

# **Impact of Climate Change on the Environment: A Synthesis Study**

## **Abstract**

Climate change has a significant impact on both physical and social components of the environment. Every component of the environment has been suffering the impacts of climate change. All components of the environment are interrelated through the exchanging of energy and matter; hence they actively interact. Major components of the environment like the biosphere, lithosphere, atmosphere, and hydrosphere are open systems to impact climate change. This paper describes the major impacts of climate change on major components of the environment. Human beings are the major contributors to climate change through anthropogenic greenhouse gas emissions. Humans are also on the front line to experience the impacts of climate change outcomes through the loss of valuable ecosystem goods and services. In other ways, loss of biodiversity, changes in atmospheric composition, changes in chemical reactions in soil and rocks, changes in water quality, availability, and hydrologic cycles, frequent occurrence of extreme weather conditions, and impacts on the global economy have been briefly discussed in this paper.

**Keywords:** Climate change, Carbon dioxide, Environmental components, Greenhouse gases

## **1. Introduction**

Climate change is defined as the average state of the weather conditions prevailing in a region over a long period. The Intergovernmental Panel on Climate Change (IPCC) refers to climate change as "the state of the climate that can be identified statistically by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer".

The word environment is derived from the French word “environ” which means “surrounding”. The environment is a complex of many variables, which surrounds man as well as living organisms. The environment includes water, air, land, and the interrelationships that exist among and between water, air, land, human beings, and other living creatures such as plants, animals, and microorganisms (Kalavathy, 2004). The environment consists of an inseparable whole system constituted by physical, chemical, biological, social, and cultural elements, which are interlinked individually and collectively in myriad ways. The natural environment consists of four interlinking systems namely, the atmosphere, the hydrosphere, the lithosphere, and the biosphere. These four systems are in constant change and such changes are affected by human activities and vice versa (Kumarasamy et al., 2004). Climate change has significant and broad impacts on the environment; changes in climate cause increased temperature, sea level rise, change in precipitation, and more frequent or intense extreme events that in turn affect human needs such as food, water, shelter, and health. Climate change may also threaten key natural resources, affecting water and food security which can trigger conflict, mass migration, health impacts, death, and environmental stresses.

Although climate change is an inherently global issue, the impact is not felt equally across the globe. Impacts are likely to differ in continents, countries, and regions. Some nations are experiencing more adverse effects than others. Climate change has inclusive impacts on all components of the environment, including the biosphere, atmosphere, hydrosphere, and lithosphere.

Global estimates predict major losses of biodiversity due to global climate change, which is generally higher than the current rate of loss and much higher than rates of species extinctions documented in fossil records. One of the first global studies estimated that by 2050; 15-37% of species will undergo extinction under intermediate climate change, Malcom and colleagues stated

in 2006 that the extinction rate of endemic species could reach up to 39-43% under worst case scenarios which represent a potential loss of 56000 endemic plant species and 3700 endemic vertebrate species.

In another way, climate change has a great impact on the hydrological cycle & water availability. One of the consequences of global warming is an increase in temperature and thus water holding capacity of the atmosphere. Another consequence is an increase in evaporation over the ocean and evapotranspiration on land, accordingly the water cycles speed up (Trenberth 2011). A robust finding in all climate models with global warming is an increase in evapotranspiration (Trenberth et al.2003; Trenberth 2011).

Climate change has also a significant impact on soil and rocks. Accelerated weathering of rocks and minerals in soils will be promoted by higher atmospheric CO<sub>2</sub> concentration. The temperature increases the extent and rates of weathering and intensive rainfall which facilitates the removal of reaction products either by surface runoff percolation water, heat waves, and extended periods of drought which promote physical alteration of rocks and minerals. The results from 44 years of field study show that weathering rate already increasing because of global warming (Gislason et al.2009). Therefore: the objective of this paper is, to review the impact of climate change on the environment.

## **2. Impact of climate change on major environmental components**

### **2.1. Impacts of climate change on agriculture and related impacts on human beings**

Agriculture is a sector that has been facing impacts from climate change. Heat stress, drought, and flooding events may lead to a reduction in crop yields and livestock productivity. Agriculture is important for food security in two ways: first, it produces the food people eat; secondly, it provides the primary source of livelihood for 36% of the world's total workforce. In the heavily populated countries Asia and the Pacific, this share ranges from 40-50%, and in sub-Saharan Africa; two-thirds of the working population still; make their living from agriculture (ILO, 2007). If agricultural production in the low-income developing countries of Asia and Africa is adversely affected by climate change, the livelihood of a large number of the rural poor will be put at risk and their vulnerability to food insecurity can be increased. However, in many low-income countries with limited financial capacity to trade and high dependence on their production to cover food requirements, it may not be possible to offset declines in local supply without increasing reliance on food aid. Evidence indicates that more frequent and more intense extreme weather events (droughts, heat, cold waves, heavy storms, floods, rising sea levels, and increasing irregularities in seasonal rainfall patterns are having immediate impacts on food products and hurting human beings directly. Due to climate change an average of 500 weather-related disasters are now taking place each year compared with 120 in the 1980<sup>s</sup>; the number of floods has increased sixfold over the same period (Oxfam,2007).

## **2.2. Impacts of Climate change on human health**

The prevalence of some tropical diseases and other threats to human health depend largely on the local climate. According to the Intergovernmental Panel on Climate Change (IPCC, 2007) extreme temperatures can lead directly to the loss of life, while climate-related disturbances in ecological systems can directly impact the incidence of infectious diseases such as water-borne and air-borne. On the other hand, warm temperatures can increase air and water pollution, which in turn harm human health. Extreme weather events destroy shelter, contaminate water supplies, cripple crop and livestock production, and tear apart existing health and other service infrastructures. This will ultimately increase the existing burden of disease and other non-health needs of vulnerable human communities. The magnitude and nature of climate change's impact on human health depend on the relative vulnerability of population groups by the extent and duration of exposure to the climate itself and society's ability to adapt or cope with the change (IPCC, 2007). The risk of emerging disease may increase due to changes and survival of pathogens in the environment, changes in migration pathways of carriers and vectors, and changes in the natural ecosystem (Afrane et al., 2006). The increased frequency of drought and flooding is likely to increase the frequency and magnitude of epidemics or waterborne diseases as well as influence the incidence of vector-borne diseases.

Climate-sensitive diseases, like vector-borne diseases, are sensitive to climate change, because temperature and precipitation changes can alter vector development rates shift their geographical distribution, and alter transmission dynamics attributable to rising global temperatures (Chivian and Bernstein, 2004). Vector-borne and water-borne diseases are known to be climate-sensitive diseases. The IPCC has noted that the global population is at risk from vector-borne diseases will increase between 220 million to 400 million in the next century, this increase is predicted to occur

in Africa (IPCC, 2007). Climate change directly affects disease transmission by shifting the vector's geographic range and increasing reproductive and biting rates by shortening the pathogen incubation period. Malaria is by far the most important vector-borne disease causing high morbidity and mortality in Sub-Saharan Africa. However, due to changes in socio-economic, environmental, and vector-related factors, the disease is now common in previously malaria-free highland areas (Mboera and Kitua, 2001; Mboera, 2004).

According to a study conducted in Tanzania, modeling malaria endemicity using an outpatient case (2004-2008) about mean temperature and mean precipitation has shown that almost all the whole of Tanzania is endemic for malaria (Mboera et al.;2010). The disease is prevalent throughout the tropics and subtropics and is very important in highly urbanized communities with poorly managed water and solid waste systems.

Climate change effects on human health can be divided into primary, secondary, and tertiary. **Primary** effects are heat waves, fever, cold waves, injuries, floods, and fires, while **secondary** effects are infectious diseases, especially vector-borne, allergies, and air pollution. **Tertiary** effects are; famine, conflicts, population displacement, and refugees.

### **2.3. Impact of climate change on biodiversity**

Indeed, the changing climate results in endangering and loss of biodiversity, especially in critical ecosystems of the world. One of the widely accepted definitions of biodiversity is the one put forward by the International Union for Conservation of Nature (IUCN, 2010). Which states that biodiversity is the variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and ecological complexes of which they are part; this includes diversity within species and ecosystems (IUCN,2010). Biodiversity is affected by climate

change at different levels from low land to high mountains and from small rivers to deep seas. Extinction can disrupt the fundamental ecological processes (Sodhi et al., 2011). In the case of the mountain environment, the effects of climate change can be observed through snow cover loss, melting permafrost, receding avalanches, and landslides. Similarly, the loss of biodiversity is one of the most significant aspects of global environmental changes, given the extent to which it undermines the global economy and human welfare (Martins & Rotmans, 2005). Although threatened and endangered species at vulnerable locations such as in polar regions and the high Mountains have uncertain life or existence, they play a major role in controlling the functioning of the ecosystems. Current climate projection indicates that more ecological change will occur in the coming decades (IPCC, 2013). Species behaviors are altering and disrupting at an excessive role which has already been seen in the past and this process is continuing at present and may remain in the future. The earth's terrestrial system has been extensively altered by human activity significantly contributing to climate change. According to the report by Millennium Ecosystem Assessment, nearly 75% of the Mediterranean and Temperate forests have been adopted by human activity whereas five out of thirteen biomes analyzed showed 50% conversion on average among a few (Mooney et al.;2009). Similarly, marine ecosystems experience adverse effects posed by the impacts of climate change. Marine ecosystems are of huge importance to the biology of the planet because they are among the largest of all the health of both marine and terrestrial environments (Towsend et al., 2013). A study conducted by Jackson (2008) in coastal estuaries revealed that 80% of the largest vertebrates and blue whales, 90% of oyster, 65% of sea grass, and 67% of wetlands were lost due to the changes in climatic variation weather patterns.

Freshwater ecosystems may well be the most endangered ecosystems in the world due to climate change. They are biologically rich and play major roles in providing ecosystem services to a greater

magnitude (Mooney et al., 2009). Freshwaters are principally vulnerable to climate change because many species within these fragmented habitats have limited abilities to disperse as the environment changes, water temperature and availability are climate dependent, and many systems are already exposed to various anthropogenic stressors such as contaminants and pollutants (Woodward, Perkins, & Brown, 2010). Extinction rates and extirpations of freshwater species either match or exceed those suggested for better-known terrestrial taxa (Virakkala, & Toivonen.,2009). The degree of alteration of river and lake systems by humans is clear. Humans have been exploiting freshwater systems for drinking water, transportation, irrigation, and power generation. However, proper attention has not been given to other ecosystem services that this system provides, such as temperature regulation, water purification, erosion and flood control, and cultural services (Moone et al., 2009).

#### **2.4. Impact of climate change on the atmosphere**

Anthropogenic leads to an increase in the concentrations of greenhouse gases and aerosols that perturb the Earth's energy amounts and cause a radiative forcing of the climate system. Collectively, greenhouse gases and aerosols can be considered radiative forcing agents, which lead to either increased (positive forcing) or decreased (negative forcing) global mean temperature, with associated changes in other aspects of climate such as precipitation and sea level rise. The concentrations of the major greenhouse gases carbon dioxide, methane, and nitrous oxide have increased due to human activities, and ice core data show that these gases have now reached concentrations not experienced on Earth in at least several thousand years (Luthi et al., 2008; Joos & Spahni, 2008; MacFarling-Meure et al., 2008). The recent rates of increase in CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O are unprecedented in at least 20,000 years (Joos & Spahni, 2008). Atmospheric CO<sub>2</sub> concentration has crossed from 280 to 400 ppm while Methane concentration increased from 800

to 1800 PPb and Nitrous oxide concentration increased from 270 to 320 PPb, IPCC 5<sup>th</sup> Assessment Report (2014).

The abundances of CO<sub>2</sub>, N<sub>2</sub>O, and CH<sub>4</sub> are well-mixed over the globe, and hence their concentration changes radiative and the greenhouse effects. Tropospheric ozone has also increased largely as a result of emissions of antecedent from nitric oxide and organic molecules including volatile methane. The short atmospheric lifetimes of aerosols and tropospheric ozone lead to very large variations in their abundances depending upon proximity to local sources and transport, increasing the uncertainty in estimates of their global mean and forcing their spatial distribution. Shortwave-absorbing aerosols change the vertical distribution of solar absorption, causing energy that would have been absorbed at the surface and communicated upward by convection to be directly absorbed in the atmosphere instead; this can potentially lead to changes in precipitation and atmospheric gas circulation even in the absence of warming (Menon et al., 2002).

## **2.5. Impact of climate change on the lithosphere**

Chemical weathering of rocks by carbon dioxide dissolved in rainwater has never been taken into account in models of future climate change so far. However, researchers from the Laboratoire Géosciences Environnement Toulouse, in collaboration with the Laboratoire des Sciences du Climat et de l'Environnement and the University of Bergen (Norway), demonstrated its sensitivity; the higher the carbon dioxide levels in the atmosphere, the more powerful the carbon sink, which accelerates the dissolution of rocks. The carbon dioxide in the atmosphere dissolves in rainwater forming carbonic acid, which, once in contact with rocks, slowly dissolves them. A study conducted on one of the biggest arctic water sheds, the Mackenzie River basin located in northwest Canada shows that when the amount of atmospheric CO<sub>2</sub> rose from 355 PPmv (at the end of the twentieth century) to 560 PPmv (by 2100), the Mackenzie River basin responded by capturing

50% more atmospheric CO<sub>2</sub> through chemical weathering. From this increment 40% of this increase is directly linked to climate change, higher temperatures and rainfall accelerate mineral dissolution, while the remaining 60% is put down to changing vegetation activity. Higher atmospheric CO<sub>2</sub> levels reduce evapotranspiration in plants, which intensifies the circulation of water in soils. The increased circulation speeds up the chemical weathering of rocks.

Soil is another important terrestrial component that can be influenced by climate change. Significant and abrupt changes in daily, seasonal, and inter-annual temperature; changes in the wet/dry cycles; intensive rainfall and heavy storms; extended periods of drought; extreme frost; heat waves and increased fire frequency, are expected to significantly impact terrestrial systems, soil properties, surface water and stream-flow (Patterson et al., 2013). The results from a 44-year field study show that weathering rates are already increasing because of global warming (Gislason et al., 2009). However, the spatial patterns, temporal trends, and controlling factors of the processes and reactions and their effects on different scales, especially regional, continental, and global scales, are not fully understood at this time (Moosdorf et al., 2011). In another way the dissolution of atmospheric CO<sub>2</sub> gas in soil water and the subsequent formation of carbonic acid followed by its dissociation causes a decrease in soil pore water pH as a result of aqueous phase proton enrichment through the following chemical reaction:  $\text{CO}_2(\text{g}) + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{HCO}_3^- (\text{aq}) + \text{H}^+(\text{aq})$ . The organic matter content of soils is one of the most important soil properties that define soil fertility and, to a large extent, control the chemical and biological behavior of the soil system. Organic carbon incorporated into SOM may play a major role in controlling soil behavior as a sink or source of atmospheric CO<sub>2</sub> (Ghee et al., 2013), thus contributing significantly to the global carbon cycle. The predicted climate change and the need for a more unified approach to mitigate greenhouse gas emissions, the soil's ability to sequester and release carbon into the

atmosphere, and thus to act as a carbon sink or source for atmospheric CO<sub>2</sub>, has received growing attention (Solomon et al. 2012). For example, enhanced soil respiration in response to global warming may substantially increase atmospheric CO<sub>2</sub> concentrations above the anthropogenic contribution, depending on the mechanisms underlying the temperature sensitivity of soil respiration (Tucker et al., 2013).

## **2.6. Impacts of climate change on hydrosphere**

The water resource is a very important component of the environment that is vital for living things and the existence of balanced systems on the earth. The impacts of climate change on the hydrosphere can be seen from the quantity and quality of water that exists under the ground, on the surface, and in the atmosphere as well as changes in the water cycle. In terms of water availability, projected effects include more seasonal and higher intensity rainfall; increasing seasonality of river flows; modification of groundwater recharge patterns; and risk of significant reduction in the volume of reliable surface water resources. Implications include reductions in the reliability of rainwater harvesting schemes; greater need for and reliance on both natural and man-made water storage; the potential breaching of damage to low-capacity sewage and drainage systems; and increased dependence on groundwater in Africa and South Asia to meet future water demand. The hydrologic cycle, often called the water cycle, is one of the main components of the planetary system regulating human, animal, and plant life. This cycle also forms the foundation of other cycles, such as carbon cycle, nitrogen cycle, etc. Therefore, the stability of the water cycle is critical for the sustainability of biological populations and ecosystems. The hydrologic or water cycle describes a natural set of continuous and dynamic processes through which water masses in the form of liquid, vapor, or solid, move, circulate, and are stored within the earth system (IPCC, 2013). This cycle controls the circulation and the state of moisture within the atmosphere, the

biosphere transpiration, the cryosphere, the pedosphere, and the lithosphere. The movement of water is driven by different energy gradients, including gravity, pressure, and temperature as well as the difference of concentration e.g., stomatal conductance for plant transpiration. In sum, the water cycle embeds several terrestrial phenomena among which we can list evapotranspiration, surface water flow, groundwater flow, and water storage glaciers, ice covers, and aquifers. The changes may be examined by focusing on the main components of the water budget, namely precipitation, infiltration including groundwater flux and base-flow, runoff, and evapotranspiration. However, the disturbances caused by climate change are also sensed with different magnitudes, depending on the component targeted, the time, and the location. For instance, some regions of the globe experience a decreasing trend of precipitation amount. At the same time, several regions are reported with extraordinary peaks of precipitation, while others are still having stable precipitation patterns.

## **2.6. Impacts of climate change on the global economy**

The overall aggregate effect of climate change on economic growth will most likely be negative in the long run. Although there will be winners and losers from climate change at varying levels of warming, the impact of rising temperatures will be widespread, in part due to the financial, political, and economic integration of the world's economies. Global warming will primarily influence economic growth through damage to property and infrastructure, lost productivity, mass migration, and security threats. For instance, Hurricane Sandy, which flooded much of New York in 2012, are prime example of the economic damage such extreme weather events can cause. Rising sea levels will also likely harm economic output as businesses become impaired and people suffer damage to their homes. While the initial economic response to recover this damage may be positive for GDP when it is possible to do so, once it is recognized that such events are a permanent

feature of the environment, the world economy faces an extreme challenge. Many will find that it is not worth replacing capital stock unless measures can be taken to prevent future damage, or there is an opportunity to move the business to safer ground. At best, this could involve a short period of disruption as businesses relocate and; at worst, a permanent loss of capital stock and output. According to Mendelsohn (2013), the biggest threat climate change poses to economic growth is from immediate, aggressive, and inefficient mitigation policies. Agricultural yields are sensitive to weather conditions and as our climate becomes ever more extreme, more frequent droughts may reduce crop yields in areas where food production is vital. We must acknowledge that these effects will be partially offset as other regions become suitable for crop production and new drought-resistant crops are developed. However, in aggregate, and as the level of warming becomes even greater, food price inflation should rise. Rising inflation may also materialize through reduced land availability. The surge in global temperatures may eventually cause some areas of the world to become inhabitable and with this will come mass migration. As our climate becomes more extreme, we are likely to demand greater energy to both cool our working and living environments during the summer and heat them when we experience harsher winters. Not only will energy demand change, but supply may shrink as the efficiency of existing power stations is compromised due to higher temperatures.

## **Conclusion**

Generally, the impact of climate change is significant on all components of the environment. Human beings are the final receiver of the cumulative impacts of climate change on all components of the environment. So, unless consistent mitigation measures and adaptation mechanisms are effectively implemented, the adverse impacts of climate change will be more pronounced.

Especially, the impacts of climate change on developing countries are highly concerning. Mitigation measures need collective actions of developed and developing countries. This can be achieved through having positive policy of mitigation measures by different countries. Every politician and leader should have a strong commitment to adaptation and mitigation measures. Persistent dialogue between developed and developing countries and financial support from developed nations to increase the capacity of developing nations on mitigation and adaptation measures will be necessary. Simultaneously, encouraging scientists, and experts, and ensuring the active participation of all concerned stakeholders to create and implement effective adaptation and mitigation measures has no alternative.

## References

- Afrane, Y.A., Zhou, G., Lawson, B.W., Githeko, A.K., Yan, G. (2006) Effects of microclimatic changes caused by deforestation on the survivorship and reproductive fitness of *Anopheles gambiae* in Western Kenya Highlands. *American Journal of Tropical Medicine and Hygiene* 74, 772-778. Available at: [www.bbc.com.uk](http://www.bbc.com.uk).
- Caldeira K., and J. F. Kasting, Insensitivity Of global warming potentials to carbon dioxide emission scenarios, *Nature*, 366, 251-253. doi:10.1038/366251a0, 1993.

Chivian, E.& Bernstein, A.S. (2004) Embedded in nature: human health and biodiversity. Environmental Health Perspective 112, A12–A13 edition. Available at: [www.ilo.org/public/english/employment/strat/kilm/download/kilm04.pdf](http://www.ilo.org/public/english/employment/strat/kilm/download/kilm04.pdf).

Clyde, D.F. (1967) Malaria in Tanzania. Oxford University Press 1147. edition. Available at: [www.ilo.org/public/english/employment/strat/kilm/download/kilm04.pdf](http://www.ilo.org/public/english/employment/strat/kilm/download/kilm04.pdf).

Forster, P., et al., Changes in atmospheric constituents and radiative forcing, in Climate Change 2007: The Physical Science Basis, (S. Solomon et al., eds.), pp. 129–234, Camb. Univ Press, 2007.

Githeko, A.K., Lindsay, S.W., Confalonieri, U.E. & Patz, J.A. (2000) Climate change and vector-borne diseases: a regional analysis. Bulletin of the World Health Organization 78, 1136

Harley, C. D, Randall, H. Hultgren, K. M., Miner, B. G., Sorte, C. J., Thornber, C. S., ..Williams, S. L. (2006). The impacts of climate change in coastal marine systems. Ecology Letters 9(2), 228-241.

ILO. 2007. Chapter 4. Employment by sector. In Key Indicators of the Labor Market (KILM), 5th

IPCC Online. 2001. Glossary of Terms used in the IPCC Third Assessment Report. Available at:

IPCC. (2013). Climate Change 2013: The Physical Science Basics. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC.2007a.Climate Change 2007 Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of IPCC. Cambridge. The UK. Cambridge University Press.

IPCC.2007b. Climate Change 2007 –Mitigation of climate change. Contribution of Working Group III to the Fourth Assessment Report of IPCC. Cambridge. The UK. Cambridge University Press.

IPCC.2007c. Climate Change 2007 the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of IPCC. Cambridge. The UK. Cambridge University Press

IUCN. (2010). 50 Years of Working for Protected Areas: A Brief History of IUCN World Commission on Protected Areas. Gland, Switzerland: IUCN.

Jackson, J. B. (2008). Ecological extinction and evolution in the brave new ocean. Proceedings of the National Academy of Sciences, 105(Supplement 1), 11458-11465

Joos, F., and R. Spahni, Rates of change in natural and anthropogenic radiative forcing over the past 20000 years, Proc. Nat. Acad. Sci., 105, 1425-1430, doi: 10.1073/pnas.0707386105, 2008.

Luthi, D., et al. 2008 High-resolution carbon dioxide concentration record 650,000– 800,000 years before present, Nature 453, 379-382, doi:10.1038/nature06949, 2008.

Martens, P., & Rotmans, J. (2005). Transitions in a Globalizing World. Futures 37, 1133-1144

Moir, L.E.G. & Kitua, A.Y. (2001) Malaria epidemics in Tanzania: An overview. African Journal of Health Sciences 8, 14-18.

Moir, L.E.G. (2004) Environmental and socio-economic determinants of malaria epidemics in the highlands of Tanzania, Tanzania Health Research Bulletin 6, 11-17.

Mendelsohn, R. (2013), “Climate Change and Economic Growth, Commission on Growth and Development”, Working paper no.60

Menon S, J. Hansen, L. Nazarenko, and Y. Luo, Climate effects of black carbon aerosols in China and India, *Science* 297,2250-2253. DOI: 10.1126/science.1075159, 2002.

Mooney, H., Larigauderie, A., Cesario, M., Elmquist, T., Hoegh-Guldberg, O., Lavorel, S., ... Yahara, T. (2009). Biodiversity, climate change, and ecosystem services. *Current Opinion in Environmental Sustainability* 1(1), 46–54

Moore, S., Shrestha, S., Tomlinson, K.W. & Vuong, H. (2011) Predicting the effect of climate change on African Trypanosomiasis: integrating epidemiology with parasite and vector biology. *Journal of the Royal Society Interface*. doi: 10.1098/rsif.2011.0654.

Oxfam. 2007. The report cited in BBC Online Weather disasters getting worse. 25 November 2007:

Patz, J.A., Martens, W.J.M., Focks, D.A. & Jettend, T.H. (1996) Dengue fever epidemic potential as projected by general circulation models of global climate change. *Environmental Health Perspectives* 106, 147–153

Patz, J.A., Campbell-Lendrum, D., Holloway, T. & Folley, J.A. (2005) Impact of regional climate change on human health. *Nature* 438, 310-317.

Sodhi, N. S., Şekercioğlu, C. H., Barlow, J., & Robinson, S. K. (2011). *Conservation of Tropical Birds*. John Wiley & Sons, Oxford.

T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung ... P. M. Midgley, Eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. United Kingdom and New York, NY, USA: Cambridge University Press.

Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press.

Townsend, A. R., Robert, W. H., Fakhri, A. B., Mary, S. B., Cory, C. C., Sharon. K. C. ...& Andrew, P. D. (2003). Human health effects of a changing global nitrogen cycle. *Frontiers in Ecology and the Environment* 1(5), 240-246. Weinberg, T., Russell, B. D., Moore, P. J., Ling, S. D., Smale, D. A., Campbell, A., ... & Connell, S. D. (2011). Impacts of climate change in a global hotspot for temperate marine biodiversity and ocean warming. *Journal of Experimental Marine Biology and Ecology*, 400(1), 7-16.

Trenberth KE, (2011) Changes in precipitation with climate change. *Climate Research*, 47: 123-138. doi: 10.3354/cr00953

Woodward, G., Perkins, D. M., & Brown, L. E.(2010). Climate change and freshwater ecosystems: impacts across multiple levels of the organization. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 365(1549), 2093-2106. [www.ipcc.ch/glossary/index.htm](http://www.ipcc.ch/glossary/index.htm).

Xu, J., Grumbine, R. E., Shrestha, A., Eriksson, M., Yang, X., Wang, Y. U. N., & Wilkes, A. (2009). The melting Himalayas: cascading effects of climate change on water, biodiversity, and livelihoods. *Conservation Biology*, 23(3), 520-530.