Global Warming and its Impact on Kenya's Coastal Structures

Seroni Anyona and Bernard K. Rop

Abstract - As the controversy over the pros and cons of the coastal zones worldwide, due to global warming, there is need particularly in Kenya to have the Coastal Development Authority (CDA) to initiate plans of managing and prescribing a safer distance from the current coastal development areas. The Kenya coastal structures, once a beauty of natural attraction, have potential of being ruined as a result of global warming due to environmental destruction. The gradual increase of sea level will definitely submerge the coastal structures. There is consensus among scientists that global warming will cause these levels to rise because of thermal expansion of seawater and melting of ice.
This premise requires setting the Coastal Regulation Zone (CRZ) rules to protect future potential disastrous damages to structures along the coastal development region. There is always a conflict between developers and environmentalists. Thus, we need to advocate for sustainable development where both parties agree, so that as we develop, we conserve and preserve nature as much as possible. Environmentalists are for the sustainable development. Sustainable development is bolstered by Nature-friendly advance of mankind with aesthetic, holistic and creative manifestation of spiritual and material faculties and potential of every person.
Global warming (observed increase in the average temperature of the Earth's atmosphere and oceans over the last two centuries, which has been noticed by meteorologists and other scientists, has amazingly clear indicators in a world today that man has been trying to respond to these phenomenon) of the Earth is a looming disaster on coastal structures and greenhouse effect that must be addressed by all and sundry in this time and age. The release of greenhouse gases (water vapour, carbon dioxide, methane, nitrous oxide and ozone) delay the escape of infra-red radiation from Earth to space, thus causing general climatic warming known as greenhouse effect. The current "developmental (industrial) human activities" are increasingly producing carbon dioxide and simultaneously increasing global temperature due to fossil fuel combustion and the global deforestations**.**

Keywords: Landslide, land use, slope, mitigation measures, volcanic rocks, geo-hazards.

I. INTRODUCTION

To many Kenyans, global warming is one of those ambiguous and abstract phenomena. It is only until the same is related to our practical day-to-day way of living that this phenomenon begins to make sense.

Global warming, defined as the observed increase in the average temperature of the Earth's atmosphere and oceans has amazingly clear indicators in our world today. Research has lately shown that the temperatures of both land and water bodies have increased over the past one hundred years, mainly due to certain human activities. The increased amounts of carbon dioxide and other greenhouse gases (water vapour, methane, nitrous oxide and ozone) are the primary causes of the human-induced component of global warming.

The immediate clear indicators of global warming in the world today include: rising of sea levels, changes in rain patterns, increase in extreme weather conditions such as floods, prolonged droughts, heat waves, hurricanes, tornadoes, etc. Consequently, there is an apparent receding of icecaps on mountaintops such as the Himalayas, Kilimanjaro (Figure 1a) and even Mt. Kenya, which is situated right on the Equator. All these effects have, over the past few years, been experienced in many parts of the world, including Kenya. It is the premise of this paper that the effect of global warming, particularly along the Kenya coastal areas, is a looming disaster that threatens the livelihoods of the coastal people and the imminent submergence of the coastal structures.

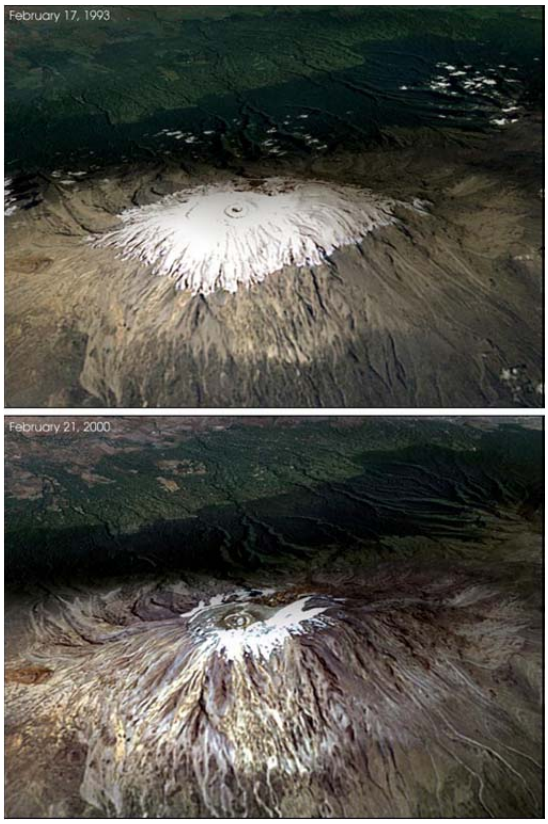

Figure 1a: Apparent receding of icecaps on mountaintop in Kilimanjaro, Tanzania, East Africa (Top 1993 & 2001)

Seroni Anyona, Bernard K. Rop, Department of Mining, Materials & Petroleum Engineering,Jomo Kenyatta University of Agriculture and Technology, Kenya. Corresponding author's email: sanyona@jkuat.ac.ke

II. EFFECTS OF GREENHOUSE

Water vapour, carbon dioxide, methane, nitrous oxide and ozone comprise the natural fraction of what are called the *greenhouse gases*. These gases delay the escape of infrared radiation from the Earth to space, thus causing general climatic warming known as *greenhouse effect*. Greenhouse effect is the trapping of heat in the atmosphere. Incoming short-wavelength solar radiation penetrates the atmosphere but the longer-wavelength outgoing radiation is observed by greenhouse gases and radiated to the Earth, causing a rise in surface temperature (Siddhartha, 1999). Human activities are rapidly intensifying this natural greenhouse effect. Carbon dioxide (CO_2) and chloro-fluoro carbons (CFCs) produced by human activities are also increasing global temperature (Figure 1). One molecule of CFC-11 and CFC-12 can trap as much as 10,000 molecules of CO_2. CFC level is increasing at the rate of 5% to 7% a year.

The fossil combustion and global deforestations are the causes of the increasing CO_2 concentration. The theory that increasing CO_2 would cause this greenhouse effect was first advanced in 1896 by a Swedish Physicist and Chemist named Svante Arrhenius. However, the idea took on a startling new significance in 1958 when Charles D. Kneeling, a Chemist and Professor of Oceanography, at Scripps Institution of Oceanography, began measuring CO_2 on Mauno Loa in Hawii. Since Kneeling's measurements began, the concentration of the gas has increased every year (Figure 2). It jumped from 315ppm in 1958 to 349ppm in 1987, a 25% increase from the levels that are thought to have been present before the Industrial age.

A forest stores about 100 tons of carbon per acre, and, in the last 50 years it is estimated that as much as half of the world's forests have been destroyed. Given current emission levels, the atmospheric (troposphere, stratosphere, mesosphere, thermosphere and exosphere) concentrations of CO_2 are expected to reach about 420ppm by the year 2030 (Patwardhan, 1999). In the last 100 years, the global mean temperature has gone up, more or less, by about 0.5°C. As per the scientists, the temperature could increase by a total of as much as 4.5°C in the next 50 years, as the basis of current greenhouse omissions.

.

III. EFFECTS OF GLOBAL WARMING

As the controversy over the pros and cons of the coastal zones worldwide, due to global warming, there is need for the Kenyan Government to have the Coastal Development Authority (CDA) to initiate and enforce regulatory measures that would manage our coastal resources. The Kenyan coastal structures, such as the beautiful shores, hotels and other upcoming impressive buildings, have potential of being ruined as a result of global warming. The gradual rise of sea level will definitely submerge these coastal structures in the near future. There is consensus among scientists that global warming will cause the sea level to rise because of thermal expansion of seawater and melting of ice at the poles (Figures 1 and 2).

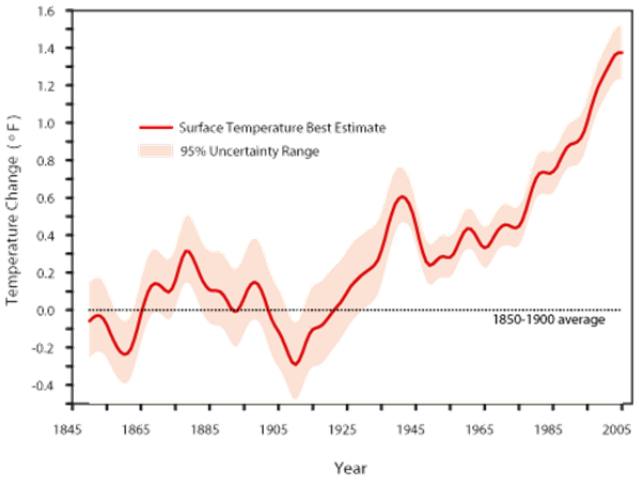

Figure 2: Atmospheric CO_2 and surface temperature trends. Source of CO_2 concentration data: Koeling C.D. and T.P. Whorf 2005. Atmospheric CO_2 records from sites in the SIO air sampling network.

Global warming is a climate-related hazard that affects atmospheric and ocean processes in any given ecosystem. Due to climate changes, the low-lying coastal areas/zones, worldwide, are vulnerable and risk being flooded/destroyed as a result of the melting of ice and rising of sea levels. These climatic-hazards often result in tropical cyclones that cause havoc, especially along the east coast of Africa. Thus, inappropriate coastal structures and designs development should be discouraged and/or avoided. The Government of Kenya must, therefore, set up Coastal Regulation Zone (CRZ) rules to avoid future disastrous damages to structures developed along the coastal areas, thus mitigating the looming environmental catastrophes. These problems result from the implementation of projects without considering the environmental impact assessment (EMCA – 1999 Act of National Environment Management Authority – NEMA).

IV. MELTING ICE

Ice contains large freshwater supplies and is an important part of the ecosystem. A rise in temperature leads to a reduction of ice and snow in mountain chains like the Himalayas of Asia and the Andes of Latin America. Mount Kenya, Kenya's scenic snow-cap, rising above the surrounding savanna and lying directly on the equator is equally affected by global warming. From the forest belt growing between 3 000 and 4 000 m to the glacial summit at 5 199 m, Mt. Kenya receives over 2 000 mm of precipitation annually. The eminence of the glaciers on mount Kenya in the early 1970s is evident from the satellite imagery (Figure 3). This water feeds the Ewaso Nyiro River and the Tana—Kenya's largest rivers. Mount Kenya's contribution to the Tana provides roughly half the water needed for its crucial hydropower facilities. Due to the effect of global warming glaciers are no longer an issue to be proud

about on Mount Kenya (Figures 4,5,6 and 7) and equally other mountains across the world. This changes the supply of freshwater via rivers, and affects agriculture, human health, plant and animal life in the areas which depend on this flow of freshwater from the mountains (World Environment Day, 2007). Only 11 of the 18 glaciers that covered Mount Kenya's summit a century ago remain, leaving less than one third of the previous ice cover. The ice on Mount Kenya has also become thinner. While this trend dates to the late 1800s, emerging evidence suggests that it has accelerated since the 1970s.

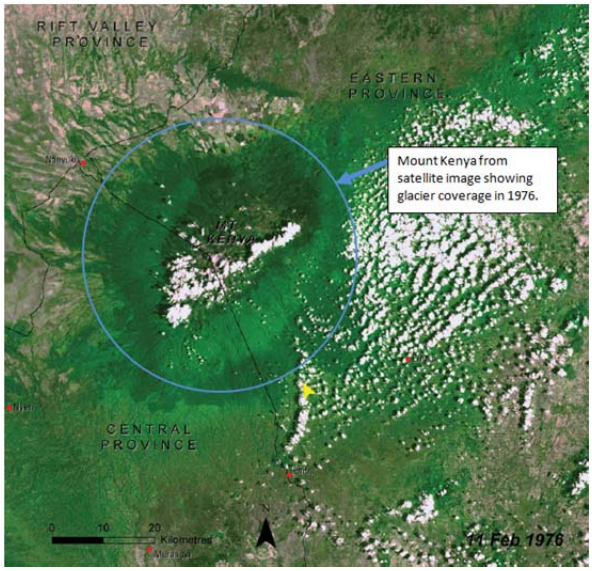

Figure 3: Glacial summit of Mount Kenya in the 1970s

According to Environment News Service (2007), the international community now widely agrees that climate change will constitute one of the major challenges of the 21st century, which is directly related to melting of ice. Melting polar ice sheets contribute to a rise in sea level, which affects the people living on low islands and in low lying coastal areas.

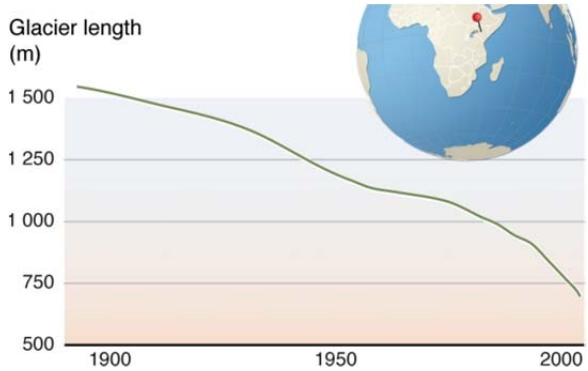

Figure 4: Shrinking Lewis Glacier, Mount Kenya. The tropical Lewis Glacier retreated by more than 800 m between 1893 and 2004 and lost almost 16 m water equivalent of its thickness between 1979 and 1996. Located on Mount Kenya, this is one of few locations in Africa

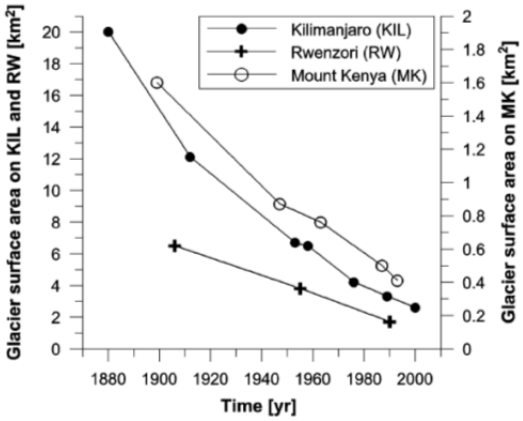

Figure 5:Time series of glacier surface areas on Kilimanjaro, Kenya and Mt. Rwenzori. Data from Osmaston (1989)

Numbers of climate refugees might reach enormous dimensions if millions of people in densely populated, low-lying countries are forced to move by rising sea levels. In the South Pacific, this has already begun to occur in some low-lying islands. Likewise, World watch Institute (2000) has mentioned 18 different locations from all around the world, where the threat of melting ice is alarming

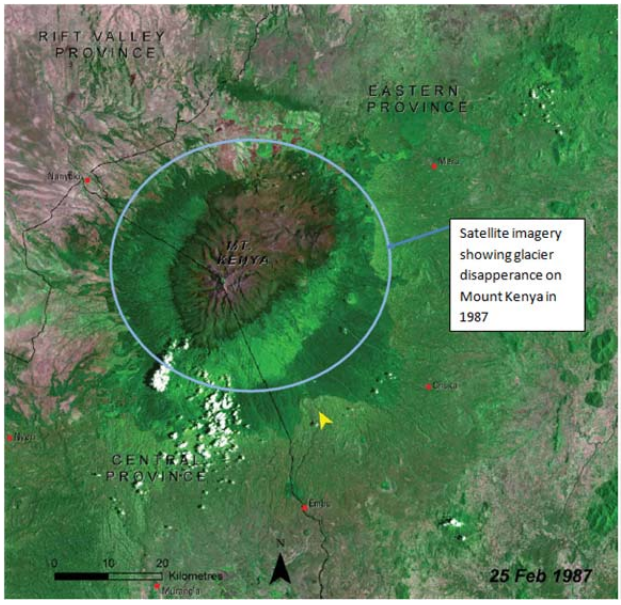

Figure 6: The effect of global warming is evident from the melting and disappearance of glaciers on the peak of Mount Kenya.

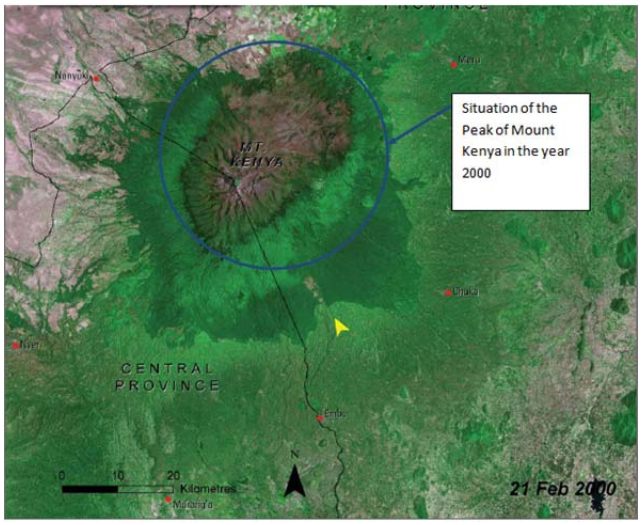

Figure 7: Peak of Mount Kenya with no sight of the glaciers

V. RISE OF SEA LEVEL

There is consensus among scientists that global warming will cause these levels to rise because of thermal expansion of seawater and melting of ice. There will be changes in salinity, tidal flooding in oceanic currents, storm intensities and frequencies, biological process, in run-off and land-mass erosion patterns, salt-water intrusion, etc. The shape of the coastal line will be altered, resulting in the loss of fragile coastal land and marshes. Coastal wetlands act as filters for such as heavy metals, radio-isotopes, fertilizer run-off and sewage effluent. They also act as sponges in tidal circulation and increased wave action. The mangroves, which bind the shorelines with density intertwined root system, rely for survival on periodic flushing of water. They are extremely susceptible to alterations in the water balance.

During the recent 100 years, the global mean rise in sea level has been about 5cm. The most likely explanation for this rise is global atmospheric warming. The models base on global warming of 1.5^{o}C to 4.5^{o}C have predicted a rise in global mean level of 0.3 to 0.4 meter by 2050, and a rise in 2m by 2100. A 0.7m global sea level rise would produce major loss of valuable natural resources and ecosystems such as coastal structures' beaches, dunes, estuaries, barrier island and Wetlands (Figure 8). It would result in salination of coastal drinking water supplies. Thus serious threats to already weakened coastal infrastructure are expected. Many of the adverse consequences of accelerated sea level rise can be reduced, or even avoided, by coastal land and water planning that takes the effect of sea level rise and global warming into account. Many countries that have no plans to combat sea level will experience drastic consequences from even a moderate rise. Two such countries are Bangladesh and Egypt.

In Egypt, for thousands of years, the national economy and people's livelihood had been intimately connected to the Nile River. In 1964 closure of the high dam at Aswan, some 900 km up the river cut off the sediment supply to the delta. The constant supply of sediment carried down the giant river had build up the delta at a comparable rate effectively nullifying the adverse effects. Now the coastal residents feel the impact of the action. Should the current trend of relative sea level continue in Egypt some 8 to 10 million people may be displaced as flooding waters submerge their land. One metre rise in sea level, approximately 15% of country's gross domestic product (GDP) will be affected in the same way.

Bangladesh, the most densely populated country, 80% of the land is made up of complex delta systems, fed by the Ganges, the Brahmaputra and the Meghna rivers. 85% of Bangladesh people depend on agriculture for their livelihood. A one-centimeter sea level rise will affect approximately 9% of the country's population, destroy 11% of nation's crops and affect 6% of GDP. Historically, Bangladesh is vulnerable to major cyclonic activity. The country is neither financially nor socially prepared to cope with the predicted rise in sea level.
Assuming worst-case scenario of one metre rise in the level of the sea caused by the greenhouse effect, more than 200 sq.km of Kenya's coastal area could be submerged by the year 2100. The tropical cyclones along the east coast of Africa would have approximately 5% of its area inudated with mangroves and wetland unique fragile ecosystems on the coast being wiped out. Presently, about 7 million people live in the coastal districts of Malindi, Lamu, Mombasa, Kilifi and Kwale. These areas, susceptible to submergence, are homes for about 2.5 million people (Figure 8). Thus, there is need for CDA, through Coastal Zone Management (CZM), to identify the most appropriate and adaptive options and policy implications of sea level and climate change along the Kenyan coastline. CZM would provide information and recommendations to national (NEMA) and international policy centers regarding integrated coastal zone management strategies for the next twenty years, as well as long-term policies dealing with adaptation to the impact of global climate change, including sea level rise. Other predicted consequences of global climate change, apart from sea level rise, include prolonged droughts, desertification and flooding. Deforestation, inappropriate coastal development and poor land management will further aggravate the effects of climate variability and change.

Figure 8: Vulnerable Coastal structures (recreational facilities) along Mombasa Beaches

The integrated CZM should urge coastal people to begin the process of adapting to sea level rise, not because there is an impending catastrophe, but because there are opportunities to avoid adverse impacts by acting now. The following suggested recommendations should be enforced:-

VI. RECOMMENDATIONS

During the analysis, policy-relevant messages have emerged.

- Coasts are experiencing the adverse consequences of hazards related to climate and sea level (very high confidence).
- Coasts will be exposed to increasing risks, including coastal erosion, overcoming decades due to climate change and sea-level rise (very high confidence).
- The impact of climate change on coasts is exacerbated by increasing human-induced pressures (very high confidence).
- The unavoidability of sea-level rise, even in the longer-term, frequently conflicts with present-day human development patterns and trends (high confidence).
- Adaptation costs for vulnerable coasts are much less than the costs of inaction (high confidence).
- Adaptation for the coasts of developing countries will be more challenging than for coasts of developed countries, due to constraints on adaptive capacity (high confidence).

Subsequently, the following recommendations have been made on the better management of our coastal ecosystem

a) By the year 2012, coastal areas should implement comprehensive CZM plans through NEMA's EMCA and CDA Acts.
b) Coastal hazard-prone areas, at risk should be identified.
c) Kenya should ensure that CDA enforces coastal socio-economic development activities with a view of not increasing coastal structures vulnerability to sea level rise.
d) Emergency preparedness and coastal zone response mechanisms need to be continuously reviewed and strengthened for the betterment of our coastal resources (renewable and non-renewable).

A. What the proposed Coastal Regulation Zone (CRZ) should prohibit

- Setting up of new industries and expanding existing ones, except those directly related to water front or directly needing foreshore facilities.
- Manufacturing, handling, storing or disposing of hazardous warehousing.
- Setting up and expansion of fish processing units including warehousing.
- Setting up and expanding units/mechanisms for disposal of waste and effluents.
- Discharging untreated wastes and effluents from industries, cities or towns and other human settlements.
- Dumping city or town waste for purposes of land-filling or otherwise.
- Reclaiming land, bunding or disturbing the natural course of sea water with similar obstructions.
- Mining sand, rocks and other substrata material, except those rare minerals (e.g. titanium) not available outside the CRZ areas.
- Harvesting or drawing groundwater and construct the mechanisms therefore within 200m of the high-tide line.
- Constructing buildings in the ecologically sensitive areas (e.g. the fragile mangrove and wetland areas).
- Performing construction activity between the low-tide line and high-tide line.
- Dressing or altering sand dunes, hills, natural features (e.g. Coastal reefs).

B. What the proposed CRZ should allow

- Construction activities related to defence requirements for which foreshore facilities are essential (slipways, jetties, etc); except for classified operational component of defense projects for which a separate procedure shall be followed.
- Operational constructions for ports, harbours and lighthouses requiring water frontage.
- Thermal power plants (only foreshore facilities for transport of raw materials, facilities for in-take of cooling water and outlet for discharge of treated waste water/cooling water).
- Activities with investment exceeding 10 million shillings.
- Setting up and expanding facilities required for discharging treated effluents into watercourse, with approval under the Water Act 2002, and for storm water drains.
- Land reclamation, bunding or disturbing the natural course of sea water with structures required for control of coastal erosion and maintenance or clearing of water ways, channels, and ports and for prevention of sandbars and also for tidal regulators, storm water drains.
- Mining rare minerals not available outside CRZ areas.
- Harvesting groundwater in the 200m to 500m zones, only when done mutually through ordinary wells-for drinking, horticulture, agriculture and fisheries.
- Dressing or altering sand dunes, hills, natural features-including landscape change for beautification, recreational and other such purpose permissible under the NEMA's EMCA (1999) Act.

VII. CONCLUSION

The rigorous implementation of the NEMA's 1999 Act (EMCA), after an EIA has been approved would help conserve and preserve the fragile ecological Coastal Belt and lead to an increase in fishing industry/wealth. NEMA and the CRZ Management Plan, in liaison with CDA, should approve the construction of residential houses and hotels up to a height

of 10 metres, which would be sufficient to put up a two-to four-storeyed structure.

The greedy developers/builders and hoteliers, who would be prevented from ravaging the coastal line by NEMA, will definitely agitate against the formation CRZ Act. Experience has shown that unbridled building activities along the coast are indeed detrimental to the interests of the fishing community. If the construction activities continued along the coastal area, the big structures would definitely erase fishermen community and force them further inland. Thus, the interests of the fishermen community should be protected as sustainable socio-economic development is being implemented.

The environmentalists and political developers should demand an integrated Coastal Zone Management Plan that should contain some positive steps to protect the fragile coastal ecology. Planting of mangrove along the coast areas (shores) will and thus protect the coastal structures from grave catastrophes in future.

REFERENCES

[1] Action group on Erosion, Technology and Concentration http://www.etygroup.org
[2] Famine Early Warning Network http://www.ids.ac.ut.fews.net
[3] Institute of Development Studies
[4] International Institute for Environment & Development www.iied.org
[5] Intergovernmental Panel on Climate Change http://www.ipcc.ch
[6] Journal of Soil and Water Conservation http://www.secs.org/photo
[7] UN Convention to Combat desrtification http://www.unccd.it/main.php
[8] Natural Oceanic & Atmospheric Administration www.photoolib.noaa.gov/
[9] World Bank http://www.worldbank.org
[10] World Health Organization http://www.who.int/pub/en
[11] United Nations Environment Programme http://www.unep.org
[12] Mitchell, T. 2003. An Operational Framework for Mainstream Disaster Risk Reduction.
[13] Patwardhan A. M. (1999): The Dynamic Earth System. Prentice-Hall of India, pp.404.
[14] Siddhartha, K. 1999. Oceanography. A Brief Introduction. Kisalaya Publications Pvt. Ltd., New Delhi 347pp.
[15] 1992 UN Conference on Environment and Development (the Earth Summit) in Rio de Janeirro,Brazil.
[16] 1972: UN Conference on Human Environment (Stockholm); UNEP established.
[17] 2000: Launch of the International Strategy for Disaster Reduction (ISDR).
[18] 2000: Millennium Summit, New York, USA.
[19] 2002: World Summit on Sustainable Development, Johannesburg, South Africa.
[20] 2005: World Conference on Disaster Redacting, Kobe, Japan.
[21] Water Act 2002: Government of Kenya Printer, Nairobi, Kenya.
[22] NEMA's Environmental Management and Co-ordination Act, 1999: Government of Kenya Printer, Nairobi, Kenya.
[23] The Environmental (Impact Assessment and Audit) Regulations, 2003 (NEMA)
[24] Building Code (1997) Local Government Regulations (1963)
[25] World Environment Day. 2007: Melting ice - a hot topic?Accessed on August 29,
[26] World watch Institute. 2000: Melting of Earth's Ice Cover Reaches New High. Posted on March 6. Available at: *http://www.worldwatch.org/node/1673*