4

Impact of Climate Change under Coastal Ecosystem and Adaptation Strategies

B.L. Meena, R.L. Meena, Manish Kanwat, A. Kumar and M.L. Dotaniya

Introduction

Increasing evidence over the past few decades indicate that significant changes in climate are taking place worldwide and its effects are surreal. Major cause to climate change has been ascribed to the increased levels of greenhouse gases like carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), chlorofluorocarbons (CFCs) beyond their natural levels due to the uncontrolled human activities such as burning of fossil fuels, increased use of refrigerants, and enhanced agricultural activities. Global average sea level has risen since 1961 at an average rate of 1.8 (1.3 to 2.3) mm/yr and since 1993 at 3.1 (2.4 to 3.8) mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and polar ice sheets. The climatic changes are resulting in erratic weather patterns and the impacts are already being manifested in many parts of the world and coastal agricultural systems are nearing crisis point. The IPCC has projected that during the 21^{st} century the global surface temperature is likely to rise a further by 1.1 to 2.9 °C as per their lowest estimation model and by 2.4 to 6.4 °C as per their higher estimation model.

Increase in population and urbanization, the availability of arable land dwindled considerably from 0.48 ha in 1950 to 0.15 ha in 2005 and is likely to further reduce to 0.08 ha by 2020 (Mall *et al*., 2006). Under climate change scenario, agriculture which feeds the entire human population is under great threat. More and more chemical fertilizers are now needed to produce per kg of food grain. Since the last few decades the average surface temperatures of the earth have risen appreciably. Water is becoming scarce in many regions. These phenomena have serious implications on bio-diversity as well as economics and livelihood patterns of the people of coastal ecosystem. This is particularly true in developing countries where a large portion of their population depends directly on agriculture for their livelihoods and their economies are closely linked to agriculture.

Causes of climate change

The major cause of climate change is the Global warming. Global warming is the rise in the average temperature of the earth's atmosphere Earths temperature depends on the balance between leaving the planets system (www.epa.gov/climatechange/science/causes.html). When incoming energy from the sun is absorbed by the Earth system, it warms. When the suns energy is reflected back into space, Earth avoids warming. When energy is released back into space, Earth cools. The factors causing changes in Earths energy balance are:

1. Changes in the greenhouse effect, which affects the amount of heat retained by Earths atmosphere.
2. Variations in the suns energy reaching Earth.
3. Changes in the reflectivity of Earths atmosphere and surface.

Since the early 20th century, the earth's mean surface temperature has increased (Fig. 1) by about 0.8 °C (1.4 °F) of which about two-thirds of the increase occurred since 1980 (NASA 2010; NRC 2010). Recent climate changes, however, cannot be explained by natural causes alone such as changes in solar energy, volcanic eruptions, and natural changes in greenhouse gas (GHG) concentrations. Research indicates that natural causes are very unlikely to explain most observed warming, especially warming since the mid-20th century. Rather, human activities can very likely explain most of that warming (NRC, 2010). Scientists are certain that global warming is primarily caused by increasing concentrations of greenhouse gases (CO_2, CH_4 and N_2O) produced by human activities such as the burning of fossil fuels, deforestation, industrial production, agricultural activities (IPCC 2007; NRC 2010). The approximated contribution of different sectors of human activities to global warming is shown in Fig. 2. Carbon dioxide (CO_2) comes from the combustion of fossil fuels in cars, factories and electricity production and is most responsible for global warming. The content of CO_2 in the atmosphere is increasing rapidly in the recent years (Fig. 3). The major contributors of CO_2 are the developed countries and USA in particular (Fig. 4). The developed world's emissions had contributed most to the stock of green-house gas (GHGs) in the atmosphere and the per capita emissions *(i.e.* emissions per head of population) are still much low in developing countries. The emissions from the developing countries will now be increasing to meet their development needs. Besides CO_2 the other GHGs contributors include methane (CH_4) released from agricultural activities and from the digestive systems of grazing animals (ruminants), nitrous oxide (N_2O) from fertilizers used in agriculture, gases used for refrigeration (chlorofluorocarbons) and industrial processes and the loss of forests that would otherwise store CO_2.

The Intergovernmental Panel on Climate Change (IPCC) estimated that 31% of total emissions of greenhouse gases in 2004 came from agriculture and forestry. Different greenhouse gases have different heat trapping abilities. The other GHGs can trap more heat than CO_2. A molecule of methane (CH_4) produces more than 20 times the warming of a molecule of CO_2, Nitrous oxide (N_2O) is 300 times more powerful than CO_2. Other gases, such as chlorofluorocarbons (its use has been banned by many countries as it degrades the ozone layer) have heat-trapping potential thousands of times greater than CO_2. But because their concentrations are much lower than CO_2, none of these gases adds as much heat to the atmosphere as CO_2 does. The IPCC has also projected that during the 2151 century the global surface temperature is likely to rise a further by 1.1 to 2.9 °C as per their lowest estimation model and by 2.4 to 6.4 °C) as per their higher estimation model. The heat absorbed by the earth is not uniformly distributed throughout. The ocean is the main absorber which absorbs about 93% of the total heat absorbed by the earth.

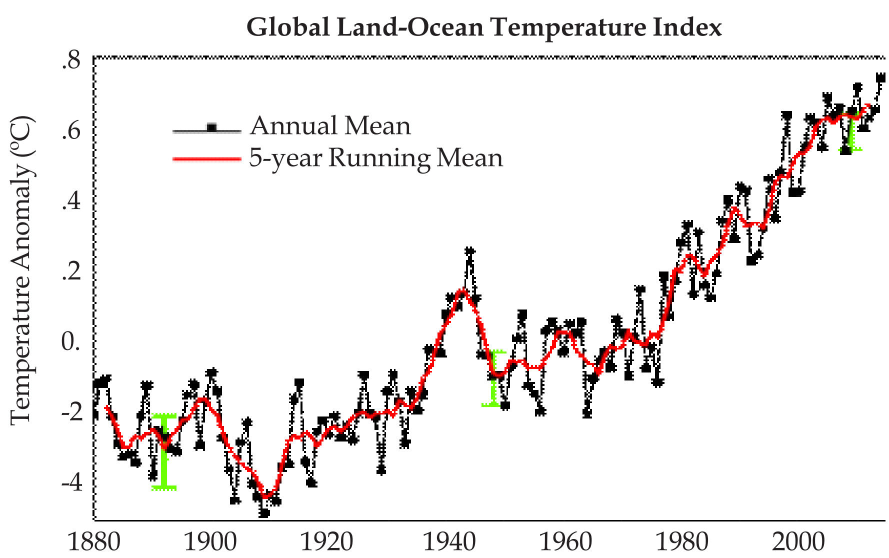

Fig. 1. Global mean land-ocean temperature changes from 1880-2000, with the base period 1951-1980. The green bars show uncertainty estimates.
(Source: NASA GISS)

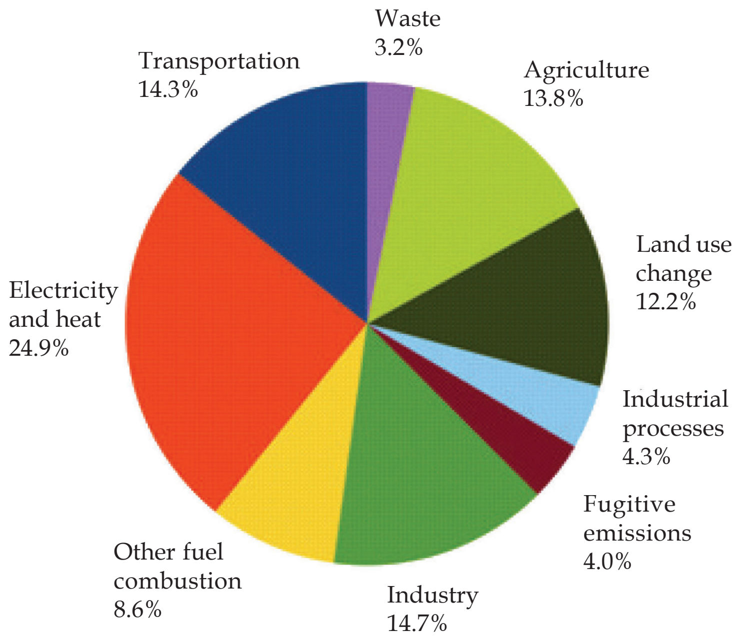

Fig. 2. Annual worldwide greenhouse gas emissions in 2005 by different sectors
Source: https://upload.wikimedia.org

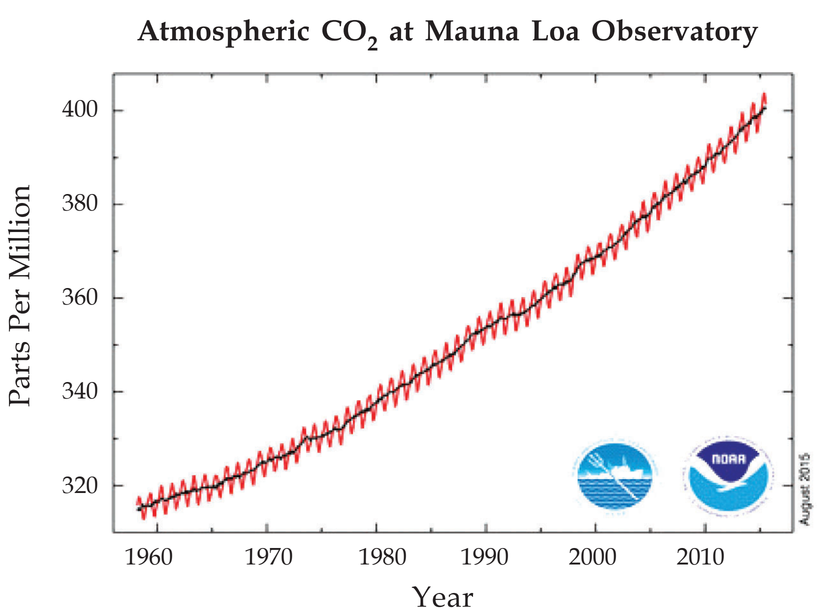

Fig. 3. Increase in atmospheric carbon dioxide over the year 1960-2010
(*Source:* http://www.esrl.noaa.gov)

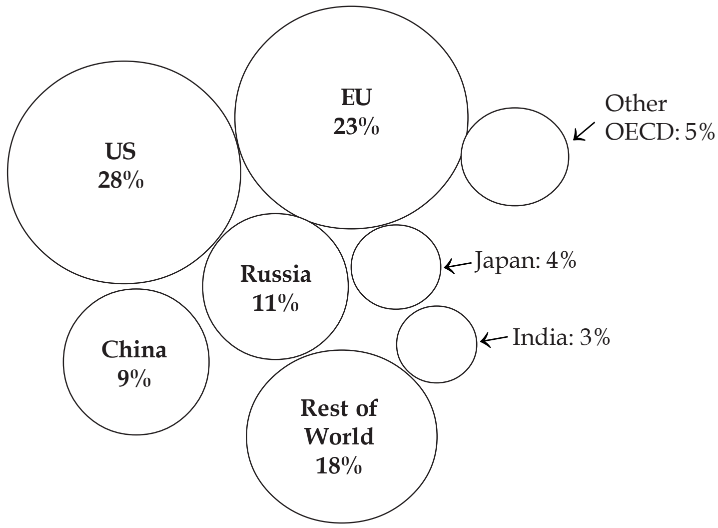

Fig. 4. Bubble diagram showing the share of global cumulative energy-related carbon dioxide emission for major emitters between 1890-2007.
(*Source:* https://www..wikimedia.org)

Impact of climate change

Climate change may result in great threat to food security (due to decreasing crop, fish and meat yields) of human being and the loss of habitat due to sea level rise, particularly in the coastal region. In coastal regions agriculture and aquaculture co-exist as major livelihood of rural communities. The impacts of climate change on coastal ecosystem are briefly given below;

1. **Agriculture:** There may be considerable impact on microbes, pathogens and insects, which may result in more infestation of crops by disease and pests and deterioration of soil quality. Increase in temperature and soil-water salinity and decrease in fresh water availability would decrease crop yield drastically. The effect is expected to be very severe in major river flood plains of the world including Indo-Gangetic plain. Sea level rise will cause saline water intrusion through rivers and estuaries and many fertile lands will be 'inundated by saline water making them unfit for agriculture.

2. **Water resource:** The ground water quality will deteriorate by saline water intrusion. There may be changes in the water cycle and fresh water availability may be more scare in coastal areas. Global average sea level has risen since 1961 at an average rate of 1.8 (1.3 to 2.3)

mm/yr and since 1993 at 3.1 (2.4 to 3.8) mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and polar ice sheets (Rao, 2011).

3. **Natural ecosystems:** Mangroves, coral reefs, sea grass, marine life, *etc.* are vulnerable due to frequent changes in rainfall pattern, sea level rise and warmer sea temperature. Coastal wetlands including salt marshes and mangroves are likely to be very badly affected by sea-level rise especially where they are starved of sediment.
4. **Fisheries and aquaculture:** Increasing sea and river water temperatures are likely to affect fish breeding, their migration and production. Migration of different marine and inland species to favorable climate region
5. **Livelihood of people:** Sea level rise will make many coastal families homeless. Climate change may increase high tides levels, storms, floods, seismic sea waves (tsunami), erosion and more climatic hazards like, cyclone, *etc.* for which coastal areas will be exposed to increasing risks. This will threaten vital infrastructure, settlements and facilities that support the livelihood of coastal communities including the island communities. A new group of refugees will emerge called the environmental refugees. Some of the most vulnerable coastal areas in India are Sundarbans, Gujarat coast, Mumbai, South Kerala, South West Bengal, Lakshadweep Islands, Andaman Islands and many other small Islands (small Islands are especially vulnerable). In India, Vishakhapatnam beaches are severely eroding, Puri beaches are slowly disintegrating, and water has started entering close to solid ground in Goa beaches and would affect tourism and local coastal communities.

Mitigations strategies to climate change

Assess biophysical and socio-economic implications of mitigation of climate change before developing policy for their implementation. The IPCC defines mitigation as activities that reduce greenhouse gas (GHGs) emissions, or enhance the capacity of carbon sinks to absorb GHGs from the atmosphere. Climate change mitigation also includes acts to enhance natural sinks, such as reforestation, increased carbon sequestration in soil through appropriate management of agriculture, *etc.* Most countries are now members to the United Nations Framework Convention on Climate Change (UNFCCC), whose ultimate objective is to prevent dangerous anthropogenic climate change activities. The member countries of the UNFCCC (UNFCCC 2011) have agreed that urgent actions are to be taken to reduce the emission of GHGs and that future global warming should be limited to below 2.0 °C relative to the pre-industrial level. Many believe that a rise of 2.0 °C is the threshold beyond which impacts are likely to be severe, and dangerous to environmental systems. Agriculture, forestry and land use practices may have a major role to play in mitigation measures. According to IPCC (IPCC 2007), forestry accounted for 17% of greenhouse gas emissions in 2004. But if deforestation can be halted, reforestation initiated and existing forests are managed more sustainably by communities, forests could become part of the solution instead of part of the problem. Agriculture contributes about 14% of GHGs emission. But if soils can be better managed it can store more carbon. Agroforestry is also an underutilized mitigation option in agriculture; it can store more carbon in trees and in soil, while improving the soil quality. Many of the options that relate agriculture and natural resources management will have immediate development benefits towards, the productivity of the natural resource or system.

Adaptations strategies to climate change

Indian farmers have tremendous experience of coping with adverse climate and a large number of indigenous practices have been evolved over time. The local knowledge is much more important in adaptation, while mitigation require a national effort, new technologies and several policy initiatives. The different adaptation strategies may be adopted for coastal areas are summarized as follows.

Crop And Cropping System Based Strategies: These are mainly centered on promoting the cultivation of crops and varieties that fit into the changed crop calendars and seasons, development of varieties with changed duration that can overwinter the transient effects of change, varieties for high temperature and heat stress tolerance, salinity, drought and sub-mergence tolerance and varieties which respond positively to high CO_2 (Challinor *et al.,* 2007). Farmers will like to have their crops/ varieties performing well in difficult environments, but also to produce very high yields when conditions are more favorable. Adjusting showing time of crops according the changing pattern of rainfall, soil-water salinity, humidity, temperature and other climatic variables may decrease the losses to crop production.

Integrated pest and disease management (IPDM): Changing climate will change the pattern and intensity of attack of pests and diseases to crops and livestock. Temperature, humidity, rainfall and other weather parameters influence the spread of pests and diseases. Higher temperatures speed up the lifecycle of some pests and diseases, and their vectors thus; infestation by pests and diseases may rise. Anticipation of pest and disease outbreaks, and integrated pest and disease management (IPDM) is an urgent need in view of climate change.

Resource conservation based technologies: The major resource conservation based technologies in combating climate change are; *in situ* moisture conservation, rainwater harvesting and recycling, efficient use of irrigation water, conservation agriculture, energy efficiency in agriculture and use of poor quality water. Low quality water/ saline water can be managed and used in conjunction mixing with good quality water and more tolerant crops/ varieties are to be developed. Agriculture in developing countries mostly uses the traditional technologies for irrigation. Agriculture consumes about 70-90% of total use of water. Alternative improved technologies must be used to produce more food with less water to feed the growing population. The key approaches include: integrated watershed development; improving rainwater use efficiency through on-farm harvesting and recycling; contingency crop planning to minimize loss of production during drought/flood years. Watershed management is now considered an accepted strategy for development of rainfed agriculture. Watershed approach has many elements which help both in adaptation and mitigation. For example, the soil and water conservation works, farm ponds, check dams etc. moderate the runoff and minimize floods during high intensity rainfall. The small farm reservoirs (farm pond, furrows, channels, *etc.)* technology developed (Ravisankar *et al.*, 2008) by Central Agricultural Research Institute, Port Blair, India for harvesting rainwater in farm and its multiple uses turned to be very successful for coastal areas of India. Wastewater is rich in several plant nutrients but it may contain load of harmful bacteria and heavy metals. Research at Central Soil Salinity Research Institute, Kamal (CSSRI, 2013) has shown that waste water can be used successfully for irrigation of agro-forestry, non-edible crops and even for grain crops like wheat.

Land shaping: Land shaping means re-shaping the surface morphology of land for raising a portion of it in form of raised land ridges through excavation of soil by making ponds/ furrows/ channels, *etc.* to address the problems related to the soil drainage as well as on-farm harvesting of rainwater for multipurpose farm uses including irrigation, aquaculture, animal husbandry, poultry, *etc.* The technology was developed and tested by Central Soil Salinity Research Institute (Ambast *et al.,* 2011). It may be particularly important for low-lying coastal delta regions of Indo-Gangetic plain in India and other delta regions of major rivers in the world, which have poor drainage condition and are subjected to submergence following heavy rains, sea level rise, *etc.*

Soil Management: Appropriate soil management will be conserving/ improving soil quality and will reduce vulnerability of farming systems in the face of climate change. Organic manure is a critical input which improves soil health. Soil organic matter may be added by compost/ vermin-compost, azolla, crop residues, green manure, animal manure, intercropping, alley cropping (N_2 fixation), crop rotation with inclusion of legumes, agroforestry and growing cover crops especially the legume cover crops. More organic matter in the soil means, better microbiological health of soil, better availability of nutrients, less loss of nutrients, less carbon dioxide in the atmosphere (due to increased carbon sequestration in soil) and in the long run higher yield, better adaption and mitigation to climate change, and better environment. Judicious fertilizer application, a principal component of SSNM approach, thus has twofold benefit, i.e. reducing greenhouse gas emissions. The microorganisms in bio-fertilizers restore the soil's natural nutrient cycle, build soil organic matter and improve soil quality/ soil health. Through the use of biofertilizers, healthy plants can be grown, while improving the sustainability and environmental quality.

Reforestation: Reforestation, wherever possible, should be undertaken as an effective step towards climate change mitigation by reducing the vulnerability of the globe to climate change through fixation of atmospheric carbon load. Mangrove plants stabilize the coastal soils and protect it from erosion through its intricate root system. Mangroves not only provide effective protection to the coastal zone but also protect the country habitations against cyclones, sea surges, Tsunami waves, *etc.* Mangroves are important habitat for breeding and growth of fries of many fish species including shrimp. Massive mangrove reforestation programme should be undertaken in all the coastal areas.

Agroforestry: Agroforestry systems like agri-silvi-culture, silvipasture and agri-horticulture offer both adaptation and mitigation opportunities. Agroforestry systems buffer farmers against climate variability, and reduce atmospheric loads of greenhouse gases. Agroforestry can both sequester carbon and produce a range of economic, environmental, and socio-economic benefits (Jose, 2009). For example, trees in agroforestry systems improve soil fertility through control of erosion, maintenance of soil organic matter and physical properties, increased N accretion, extraction of nutrients from deep soil horizons, and promotion of more closed nutrient cycling. In rangeland areas, pasture improvement is essential to combat impeding changes through planned grazing processes, enclosures for recovery, or enrichment planting.

Integrated farming systems (IFS)

Integrated farming systems approach also provides insurance against climate risks. Multiple-enterprise agriculture consisting of crop, livestock, poultry, fish farming and trees in a single unit of land will ensure protection against projected loss due to climate change and will also benefit from on farm resource use (Meena *et al.,* 2014). Several farming systems modules have been developed both for irrigated and rainfed conditions, which consists of one or more enterprises and the risk minimization potential of these modules is well documented (Behera *et al.,* 2008). The included breeds of livestock in IFS should have high feed efficiency so that they can produce high yield with less feed and can withstand multiple stresses. Climate change could open up new opportunities for fish farming as the sea encroaches on coastal lands. Research has shown that there are some strains in *Talapia fish* which have tolerance to saline environments too (Ravisankar *et al.,* 2008).

Conclusion

The recent changes in global trends such as population growth, urbanization, increasing demands for water, over-exploitation of ecosystems, *etc.* will also have great adverse impact on climate change. If we really want meaningful mitigation we must re-look into the present trend in land use pattern and agricultural practices, energy generation and industrial activities within the global system as a whole. The effective measures for adaptations and mitigations to climate change require trans-boundary partnership programmes and regional and international cooperations as well as local measures. The impact of climate change is already being distinctly felt in fragile coastal ecosystems. The farming communities of coastal areas need intensive awareness training for appropriate management of soils, crops and trees to capitalize on their carbon storage potential. Policy incentives will play crucial role in adoption of climate needy technologies in agriculture too as in many other sectors.

References

Ambast S.K., Ravisankar N. and Velmurugan A. (2011) Land shaping for crop diversification and enhancing agricultural productivity in degraded lands of A&N Islands. Journal of Soil Salinity and Water Quality, 3(2): 83-87.

Behera U.K., Yates C.M., Kebreab E., and France J. (2008). Farming systems methodology poor efficient resource management at the farm level: A review from an Indian perspective. Journal of Agricultural Science, 146: 493-505.

Challinor, A.J., Wheeler, T.R., Craufurd, P.Q., Ferro, C.A.T., Stephenson, D.B. (2007). Adaptation of crops to climate change through genotypic responses to mean and extreme temperature. Agricultural Ecosystems and Environment, 119 (1-2): 190-204.

CSSRI. (2013). Annual Report of Central Soil Salinity Research Institute, Kamal, 2012-2013, p. 52.

IPCC (2007) Intergovernmental Panel on Climate Change Synthesis Report, Fourth Assessment Report (AR4) SYR 2007.

Jose Shibu (2009). Agroforestry for ecosystem service and environmental benefits: An overview. Agroforestry System, 76: 1-10.

Mall R.K., Ranjeet Singh, Akhilesh Gupta, Srinivasan G and Rathore L.S. (2006). Impact of climate change on Indian Agriculture: A Review. *Climate Change*, 78:445-478 (Springer Science, Business Media B.V.).

Meena B.L., Meena R.L., Ambast S.K. and Pandey M. **(**2014). Impact assessment of agriculture technological interventions in tsunami affected south Andaman - a case study. Bhartiya Krishi Anushandhan Patrika, 28(3): 141-148.

NASA (2010) 2009 ends Warmest Decade on Record. NASA Earth Observatory Image of the Day, 22 January 2010.

NRC (2010). *Advancing the Science of Climate Change* . National Research Council. The National Academies Press, Washington, DC, USA.

Rao,GSLHV Prasad(2011). *Climate Change Adaptation strategies in Agriculture and Allied Sectors.* Scientific Publication (India), 336 p.

Ravisankar, N., Ambast, S.K. and Srivastava R.C. (2008). *Crop Diversification through Broad Bed and Furrow System*. Central Agricultural Research Institute, Port Blair, 220p.

UNFCCC (2011) *Status of Ratification of the Convention.*UNFCCC Secretariat Bonn, Germany: UNFCCC.

❐❐❐