergonomic, or biological stresses. He can thus give an expert opinion as to the degree of risk posed by the environmental factors or job stresses. Occupational health or industrial hygiene includes the development of corrective measures in order to control health hazards by either reducing or eliminating exposures (Takele Tadesse et al.,, 2006).

The industries in Ethiopia presently are not paying due importance for inclusion of Occupational Safety and Health as an integral part of their business. Elimination of occupation related health hazards are not well addressed so far. The legal framework developed by the government through the Ministry of Labour and Social affairs existsandthere are a few capacity building efforts in universities and some other institutions (Ministry of Labour and Social Affairs, 2006, 2006).

6.2.1. Heat Strain and Heat Stroke

The terms stress and strain are used in the conventional engineering senses. Heat stress is the burden or load of heat that must be dissipated if the body is to remain in thermal equilibrium, and is represented by the sum of metabolic rate (minus external work)and the gain or loss by convection and radiation. Heat strain is the physiological or pathological change resulting from heat stress, e.g., increase in heart rate and body temperature, sweating, heat syncope, or water and salt imbalance (WHO, 1969).

Heat stress may end up in heat stroke. Heat stroke can kill or cause damage to the brain and other internal organs. Although heat stroke mainly affects people over age 50, it also takes a toll on healthy young athletes. Heat stroke often occurs as a progression from milder heat-related illnesses such as heat cramps, heat syncope (fainting), and heat exhaustion. But it can strike even if you have no previous signs of heat injury. Heat stroke results from prolonged exposure to high temperatures -- usually in combination with dehydration -- which leads to failure of the body's temperature control system. The medical definition of heat stroke is a core body temperature greater than 105 degrees Fahrenheit, with complications involving the central nervous system that occur after exposure to high temperatures. Other common symptoms include nausea, seizures, confusion, disorientation, and sometimes loss of consciousness or coma (Reuters, 24 February 2013).

Heat stroke, the most serious form of heat-related illness, happens when the body becomes unable to regulate its core temperature. Sweating stops and the body can no longer rid itself of excess heat. Signs include confusion, loss of consciousness, and seizures. "Heat stroke is a medical emergency that may result in death. Heat exhaustion is the body's response to loss of water and salt from heavy sweating. Signs include headache, nausea, dizziness, weakness, irritability, thirst, and heavy sweating. Heat cramps are caused by the loss of body salts and fluid during sweating. Low salt levels in muscles cause painful cramps. Tired muscles—those used for performing the work—are usually the ones most affected by cramps. Cramps may occur during or after working hours. Heat rash, also known as prickly heat, is skin irritation caused by sweat that does not evaporate from the skin. Heat rash is the most common problem in hot work environments (Climate Central, 25 February 2013).

According to (Climate Central, 25 February 2013) there are many factors which can cause heat stress and heat-related illness, including:

- Dehydration – to keep healthy, our body temperature needs to stay around 37°C. The body cools itself by sweating, which normally accounts for 70 to 80 per cent of the body's heat loss. If a person becomes dehydrated, they don't sweat as much and their body temperature keeps rising.
- Lack of airflow – working in hot, poorly ventilated or confined areas.
- Sun exposure – especially on hot days,
- Hot and crowded conditions – people attending large events (concerts, dance parties or sporting events) in hot or crowded conditions may also experience heat stress that can result in illness.
- Bushfires – exposure to radiant heat from bushfires can cause rapid dehydration and heat-related illness. Bushfires usually occur when the temperature is high, which adds to the risk.

6.2.2. Heat Exhaustion and Work Capacity Loss

Climate change increases heat stress and consequently reduces work capacity. It results in hotter and more humid environment for the tropics and mid latitudes resulting in increasing economic costs of reduced work capacity due to heat stress. The study by National Oceanic and Atmospheric Administration (NOAA) scientists said work capacity has already reduced by 10 percent during extreme heat in summer months. This is likely to double to 20 per cent by 2050. One of the physical properties of warmer air is that it can hold more moisture. So in hot weather atmospheric humidity can be more extreme. But there are physiological limits of human health in coping with temperature extremes. In 2010 Scientists outlined health limits of heat stress with Climate

Change (Dunne et al., Nature Climate Change 2013).

Humans and most mammals maintain a core body temperature around 37 °C that may vary slightly among individuals.. To allow transfer and regulation of metabolic heat human skin is strongly regulated at 35 °C or below, a couple of degrees colder than core body temperature. This allows the body to dissipate heat through the skin at wet-bulb temperatures below 35 °C. In this latest study, the researchers looked at military and industrial guidelines already in place for those who work in hot and humid conditions outside, and set those guidelines against climate projections for how hot and humid it's likely to get over the next century, using Wet Bulb temperatures scale which take account of humidity and wind speed. Using a middle of the road modeling projection, they estimated that reduced work capacity due to heat stress is likely to double to 20 per cent by 2050 (NOAA media release, 25 February 2013). The study modeled the impacts out to 2200 and estimated "labour capacity reduction to less than 40% by 2200 in peak months, with most tropical and mid-latitudes experiencing extreme climatological heat stress. "Construction workers, agricultural workers, and others who work outside will all be impacted (NOAA media release, 25 February 2013).

Dunne outlined that the only way to retain labor capacity is to limit global warming to less than 3 degrees Celsius. Average global temperature has already risen by about 0.7 degree C compared to pre-industrial times and with the huge inertia in the climate system especially contained in ocean warming, we can expect at minimum another 1 degree Celsius by mid-century. But with global carbon emissions still increasing we may very well realize the worst predictions of the World Bank climate report and achieve a rise of 4 degrees Celsius by the 2060s and 6 degrees Celsius by the end of the century (Dunne *et al*., Nature Climate Change 2013).

Heat stress will continue to be a major climate hazard which will strike down the ill prepared, the elderly, the very young, those with medical conditions, and the people who can't afford technological adaptation such as air conditioning systems or efficiently insulated houses. One of the issues highlighted is the necessity of developing resilience and adaptation to weather extremes, including extreme heat and humidity. An extreme heat wave in Europe in 2003 killed an estimated 70,000 people at least partly because people did not have the resilience to adapt to the extreme heat that was well outside their experience(Dunne et al., 2013).

NOAA media release, 25 February 2013 - New NOAA study estimates future loss of labor capacity as climate warms.

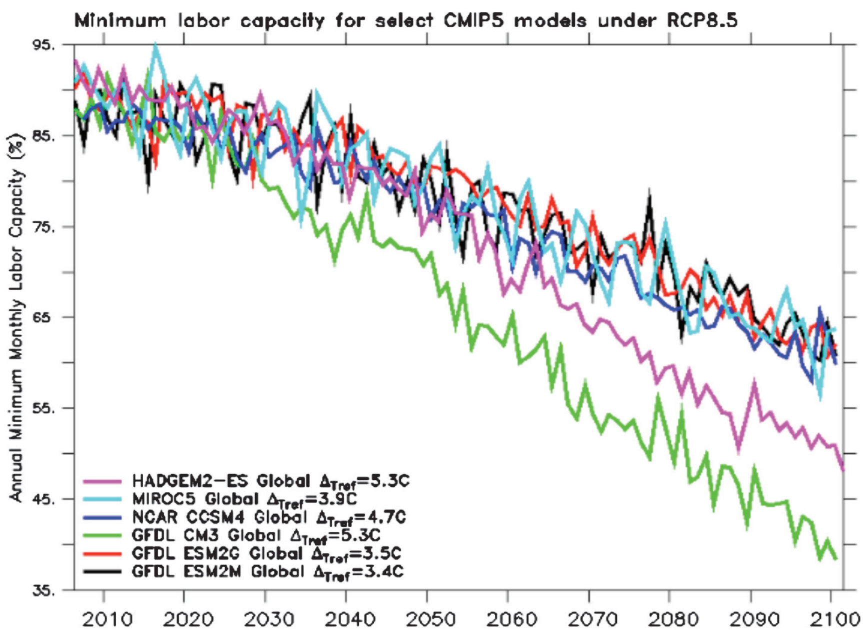


Figure-2, Graph of Minimum labor capacity for selected CMIP5 models under RCP8.5 from Supplementary information to John Dunne et al (2013)

Dehydration and its effects on performance

Fatigue toward the end of a prolonged sporting event may result as much from dehydration as from fuel substrate depletion. Exercise performance is impaired when an individual is dehydrated by as little as 2% of body weight. Losses in excess of 5% of body weight can decrease the capacity for work by about 30% (Armstrong *et al*. 1985; Craig and Cummings 1966; Maughan 1991; Sawka and Pandolf 1990).

Sprint athletes are generally less concerned about the effects of dehydration than are endurance athletes. However, the capacity to perform high-intensity exercise, which results in exhaustion within a few minutes, is reduced by as much as 45% by prior dehydration corresponding to a loss of only 2.5% of body weight (Sawka, Young, Cadarette, et al. 1985).

Although sprint events offer little opportunity for sweat loss, athletes who travel to compete in hot climates are likely to experience acute dehydration, which persists for several days and may be serious enough to have a detrimental effect on performance in competition. Even in cool laboratory conditions, maximal aerobic power (VO2max) decreases by about 5% when persons experience fluid losses equivalent to 3% of body mass or more, as is shown in figure 8.6 (Pichan *et al.* 1988). In hot conditions, similar water deficits can cause a larger decrease in .VO2max. The endurance capacity during incremental exercise is decreased by marginal dehydration (fluid loss of 1% to 2% of body weight), even if water deficits do not actually result in a decrease in .VO2max. Endurance capacity is impaired much more in hot environments than in cool conditions, which implies that impaired thermoregulation is an important causal factor in the reduced exercise performance associated with a body-water deficit. Dehydration also impairs endurance exercise performance. Fluid loss equivalent to 2% of body mass induced by a diuretic drug (furosemide) caused running performance at 1,500, 5,000, and 10,000 m distances to be impaired (Armstrong *et al*. 1985). Running performance was impaired more at the longer distances (by approximately 5% at 5,000 and 10,000 m) compared with the shortest distance (approximately 3% at 1,500 m).

A study investigated the capacity of eight subjects to perform treadmill walking (at 25% .VO2max with a target time of 140 minutes) in very hot, dry conditions (49° C [120° F], 20% relative humidity) when they were hydrated and when they were dehydrated by a 3%, 5%, or 7% loss of body mass (Sawka, Young, Francescone, et al. 1985). All eight subjects were able to complete 140 minutes walking when euhydrated and 3% dehydrated. Seven subjects completed the walk when 5% dehydrated, but when dehydrated by 7%, six subjects stopped walking after an average of only 64 minutes. Thus, even for relatively low-intensity exercise, dehydration clearly increases the incidence of exhaustion from heat strain. Sawka et al. (1992) had subjects walk to exhaustion at 47% .VO2max in the same environmental conditions as their previous study. Subjects were euhydrated and dehydrated to a loss of 8% of each individual's total-body water. Dehydration reduced exercise endurance time from 121 minutes to 55 minutes. Dehydration also appeared to reduce the core temperature a person could tolerate, as core temperature at exhaustion was about 0.4° C (0.7° F) lower in the dehydrated state.

The main reasons dehydration has an adverse effect on exercise performance can be summarized as follows:

- Reduction in blood volume
- Decreased skin blood flow
- Decreased sweat rate
- Decreased heat dissipation
- Increased core temperature
- Increased rate of muscle glycogen use

A reduced maximal cardiac output (i.e., the highest pumping capacity of the heart that can be achieved during exercise) is the most likely physiologic mechanism whereby dehydration decreases a person's VO2max and impairs work capacity in fatiguing exercise of an incremental nature. Dehydration causes a fall in plasma volume both at rest and during exercise, and a decreased blood volume, increases blood thickness (viscosity), lowers central venous pressure, and reduces venous return of blood to the heart. During maximal exercise, these changes can decrease the filling of the heart during diastole (the phase of the cardiac cycle when the heart is relaxed and is filling with blood before the next contraction), hence, reducing stroke volume and cardiac output. Also, during exercise in the heat, the opening up of the skin blood vessels reduces the proportion of the cardiac output available to the working muscles.

Even for normally hydrated (euhydrated) individuals, climatic heat stress alone decreases .VO2max by about 7%. Thus, both environmental heat stress and dehydration can act independently to limit cardiac output and blood delivery to the active muscles during high-intensity exercise. Dehydration also impairs the body's ability to lose heat. Both sweat rate and skin blood flow are lower at the same core temperature for the dehydrated compared with the euhydrated state (see figure 8.4) (Nadel and Wenger,1980; Sawka, 1988). Body temperature rises faster during exercise when the body is dehydrated. The reduced sweating response in the dehydrated state is probably mediated through the effects of both a fall in blood volume (hypovolemia) and elevated plasma osmolarity (i.e., dissolved salt concentration) on hypothalamic neurons. As explained previously, as core temperature rises towards about 39.5° C (103° F), sensations of fatigue ensue. This critical temperature is reached more quickly in the dehydrated state.

Dehydration not only elevates core temperature responses, but also negates the thermoregulatory advantages conferred by high aerobic fitness and heat acclimatization. Heat acclimation lowered core temperature responses when subjects were hydrated. However, when they were dehydrated, similar core temperature responses were observed for both un-acclimated and acclimated states (Pichan et al. 1988).

A person's ability to tolerate heat strain appears to be impaired when dehydrated, so the critical temperature for experiencing central fatigue is likely to be nearer to 39.0° C when dehydrated by more than about 5% of body mass (Sawka *et al.* 1992). The larger rise in core temperature during exercise in the dehydrated state is associated with a bigger catecholamine response, and these effects may lead to increased rates of glycogen breakdown in the exercising muscle, which, in turn, may contribute to earlier onset of fatigue in prolonged exercise.

6.2.3. Other Occupational Health Concerns

Based on the literature review in Quebec, Canada, three major consequences of the occupational health concerns were identified: consequences for individuals, consequences for natural resources, and consequences for the socio-economic context. Five categories of exposures and hazards that could impact directly or indirectly on OHS in Québec were identified: heat waves, air pollutants, ultraviolet (UV) radiation, extreme weather events, and communicable vector-borne and zoonotic diseases (IPCC, 2007).

6.2.3.1. Consequences at Individual level

6.2.3.1.1. Heat waves

The potential effects of heat exposure on occupational health and safety OHS are both direct and indirect. Generally speaking, exposure to high ambient temperatures causes an increase in body temperature, which translates into cutaneous vascular dilation, sweating, and increased heart rate. At a body temperature of 38-39 °C, the risks of heat exhaustion are high and symptoms associated with heat stress appear. Heat stroke (that is, when the central nervous system´s thermoregulation system fails) generally occurs when the body temperature reaches around 40-41 °C (LoVecchio *et al.,* 2007.;National Oceanic and Atmospheric Administration, 2010. and Intergovernmental Panel on Climate Change (IPCC). 2007).

When there is high relative air humidity, sweat evaporation and, consequently, the heat dissipation rate may also be compromised, thus accelerating the rising body temperature phenomenon. Carrying out prolonged physical activity in a hot, humid environment increases the risks of heat exhaustion and heat stroke (Tanaka,. 2007; .Kjellstrom. *et al*., 2009)

Recommendations regarding OHS in hot environments therefore, generally include measurements of the humidity level (Canadian Centre for Occupational Health and Safety CCOHS 2011). In addition to those symptoms, excessive heat exposure can cause heart and kidney problems [Kjellstrom, *et al*., 2010). Exposure to a hot environment also changes physiological parameters such as pulmonary ventilation, vasodilation, sweating, and blood flow, thereby causing increased absorption of xenobiotics through pulmonary or cutaneous routes (Gordon, C.J. 2005. Chapter 7; ;Gordon, C.J. 2005. Chapter 4)

The indirect effects of heat exposure translate into an increased risk of bodily harm and injury, caused by fatigue and reduced vigilance [Ramsey, J.D. 1995. Task performance in heat: a review. Ergonomics. 38: 154-65.]. The accident incidence is minimal when work activity is performed at temperatures of approximately 17 °C to 23 °C, but increases with lower or higher temperatures (Ramsey, *et al*., 1983). Work performed at a high ambient temperature can change worker skills and capacities when physical tasks are involved; this in turn can have consequences on work capacity, productivity, and safety.

A number of factors could explain this phenomenon. For one, psychomotor performance, including manual dexterity, can be altered by heat exposure. The physical discomfort associated with an increase in body temperature can also alter the worker's emotional state (e.g. irritability or anger), leading to negligence regarding safety procedures and reducing vigilance during the performance of dangerous tasks (Tawatsupa, B. et al. 2010). The dehydration caused by exposure to a hot environment also seems to have effects on cognitive performance, visual motor capacities, short-term memory, and vigilance (Grandjean and Grandjean, 2007).

The effect of heat on occupational health and safety also includes death of exposed individuals. Deaths attributed to excessive natural heats have been reported although the circumstances of the death were less clear (Statistics Canada, 2011). The deaths caused by hyperthermia have been observed in workplace in some settings[Letard, M. et al. 2004; Tanaka, M. 2007AndCenters for Disease Control and Prevention. 2008). Heat-related death rate in agricultural industries was twenty times higher than that for all civilian workers [Centers for Disease Control and Prevention. 2008).

Several factors can intensify the effects of heat exposure on workers. On the individual level, heat tolerance levels seem to diminish in people over 45 years of age because physical activity is more physiologically demanding on them. They sweat more readily and their metabolism takes longer to return to normal (Marszałek *et al*., 2005). In addition, workers with health problems (such as heart disease, hypertension, or blood circulation problems), workers who are overweight, and those on sodium restricted diets or who take certain medications (National Oceanic and Atmospheric Administration. 2010; Intergovernmental Panel on Climate Change (IPCC), 2007) are more likely to have problems following excessive heat exposure. Lastly, pregnant women, who have higher metabolic rate, are also more vulnerable (Intergovernmental Panel on Climate Change (IPCC), 2007).

Location, season, and type of activity are other factors that can exacerbate the effects of heat exposure. The most exposed workers are essentially those working in industries where their jobs are performed outside and require intense physical activities during the summer months, or those working at high indoor temperatures or who experience increased body heat due to the nature of their tasks (Jay, O. and G.P. Kenny. 2010). Wearing protective equipment can also aggravate the effect of heat on certain groups of workers (Park, *et al*., 2009.;Bernard, 1999.)

Other industries that pose risks of heat stroke include, mining, transportation (bus and taxi drivers, road and dam construction or repair workers, and roadside brush cutters), waste materials management, landscaping, postal services, and firefighting services. Industries involving indoor activities with risks of excessive heat exposure are glass, ceramic, brick, and rubber fabrication industries; foundries; greenhouses; canning and textile industries; and laundries, kitchens, and warehouses (Schulte and Chun , 2009; U.S. Department of Labor Mine Safety and Health Administration.2010; Morioka, . *et al*., 2006; Noweir *et al*., 2009).

Hot haps has accumulated grid cell (0.5 x 0.5 degrees) data for the whole world on monthly climate variables, which can be used to calculate the occupational heat stress index WBGT (Wet Bulb Globe Temperature), or any other heat index, in any part of the world and any month. The map below shows the example of 30-year average (1980-2009) of monthly average WBGT in the afternoons indoors or in full shade for the hottest month in each part of the world (e.g. hottest summer days are August in the USA and Egypt; April in India; January in Australia).The seven hottest days each month can be estimated at 2-3 °C higher levels than those in the map, and the three hottest days may be up to 5 °C hotter than the levels in the map. The WBGT heat level outdoors in the sun in the afternoons is usually 2-3 °C hotter than the indoor or full shade values. It is clear that moderate or high risk of heat stress in outdoor or non-cooled indoor environments is an important problem for many countries in the tropical and sub-tropical zones. The Hothaps website (www.ClimateCHIP.org) includes heat analysis tools for this type of gridded data available for each place on Earth. This map was included in the IPCC (2014) health impact chapter. The heat exposure intensity scale below the map (shown as different colors on the map) is based on the international standard for prevention of workplace heat effects (ISO, 1989). When WBGT reaches 25 or 26 °C, the heat stress on people carrying out very intensive labor is so high that frequent rest periods are recommended. The higher the WBGT, the more rest is needed (TordKjellstrom *et al*., 2014).

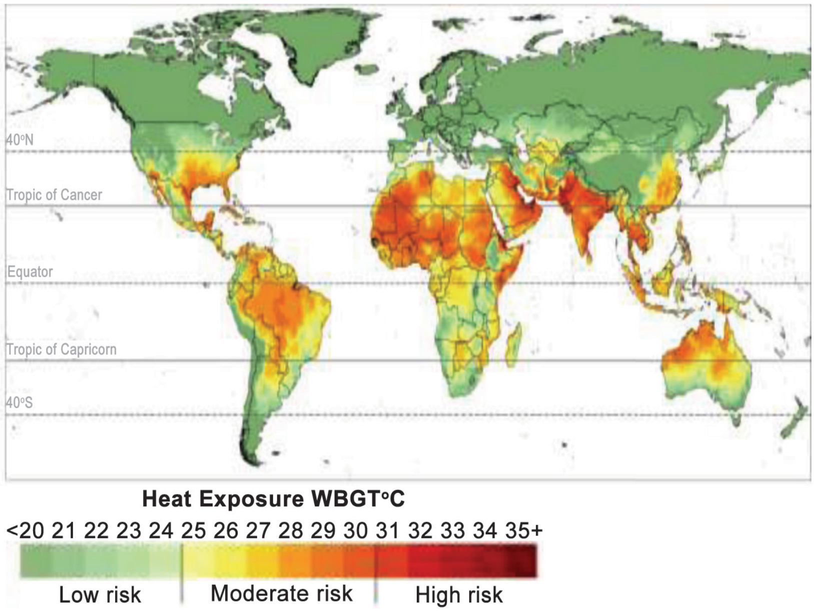


Figure 3. Global distribution of risk of heat exposure.

6.2.3.1.2. Air pollution

Air pollutants

Climate projections suggest that Climate Change may affect the levels of air pollutants, including ozone, particulate matter, volatile organic compounds (VOCs), and other greenhouse gases. Changes in weather patterns (variations in temperatures, precipitation, and wind patterns) could increase the emission of certain pollutants or their precursors (Séguin, 2008;D'Amato and Cecchi. 2008).

The effects of exposure to air pollutants consist mainly of the increased incidence and exacerbation of the symptoms of respiratory and cardiovascular diseases (Intergovernmental Panel on Climate Change (IPCC), 2007). Ground-level ozone has multiple respiratory effects: coughing, shortness of breath, inflammatory response of the mucous membranes, irritations, reduced respiratory functions, and aggravation of chronic diseases (Peden and Reed, 2010). In addition, ground-level ozone increases the respiratory tract's reactivity to irritating agents, which can lead to an increased number of asthma attacks for asthmatics and to pneumonias (Cheng *et al*., 2007 and Ayres *et al*., 2009). The ground-level ozone outside may also enter buildings, and a combination of this ozone and indoor contaminants (e.g. volatile organic compounds) could impact the indoor air quality and people's health (Apte*et al*., 2007). Regarding the effects of airborne particles on the general population, the literature indicates that they are responsible for exacerbating asthma symptoms and are associated with an increase in hospitalizations and emergency room visits, as well as an increase in respiratory and cardiovascular mortality (Dominici *et al*., 2006; Goldberg*. et al*., 2001 and Cohen *et al.,* 2005).

Higher pollutant concentrations due to climate change could therefore increase certain health problems in workers. The health effects associated with air pollutant exposure vary according to a number of factors, including environmental concentrations, exposure duration, and respiratory rate (D'Amatoand Cecchi, 2008). Workers who hold outdoor jobs performed over long periods of time and that require major physical effort have a greater potential of exposure to air pollutants (World Health Organization, 2005) mainly due to the increase in their respiratory flow and the duration of their exposure. The industries most subject to major exposure to air pollutants are the transportation, public services, landscaping, and construction industries (Schulte and Chun, 2009).

6.2.3.1.3. Pollen and other allergens

Climate projections suggest that CC could affect the distribution and concentration of pollens and other aeroallergen (moulds, spores, and mycotoxins). In fact, the increase in ambient temperatures and higher CO2 concentrations are expected to promote earlier flowering periods, lengthen pollen seasons, increase the quantities of allergens produced, intensify allergencity, and change distribution areas (D'Amato, G and L. Cecchi, 2008; LoVecchio, F. et al., 2007 and andPeden, D and C.E. Reed, 2010). The effects of exposure to pollens and other airborne allergens on OHS could translate into an increase in respiratory diseases such as asthma and allergic rhinitis. The components of air pollution interact with the allergens transported by pollen grains and could therefore increase the risks of atopic sensitivity and aggravate symptoms in already-sensitized individuals (D'Amato, G and L. Cecchi. 2008). No study reporting factors that intensify the effects in workers came to light during our literature Review. However, as is the case for workers exposed to air pollutants, workers in industries where jobs are performed outdoors over long periods of time and require intense physical effort, have a greater potential of exposure to aeroallergens, given the increase in the workers' respiratory flow and the duration of their exposure.

6.2.3.1.4 Ultraviolet radiation

In view of the impact of climate change on stratospheric ozone, the World Health Organization (WHO) predicts an increase in ultraviolet (UV) radiation levels on the earth's surface. This phenomenon appears to be attributable mainly to depletion of the stratospheric ozone layer as a result of the presence of greenhouse gases, changes in atmospheric chemistry that are affected by the warming of the polar regions, and changes in cloud distribution (Rosenthal, J. and C. Jessup. 2009;Desjarlais, C. et al. 2010 and Harrington, J.M. 1994).

Certain adverse effects on OHS have been associated with UV radiation, including the development of skin cancers. In fact, ultraviolet rays can penetrate the dermis and alter skin cell structure. Despite the beneficial production of Vitamin D, UV rays can also suppress the immune system and cause acute photokeratitis, conjunctivitis, and cataracts (Lucas, R.M. et al. 2008 and Gallagher, R.P. et T.K. Lee. 2006).

A number of factors can contribute to increasing the incidence and severity of these effects. On the individual level, the people at highest risk of skin cancer are those who have particularly white skin and freckles, and who tend to burn rather than tan in the sun. Taking certain medications (diuretics, some antibiotics, and oral contraceptives) can also sensitize the skin to the sun's effects (Canadian Centre for Occupational Health and Safety (CCOHS). 2011). In a work environment, snow, light-coloureds and, and concrete also reflect UV rays and increase potential exposure. During the summer season, workers are at the greatest Risk (Centers for Disease Control and Prevention 2010).

With regard to type of industries, farmers and fishermen are among the workers at the highest risk of developing skin cancer since they are exposed to the sun on a daily basis. Very high skin cancer rates have been reported in the United States in farmers and seasonal farm workers (National Agricultural Safety Database, 2002 and Arcury, T.A. et al., 2006). Increased exposure to UV radiation also applies to workers in other industries, such as those working in the construction, roadwork, landscaping, and horticulture sectors, as well as life guards (Centers for Disease Control and Prevention (CDC), 2010). Exposure to coal-tar pitch and petroleum products containing polycyclic aromatic hydrocarbons (PAHs), as well as certain chemicals used in the printing industry, can also sensitize skin to the effects of UV radiation [Canadian Centre for Occupational Health and Safety (CCOHS), 2011).

6.2.3.1.5. Extreme weather events

According to the IPCC's predictions, episodes of heavy and frequent precipitation should greatly increase in many regions around the globe, including regions where a decrease in mean precipitation is anticipated (Séguin , 2008). Extreme weather events have multiple effects on OHS. Thunderstorms can exacerbate asthma (D'Amato and Cecchi, 2008) by increasing people's exposure to pollens and other allergens (Apte, M.G. et al., 2007). Summer storms, characterized by heavy rains and flooding, are associated with an increase in heart problems, propagation of vector-borne communicable diseases, risks of hypothermia, and death by drowning (Desjarlais, C. et al., 2010 and Intergovernmental Panel on Climate Change (IPCC), 2007). Environmental disasters can also induce sinus congestion, throat irritations, and skin rashes in emergency response workers (Tak, S. et al., 2007). Apart from increasing the risks of accidents during emergency interventions, extreme weather events can also have repercussions on workers' mental health, notably in the form of post-traumatic stress disorders (Tak, S. et al., 2007).

Another indirect consequence associated with rapid changes in weather conditions that was stressed during the workshops is an increased risk of accidents due to an accelerated work pace adopted by construction or other outdoor workers who may try, for example, to finish their tasks before a storm. The main factors that change the risk of injuries associated with extreme weather events are the type and location of occupational activity involved and where it is carried out. Response workers who handle environmental emergencies (first aiders, firefighters, police officers, and other workers from the healthcare sector), as well as those in the construction, fishing, transportation, and tourism industries are at greater risk of exposure to the hazards associated with sudden, extreme weather events. Farmers are also at greater risk of exposure to contaminants (moulds, chemical products, biological agents) and to fecal matter in the soil during floods, which increase, mobilization and bioavailability of this matter (Rosenthal, J. and C. Jessup. 2009; Morgan, E.R. and R. Wall. 2009). Moreover, firefighters' exposure to extreme temperatures, smoke, vapours, and toxic gases could increase due to the anticipated increase in forest fire frequency (Intergovernmental Panel on Climate Change (IPCC). 2007). Lastly, extreme weather events could force workers in remote regions to stay longer than planned on work sites or in mines before being replaced by other workers, thus prolonging their work hours and increasing their accident risk due to lack of rest. This issue was mentioned at the workshops.

6.3. Communicable vector-borne and zoonotic diseases

The prevalence of vector-borne and zoonotic diseases could increase, according to predictions made in connection with CC (Séguin, J. 2008). Higher temperatures would change incubation rates, transmission seasons, and geographic distributions of vector insects (ticks and mosquitoes) and disease-carrying animals [Séguin, J. 2008 and Desjarlais, C. et al. 2010.) and the rise in temperatures would facilitate the development or introduction of new pathogens or disease vectors in livestock (Gale, P. et al. 2009 and Boxall, A.B.A. et al. 2009).

The OHS effects associated with these phenomena would be an increased incidence of infectious diseases and the appearance of new vector-borne diseases (Séguin, J. 2008). In Québec, currently there are only a few vector species that carry human diseases, but some are present in the southern part of the province. Rising temperatures will prolong the transmission season and change the distribution areas of the virus-vector arthropods responsible for St. Louis encephalitis, La Crosse encephalitis, Eastern Equine encephalitis, and the West Nile Virus as well as the distribution of the virus host (rodent) responsible for hantavirus pulmonary syndrome (HPS), the first case of which was reported in Québec in 2005 (Desjarlais, C. et al., 2010). Lyme�s disease is also an emerging zoonotic disease in Canada, and it is expected that this pathology will propagate in several regions of eastern Canada, including Québec, within the next ten or 20 years (Desjarlais, C. et al., 2010 and Ogden, N.H. et al., 2009).

The type of occupational activity and work environment are among the main factors that contribute to the development and propagation of those diseases. People who work outdoors are those at the greatest risk of exposure to vector-borne and zoonotic diseases [Schulte, P. and Chun, H. 2009). Cases of infection by the West Nile virus were reported in American farmers in 2002 and 2004 and the rate of infection with Lyme's disease among construction workers in New York State was two times higher than that in the general population(National Institute for Occupational Safety and Health (NIOSH), 2005). The highest-risk industries are agriculture, forestry, fishing, construction, mining, road maintenance, and oil and gas extraction (National Institute for Occupational Safety and Health (NIOSH), 2005); CPWR - The Center for Construction Research and Training. 2002 and Centers for Disease Control and Prevention. 2010). Environmental emergency responders, entomologists, and people who perform necropsies on animals, or who handle possibly infected tissues or fluids are also at risk. Moreover, the propagation of vector-borne diseases could potentially necessitate the increased use of pesticides, in turn increasing worker exposure to these products [Boxall, A.B.A. et al., 2009).

6.4. Occupational Health and Safety in Ethiopian Situation

Though the existing Labor Legislation obliges employers to report all accidents occurring at work places, the employers do not usually comply to the Law. Due to that, there is high under reporting. The accidents are reported only from around 10% of the undertakings that are covered by the legislation. On average, about 4000 non-fatal and 9 fatal accidents were reported from 1993-2004 (Ministry of Labour and social Affairs, 2006).

In Ethiopia, there is no work place and plant registration system put in place due to absence pertinent law which obliges occupier or employer to do so.

No arrangement designed so far to do so both at the regional and national levels.. Regional and Federal Labor inspection services are notified to undertake inspections after the establishments were registered by investment offices and other licensing institutions (Ministry of Labour and social Affairs, 2006.).

The Labor Inspection established in the regions and the Federal Department undertake planned or on request basis training programs for workers and employers on occupational safety and Health and working environment. The training programs are aimed at raising awareness of workers and employers on the basic principles OSH and the services are meant to provide trainings that will help the social partners to comply with duties and responsibilities underlined by the law. Special trainings in the form of TOT are given for safety officers and technical personnel for the duration of up to 10 days twice or trice in a year. These training are given to those working in relatively developed regions such as, Addis Ababa, Oromia, Tigray, Amhara, Southern Nations Nationalities and Peoples Region

With regard to awareness creation campaign, rarely Radio and TV programs for public consumptions are conducted both at the Federal and regional levels. Lectures and speeches are also delivered on special occasions organized by both the workers and employers organizations. It is also gratifying to mention that in order to promote the safety and health cultures at national level there is a practice of celebrating Annual Occupational safety and Health Day (April 28) since 2004 for three consecutive years. The practice has helped to make public campaigns and bring all the relevant bodies and the public at large to work together for concerted cooperation to bring about a difference in the field (Ministry of Labour and social Affairs, 2006).

Basic work environment monitoring equipment are available at the Federal and some regional offices. However, there are no dedicated Occupational Safety and Health Research laboratories or hazard monitoring instruments in Ethiopia that can be used for analytical research or assessment of work related exposure of workers to various occupational hazards (analysis of air samples, biological samples, audiometric testing, etc.), awareness creation and giving advice to all the parties on the subject of occupational safety and health.

During the assessment, it was known that there is a laboratory established under the Ministry of Mining and Energy with the necessary laboratory facilities fulfilled. It gives analysis services for various organizations on request and payment basis for its services. On the other hand, the Drug Quality Assurance Toxicology Laboratory which is organized under the Drug Administration and Control Authority of Ethiopia also assesses and notifies work related exposure values by analysing blood samples of those workers exposed to various pesticides and other chemicals upon the request of various employing institutions. Both laboratories (under Ministry of Mining and Energy and the Drug Administration and Control Authority of Ethiopia) are equipped with modern laboratory equipments and can be used for as base line investigation and research purpose if formal networking and collaboration is established (Ministry of Labour and Social Affairs, 2006).

A study conducted by (Osman Yiha, Abera Kumie, 2010) on occupational injury revealed the prevalence to be 783 per 1000 exposed workers per year. Seventy (11%) injured workers were hospitalized. Most (90%) of hospitalization was for more than 24 hours. Only one death was reported in the preceding 12 months prior to the study. A total of 6153 work-days were lost, at an average of 11.4 days per injured worker per year. Working more than 48 hours per week [AOR: 8.27, 95% CI:(4.96-13.79)], absence of health and safety training [AOR: 2.87, 95% CI: (1.02-8.06)], sleeping disorder [AOR: 1.64, 95% CI: (1.12-2.41)], alcohol consumption [AOR: 1.72, 95% CI: (1.06-2.80)], job dissatisfaction [OR: 1.83, 95% CI: (1.30-2.58)] and absence of protective devices [OR: 3.18, (1.40-7.23)] were significant factors that contributed to the prevailing occupational injuries.

6. 5. Near-Term Future

Projections have been made of the future effects of heat on work capacity (Dunne, J., R. Stouffer, and J. John, 2013 and Kjellstrom, T., R.S. Kovats, S.J. Lloyd, T. Holt, and R.S. Tol, 2009). Temperature and humidity were both included, and the modeling took into account the changes in the workforce distribution relating to the need for physical activity. In Southeast Asia, in 2050, the model indicates that more than half the afternoon work hours will be lost due to the need for rest breaks (Kjellstrom, T., B. Lemke, and M. Otto, 2013). By 2100, (Dunne, J., R. Stouffer, and J. John, 2013) reductions in labour capacity from heat stress under climate warming. It is projected that up to 20% loss of productivity globally will occur. There is an unfortunate trade-off between health impact and productivity, which creates risks for poor and disenfranchised laborers working under difficult working conditions and inflexible rules (Kjellstrom, T., B. Lemke, and O. Hyatt, 2011).Workplace heat stress, health and productivity - an increasing challenge for low and middle-income countries during climate change (Sahu, S., M. Sett, and T. Kjellstrom, 2013). Heat exposure, cardiovascular stress and work productivity in rice harvesters in India: implications for a climate change future (Industrial Health, 2011)

6.6. Mental Health

Harsher weather conditions such as floods, droughts, and heat waves tend to increase the stress on all those who are already mentally ill, and may create sufficient stress for some who are not yet ill to become so (Berry, H.L., K. Bowen, and T. Kjellstrom, 2010). Manifestations of disaster-related psychiatric trauma include, severe anxiety reactions (such as post-traumatic stress) and longer-term impacts such as generalised anxiety, depression, aggression, and complex psychopathology (Ahern, M.J., R.S. Kovats, P. Wilkinson, R. Few, and F. Matthies, 2005 and Ronan, K.R., K. Crellin, D.M. Johnston, K. Finnis, D. Paton, and J. Becker, 2008). For slow-developing events, such as prolonged droughts, impacts include chronic psychological distress and increased incidence of suicide (Alston, M. and J. Kent, 2008 and Hanigan, I.C., C.D. Butler, P.N. Kokic, and M.F. Hutchinson, 2012) Extreme weather conditions may have indirect effects on those with mental illness, through the impacts on agricultural productivity, fishing, forestry and other economic activities. Disasters such as cyclones, heat waves and major floods may also have destructive effects in cities. Here again, the mentally ill may be at risk: cities often feature zones of concentrated disadvantage where mental disorders are more common (Berry, H.L., 2007) and there is also higher risk of natural disasters (such as flooding). In addition to effects of extreme weather events on mental health via the risk/disadvantage cycle, there may be a distressing sense of loss, known as ‘solastalgia,’ that people experience when their land is damaged (Albrecht, G., G.M. Sartore, L. Connor, N. Higginbotham, S. Freeman, B. Kelly, H. Stain, A. Tonna, and G. Pollard,2007) and they lose amenity and opportunity.

Violence and Conflict

Climate change will have an enormous impact on environmental, social and economic conditions. This means that climate change also raises concerns regarding human security. Factors linking climate change and the potential for conflict include a number of powerful threats to human security, such as land degradation, water scarcity, decreased food production, increased mortality from diseases, unplanned migration, and hazards associated with extreme weather events. Populations will have to grapple with these severe challenges, and as numerous experts have noted, these effects are likely to be most acute in countries already struggling with low levels of development, persistent poverty, limited social service systems, and in some cases, pre-existing political and social instability. Such threats to human security, especially if unmitigated, have strong potential to increase dramatically grievances that often are the precursors to conflict (USAID, 2009).

Climate change may also affect human security by exacerbating violent conflict. Recently, high level policy documents point to climate change being a risk multiplier for conflict. The UN Security Council in July 2011 expressed concerns that the possible adverse effects of climate change could, in the long-run, aggravate certain threats to international peace and security. There are studies claiming that water and climate related conflict may result from scarcity of water resources, a situation that may become more frequent or severe through climate change (Clico, 2012).

Overall findings of the critical literature review conducted by Oxfam America, suggest that the original framing on climate change causes conflict is misleading. It is not simply that there are areas of agreement and disagreement on climate change and conflict links. All agree that climate change is always associated with conflict. The more constructive question is how political context shapes conflict and its transformations. In fact, many experts attest that it is inaccurate to conclude that water scarcity, drought, desertification, or climate change cause political instability and rebellions; in their opinion, it is the political context that shapes such conflicts and natural resource degradation (Messer, Ellen, 2010). Drought and famine have been powerful factors in shaping governance in Ethiopia over the past 40 years (USAID, 2011).

7. Adaptation to Protect Health

7.1. Improving Basic Public Health and Health Care Services

There is a strong and growing, global, scientific consensus that warming of the climate system is a fact and is affecting human health (WHO, 2009). Vulnerability assessment indicated that the health sector is one of the most vulnerable sectors are due to climate change (Kidane et al.,2009).

7.2 Health Adaptation Policies and Measures

Adaptation refers to activities that make people, ecosystems and infrastructure less vulnerable to the impacts of climate change. This includes things like building defenses to protect coastal areas from rising seas, switching to drought or flood resistant crop varieties, and improving systems to warn of heat-waves, disease outbreaks, droughts and floods (Shanahan M, Shubert W, Scherer C and Corcoran T, 2013).

Evidences generated by the Population Action International, (2009) based on a study conducted in Oromia and SNNPR revealed that women and men from two regions of Ethiopia reported about the increasing challenges they face in adapting to climate change. They recounted how rising temperatures, more frequent droughts, increased flooding, receding grazing land and diminishing forests are making it more difficult for their families and communities to cope. They also underscored the role of health services including reproductive health services to minimize the possibility of having a big family size. As the result it was suggested that:

- Support integrated approaches to climate change adaptation that build on people's expressed needs, and strengthen community- based adaptation strategies to include expanding access to reproductive health and family planning services.
- Give more high-level policy support to Ethiopia's reproductive health and family planning programs to reduce the high unmet need for contraception and to improve maternal and child health.
- Researchers should include population growth, fertility and access to family planning and reproductive health services in future studies of impacts, adaptation and vulnerability to climate change.

The Health sector is affected by weather variability and climate change. This includes morbidity and mortality due to climate sensitive diseases, health infrastructure damage and shift of resources to respond to health crisis related to weather variability and climate change. The most common climate change related effects on health in Ethiopia are morbidity and mortality due to vector-borne infectious diseases like Malaria, Trypanosomiasis, Onchocerciasis, Schistosomiasis and Leshmaniasis. Water born diseases mainly diarrhea, including outbreak of Acute Watery Diarrhea in the past and malnutrition are also among the major public health problems linked to weather variability and climate change. In response to climate sensitive diseases like malaria, the Federal Ministry of Health Ethiopia is working with the National Meteorological Agency's capacity to digitize rainfall, temperature and humidity data. This enables to map areas where malaria transmission may increase. Ethiopia is also among the four countries targeted for building adaptation to climate change in health for least developed countries through resilient WASH under WHO with the support from DFID for over 3 years (2013-2016). The Federal Ministry of Health of Ethiopia in collaboration with partners has prepared Climate Change Adaptation Program Plan for Health 2011-2015 and different strategic documents including Road Map for Health Sector Disaster Risk Management have been developed (FMOH, 2014).

A document developed by the National Meteorological Agency, (2007) outlined the following adaptation measures to be undertaken by the health sector:

- Implement programs that help to prevent and control communicable diseases like malaria through community participation
- Organize and implement community – based health education programs to create the awareness &develop the knowledge about personal hygiene & environmental health management
- Develop & introduce surveillance system, introduce methods of health prevention & vector control for health workers and the community
- Provide training programs to build the manpower capacity to improve the provision of health extension services at local level
- Support health research & community health services through the supply of drugs and help the development of health facilities & infrastructure

7.3 Early Warning Systems

Early Warning is a process with set of defined activities that help to provide advance information of an incoming threat in order to facilitate the adoption of measures to reduce its potential health impact (Ethiopian Health and Nutrition Research Institute, 2012).

An early warning system (EWS) is made up of several components and is not well represented as being only the formulation and issuance of a warning. A holistic EWS includes, the formulation of the warning, the issuance of the warning, the reception of and response to the warning, and finally feedback to those who developed and issued the warning in the first place. Each component has to be considered in evaluating the system. A weakness in any part of this chain of steps, from warning preparations to responses, can render an early warning system ineffective – an outcome critical to avoid because a system that does not warn will not be taken seriously. Furthermore, an effective EWS must always contain a well-functioning feedback loop, so those responsible for developing and issuing warnings can determine the value of specific types of warnings to at-risk populations and also evaluate the effectiveness of their systems in general (a hind casting activity) (Michael H. Glantz, 2009).

Strengthening Climate Information and Early Warning Systems in Africa and elsewhere enables strengthen country's capacity to establish Climate Resilient Development and Adaptation to Climate Change. Establishment of such system helps to monitor climate change, generate reliable hydro-meteorological information, and combine the collected facts with environmental and socio-economic information. Resulting data and knowledge will be used for developing information products to improve evidence-based decision-making for early warning, preparedness, and adaptation responses as well as regular development planning (UNDP and National Meteorological Agency, 2013).

A particular challenge in Africa is the scarcity of quality climate information. This hampers efforts to better characterize the current climate and climate change. Despite scientific advances in understanding and modeling our climate, the largest element of uncertainty is our future development and greenhouse gas emission path. As such, there is need for continuous climate and environmental monitoring, regular vulnerability assessment and reliable early warning climate information systems. There is also a great deal of uncertainty about feedback loops and interactions. Improving the early warning systems to reduce exposure to climate vulnerabilities and enable the opportunistic exploitation of favorable climate conditions has paramount importance. The early warning system has to be networked to highly benefit in generating evidences. The system is more beneficial when it is integrated and community based (African Development Forum, 2010). In Ethiopia early warning surveillance system program has been established to enable communities to adapt to potential out breaks of diseases (National Meteorological Agency, 2007).

To ensure early detection of an outbreak in an emergency situation, a basic surveillance system with an early warning mechanism agreed by all operational agencies is essential. Reporting forms, case definitions and reporting mechanisms should be developed by the lead health agency at the beginning of the emergency and consensus reached with all agencies. Clinical workers at primary and secondary care levels are e key components of this early warning system. They must be trained to report any suspected case of a disease with epidemic potential immediately to the health coordinator, using direct communication and/or the outbreak alert form.

- To ensure rapid detection of an outbreak in an emergency situation, it will be necessary:
- To set up an early warning system within the surveillance system, with immediate reporting of diseases with epidemic potential;
- To train clinical workers to recognize priority diseases/syndromes;
- To train clinical workers to report cases of priority diseases/syndromes immediately to the health coordinator;
- For the health coordinator to report to the lead health agency;
- To arrange for enhanced surveillance during high-risk periods and in high risk areas, e.g. for meningococcal meningitis during the dry season in the meningitis belt, for malaria between the beginning and the end of raining season and during the beginning of the raining season for Cholera (Ethiopian Health and Nutrition Research Institute, 2012).

7.4 Role of Other Sectors in Health Adaptation

The National Meteorological Agency proposed the role of other sectors in health adaptation as follows. The adaptation measures may have direct or indirect contribution to the health sector (National Meteorological Agency, 2007).

7.4.1. Agriculture

- Enhancing erosion control
- Improve and changing management practices and techniques such as planting date, seedling rate, fertilizer application rate, etc
- Engagement in obtaining food from other sources and income generating activities in times of crises
- Proper use of climate information for land use planning and early warning systems, etc
- Grow crops which require less water
- Selection of crops and cropping systems that maximize biomass production and therefore, CO_2 and N_2 fixation
- 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 animas, in addition to supplying fuel and fertilizer from their excreta
- Introduce mixed farming system, where appropriate
- De-stocking of livestock on a regular basis
- Promote lifestyle choices of pastoralists through access to education and local urban development
- Conservation and utilization of hay from natural pastures
- Promotion of grazing management schemes
- Integrated approach for pastoral development
- Rehabilitation of bush encroached areas
- Promote traditional range conservation and management systems
- Use of local legume forage including, Acacia fruits and leaves,
- Promotion of irrigation for agricultural development
- Establish community gene banks specially for drought and diseases resistant land races
- Capacity building and institutional strengthening of the local

community

- Community empowerment for improved agricultural production and natural resources conservation
- Restrict free range grazing and promotion of stall feeding
- Water resources development
- Control and management of Invasive Alien Species (IAS)
- Introduction of various agro-forestry systems in the existing farming systems
- Promotion of renewable energy sources to minimize the use of agricultural residues for house hold energy rather than using it as soil conditioner to enhance soil fertility and there by agricultural productivity and production
- Conservation of Agro biodiversity resources
- Establishment of fodder factory
- Allocation of water supply through market based systems
- Conservation of water and use of river basin planning and coordination
- Flood control
- Combating drought
- Construction of reservoirs for hydropower, irrigation, water supply, flood control over and/or multipurpose uses and establishment of flood forecasting and drought monitoring system have been identified as high and effective climate adaptation options in the Nile Basin.
- Improve underground water resources potential and management
- Promotion of water resources saving techniques in drought and climate change vulnerable areas
- Introduction of Fish Ponds; establishing, legalization and regulation of fish resource exploitation
- Introduction of water quality monitoring systems
- Building upon existing traditional irrigation systems by the local communities/Water resource users through capacity building
- Integrate and implement climate adaptation options in the River Basin Master Plan Studies
- Introduce wise use and management of wetlands to improve among others, recharging capacity of underground water
- Undertake studies on possible future demand for water by

considering future development plans from the Rift Valley lakes and establish a system to control the amount of water to be abstracted from the lakes

- Introduce drip irrigation system
- Introduction of integrated watershed management for the management of the vegetation cover and abatement of erosion and siltation of water bodies
- Regulation and prevention of discharged domestic and industrial organic wastes as well as toxic chemical pollutants that cause hazards entering into water bodies

7.4.2. Water Resource, Energy and Irrigation

- Initiate & develop projects that promote use of alternative and or non-wood energy sources (e.g. bio-gas, fuel saving stoves, etc)
- Increase awareness about the effect of pollution on the environment through IEC with focus on energy utilization and environmental education
- Enforce laws and regulations to protect and prevent pollutions and ensure utilization of local factories that are environmentally friendly.
- Conduct water resources assessment studies (inventory of water quality and quantity, surface and underground water in time and space to develop proper use of available water resources
- Introduce improved methods of water conservation, storage and rational use
- Construction of small check dams and rainwater harvesting schemes to meet water supply for domestic and irrigation use
- Undertake soil conservation measures that help to reduce soil erosion and siltation and also protect the pollution of water sources
- Implement watershed management and water conservation programs and projects that promote local community participation
- Introduce methods to tackle & prevent flood , disaster ; and maintenance of flood control structures
- Manage and tackle droughts as well as associated slow on-set diseases

In addition to the aforementioned roles by different partners, there is also experience of establishing of a Climate and Health Working Group (CHWG) comprising of, the Federal Ministry of Health, National Meteorological Agency and other partners. The climate and health working group creates a climateinformed health sector that routinely requests and uses appropriate climate information to improve the effectiveness of health interventions (Hiwot Teka *et al.*, 2010). The objectives of the Working Group are to create awareness on the impact of weather and climate on health; to develop effective and functional means for the Health Sector and beneficiary communities to routinely use appropriate climate information; to estimate populations at risk from climate-sensitive diseases (where and when and including early warning systems) (T.A. Ghebreyesus1, et al., , 2008).

8. Adaptation Limits under High Levels of Warming

8.1. Physiological Limits to Human Heat Tolerance

Thermoregulation is the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different. A thermo conforming organism, by contrast, simply adopts the surrounding temperature as its own body temperature, thus avoiding the need for internal thermoregulation. The internal thermoregulation process is one aspect of homeostasis: a state of dynamic stability in an organism's internal conditions, maintained far from equilibrium with its environment (the study of such processes in zoology has been called ecophysiology or physiological ecology). If the body is unable to maintain a normal temperature and it increases significantly above normal, a condition known as hyperthermia occurs. For humans, this occurs when the body is exposed to constant temperatures of approximately 55°C, and any prolonged exposure (longer than a few hours) at this temperature and up to around 75°C death is almost inevitable. Humans may also experience lethal hyperthermia when the wet bulb temperature is sustained above 35°C for six hours. The opposite condition, when body temperature decreases below normal levels, is known as hypothermia (Romanovsky, 2007).

8.2. Limits to Food Production and Human Nutrition

One of the serious concerns is the effect of climate change on the nutritional content of food for human consumption. Studies show that increasing atmospheric levels of Carbon dioxide have an unfavorable effect on the nutrients in plants . As the carbon concentration in the plants' tissues increase, there is a corresponding decrease in the concentration of elements such as nitrogen, phosphorus, zinc and iodine. Of significant concern is the protein content of plants, which also decreases in relation to elevating carbon content (Kulshreshtha, S (March 2011; Chakraborty, S.; Newton, A. C. (2011) and TAUB, D.; Miller, B. & Allen, H. (2008).

Lack of essential nutrients in crops contribute to the problem of micronutrient malnutrition in society, commonly known as "hidden hunger"; despite adequate caloric intake, the body still is not nutritionally satisfied and therefore continues to be “hungry” This problem is aggravated by the rising cost of food, resulting in a global shift to diets which are less expensive, but high in calories, fats, and animal products. This results in undernutrition and an increase in obesity and diet-related chronic diseases (Beddington, et al., 2002).

Countries worldwide are already impacted by deficiencies in micronutrients and are seeing the effects in the health of their populations. Iron deficiency affects more than 3.5 billion people; increasing maternal mortality and hindering cognitive development in children, leading to education losses. Iodine deficiency leads to ailments like goiter, brain damage and cretinism and is a problem in at least 130 different countries (Loladze, I. (2002). Even though these deficiencies are invisible, they have great potential to impact human health on a global scale.

It must also be noted that small increases in CO2 levels can cause a CO2 fertilization effect where the growth and reproduction abilities of the plants such as soybeans and rice are actually enhanced by 10-20% in laboratory experiments. This does not take into account, however, the additional burden of pests, pathogens, nutrients and water affecting the crop yield (TAUB, D.; Miller, B. & Allen, H. (2008). Gregory, P; Johnson, S.; Newton, A.; Ingram, J. (2009).)

8.3. Thermal Tolerance of Disease Vectors

The Vector life-history traits and parasite development respond in strongly nonlinear ways to changes in temperature. These thermal sensitivities create the potential for climate change to have a marked impact on disease transmission. To date, most research considering impacts of climate change on vector-borne diseases assumes that all Populations of a given parasite or vector species respond similarly to temperature, regardless of their source population (Eleanore D. Sternberg and Matthew B.Thomas, 2014).

Lower development threshold (LDT) for both species of malaria was estimated at 13-14°C . *Anopheles arabiensis* developed consistently faster than *An*. *Funestus*. Optimum temperature (T_{opt}) and development rate at this temperature (μ_{max}) differed significantly between species for overall development and larval development. However, T_{opt} and μ_{max} for pupal development did not differ significantly between species. Development rate and survival of *An*. *funestus* was negatively influenced by fluctuating temperatures. By contrast, development rate of *An*. *arabiensis* at fluctuating temperatures either did not differ from constant temperatures or was significantly faster. Survival of this species declined by *c*. 10% at the 15°C to 35°C fluctuating temperature regime, but was not significantly different between the constant 25°C and the fluctuating 20°C to 30°C treatment. By comparison, previous data for *An*. *gambiae* indicated fastest development at a constant temperature of 28°C and highest survival at 24°C (Lyons *et al*., 2013).

8.4. Displacement and Migration under Extreme Warming

Climate change causes displacement of people in several ways, the most obvious and dramatic being through the increased number and severity of weather related disasters which destroy homes and habitats causing people to seek shelter or livelihoods elsewhere. Slow onset phenomena, including effects of climate change such as desertification and rising sea levels gradually erode livelihoods and force communities to abandon traditional homelands for more accommodating environments. This is currently happening in areas of Africa's Sahel, the semi-arid belt that spans the continent just below its northern deserts. Deteriorating environments triggered by climate change can also lead to increased conflict over resources which in turn can displace people. Extreme environmental events are increasingly recognized as a key driver of migration across the world. According to the Internal Displacement Monitoring Centre, more than 42 million people were displaced in Asia and the Pacific during 2010 and 2011, more than twice the population of Sri Lanka. This figure includes those displaced by storms, floods, and heat and cold waves. Still others were displaced by drought and sea-level rise. Most of those compelled to leave their homes eventually returned when conditions improved, but an undetermined number became migrants, usually within their country, but also across national borders (BogumilTerminski, 2012. Asia and the Pacific are the global areas most prone to natural disasters, both in terms of the absolute number of disasters and of populations affected. is They are highly exposed to climate impacts, and are home to highly vulnerable population groups, who are disproportionately poor and marginalized. A recent Asian Development Bank report highlights “environmental hot spots” that are at particular risk of flooding, cyclones, typhoons, and water stress.

To reduce migration compelled by worsening environmental conditions, and to strengthen resilience of at-risk communities, governments should adopt polices and commit financing to social protection, livelihoods development, basic urban infrastructure development, and disaster risk management. Though every effort should be made to ensure that people can stay where they live, it is also important to recognize that migration can also be a way for people to cope with environmental changes. If properly managed, and efforts made to protect the rights of migrants, migration can provide substantial benefits to both origin and destination areas, as well as to the migrants themselves. However, migrants – particularly low-skilled ones – are among the most vulnerable people in society and are often denied basic protections and access to services (Addressing Climate Change in Asia and the Pacific, 2012).

The links between the gradual environmental degradation of climate change and displacement are complex: as the decision to migrate is taken at the household level, it is difficult to measure the respective influence of climate change in these decisions with regard to other influencing factors, such as poverty, population growth or employment options (BogumilTerminski, Environmentally, 2012). This situates the debate on environmental migration in a highly contested field: the use of the term ‘environmental refugee’, although commonly used in some contexts, is not recommended by agencies such as the UNHCR who argue that the term ‘refugee’ has a strict legal definition which does not apply to environmental migrants (http://www.unhcr.org/research/RESEARCH/3ae6a0d00.pdf). Neither the UN Framework Convention on Climate Change nor its Kyoto Protocol, an international agreement on climate change, includes any provisions concerning specific assistance or protection for those who will be directly affected by climate change (http://www.brookings.edu/speeches/2007/1214_climate_change_ferris.aspx) .

In small islands and megadeltas, inundation as a result of sea level rise is expected to threaten vital infrastructure and human settlements (IPCC AR4 SYR 2007; Mimura, N., et al. (2007). “In Parry, M.L., et al. (eds2007:) This could lead to issues of statelessness for populations in countries such as the Maldives and Tuvalu (Climate change and the risk of statelessness" (PDF). May 2011. Retrieved 13 April 2012) and homelessness in countries with low lying areas such as Bangladesh.

8.5. Reliance on Infrastructure

This section identifies a set of adaptation measures in agriculture, roads, and hydropower. The following menu of adaptation options are considered (Strzepek and Cervigni, 2013):

- Increase irrigated area.
- Increase research and development for agriculture.
- Modify plans for expansion of hydroelectric power (volume or timing of investment).
- Build climate resistant road infrastructure (e.g., increase the capacity of roads and bridges to withstand greater heat and precipitation).

By and large, these options are identified by taking as given certain sector development objectives (e.g. the road network expansion plan; or the target production of electricity from hydropower), and defining ways to achieve those objectives even under varying climate conditions. More generally, however, adaptation might also involve changing the sector development plans, or promoting different allocation of resources across sectors. An illustrative investigation of this different line of reasoning is summarized in section 8.5.1 below.

8.5.1. Agriculture

Taking into account the Governments' recent development activities in the sector, as well as the significant (and yet largely untapped) potential for irrigation growth, this paper proposes a "portfolio strategy" approach to adaptation in agriculture. Such an approach combines, on the one hand programs in Research and Development (R&D) and farm management practices aimed primarily at boosting yields in rain fed areas; and, on the other, investments in irrigation and drainage infrastructure. The proposed approach is consistent with recent work on adaptation in agriculture at the global level (Nelson et al. 2009), which analyzed R&D and irrigation/drainage as a direct adaptation strategy; and the expansion of rural roads as an indirect strategy.

The two pillars of the adaptation approach analyzed here (R&D and irrigation/drainage) are meant to capture key aspects of a strategy capable of tackling the essential features of the climate of the future: i.e., an increase in temperature (common to all scenarios); and changes in precipitation patterns (in varying directions and magnitudes, depending on the climate change scenarios). Temperature increases under all scenarios, with negative impacts on crops yields. Investment in R&D is thus intended to maintain the technology induced productivity growth in the agricultural sector at the base, no climate change rate by developing new crop varieties optimized for the changed climate. In each scenario, an initial period of extensive R&D activities over the first ten years was assumed to allow time to learn what direction climate change was taking for Ethiopia. This would allow infrastructure designs to minimize the risk of "regrets" associated with the selection of the "wrong" adaptation response. In all four adaptation scenarios, the baseline irrigation development plan of 3.7 million hectares by 2050 is increased gradually to 4.1 million by 2050 (Nelson et al. 2009). The level of irrigation infrastructure is matched to the magnitude of climate change induced irrigation deficit. Note that it is possible to have increases in irrigation deficit even in wet scenarios. As warming increases, crops demand an amount of water greater than the increases in precipitation during the growing season. Changes in precipitation intensity and seasonality call for increased installation of drainage systems especially in wet scenarios. The order of magnitude of investments in agriculture adaptation was determined by taking into account the opportunity cost of diverting resources from other sectors. Using CGE modeling, an average annual cost of about USD 70 million was assessed by expert judgment to be in a reasonable range so as to avoid an excessive drain on economy wide growth Irrigation infrastructure is installed on 400,000 hectares for all scenarios.

However, for the Wet 2 scenario the design was for only stream diversion for supplemental irrigation. For the Wet 1 scenario, again only stream diversion was considered, but for a greater amount of supplemental irrigation and for Dry 1 the designs included water harvesting and small scale storage reservoirs. For Dry large, medium and large scale irrigation systems were part of the adaptation design, with correspondingly different levels of cost per hectare. While the adaptation strategy analyzed here addresses key aspects of sector vulnerability, it is admittedly defined in relatively coarse terms, given the aggregate level of analysis of this research. Future work will be needed to spell out in further detail individual components (and costs) of a more comprehensive adaptation strategy for agriculture, such as for example, specific technologies for livestock, soil or water management; changes in planting dates, crop varieties and cultivars; enhancement of large irrigation schemes, development of small irrigation projects and associated reservoirs in water shortage areas, on farm water harvesting project, and installing agricultural tile drainage in waterlogged areas (Nelson *et al*., 2009).

8.5.2. Road Transport

The adaptation considered for Ethiopia's road sector consists of a "design strategy" approach that promotes upgraded design standards for roads and bridges to integrate through the use of enhanced materials and technologies, the risk of increased climate change related stressors. In this approach, when the road is repaved at the end of its 20 year lifespan, it is repaved according to a design standard that takes into account the increase in climate variability projected over the next 20 years lifespan. This is likely to increase construction costs, but decrease maintenance costs that would have been incurred by using the earlier construction standards (Nelson *et al*., 2009).

In conclusion, there is dearth of information on climate in Ethiopia in general and for the health sector in particular. Further attention have to be given by all stakeholders in generating information on the effects of climate change to different sectors so that appropriate policy and strategy frameworks could be designed and concerted efforts could be made in implementing mitigation and adaptation measures. The health sector specifically is expected to implement the following measures.

Mitigation measures

- System development including friendly policy
- Designing and building efficient resilient infrastructure and reducing potential wastes
- Awareness creation
- Promotion of one health concept

Adaptation Measures

- Decision support tools eg establishing and strengthening early warning systems,
- Technology development eg. Introduction of vaccines and more rapid diagnostic tests ,
- Surveillance and monitoring eg. Designing effective vector surveillance and control programs that incorporate climate change concerns and ,
- Infrastructure development e.g. considering possible impacts of infrastructure development, such as water storage tanks

9. Policy Implications

Policies to respond to climate change through adaptation, mitigation, finance, technology, and capacity-building, should be devised and properly take into account the impact of climate change on health.

Improving surveillance system and including some of the parameters related to direct impacts of climate change and variability helps in designing future interventions at all level. There is a need to consider engage the research and academic institutions to generate evidence on some of the newly flourishing health impacts. Strengthening partnership and collaboration with institutions in developed countries with well-established methodology and research approaches is recommendable.

Concerted efforts are required to minimize the health impacts of climate change. Therefore, improved diseases surveillance, increased public awareness, and the use of appropriate interventions through integrated approach are required. Individual, household and community level application of integrated vector management for most of the vector-borne diseases with overlapping ecology is critically important. For water-borne disease water-sanitation and hygiene are among vital tools to curb the morbidity and mortality burdens.

It is important that integrated approaches to climate change adaptation that build on people's expressed needs, and strengthen community-based adaptation strategies to include expanding access to reproductive health and family planning services be envisioned by policy makers. It is also important to give more high-level policy support to reproductive health and family planning programs to reduce the high unmet need for contraception and to improve maternal and child health.

Strategies to respond to climate change through adaptation, mitigation, finance, technology, and capacity-building, should be devised and properly take into account the impact of climate change on health. The most effective adaptation measures for health in the near-term are programs that implement basic public health measures such as provision of clean water and sanitation, secure essential health care including vaccination and child health services, increase capacity for disaster preparedness and response, and alleviate poverty.

Strengthening Climate Information and Early Warning Systems enables strengthen country's capacity to establish Climate Resilient Development and Adaptation to Climate Change. Establishment of such system helps to monitor climate change, generate reliable hydro-meteorological information, and combine the collected facts with environmental and socio-economic information. Resulting data and knowledge will be used for developing information products to improve evidence-based decision-making for early warning, preparedness, and adaptation responses as well as regular development planning.

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