CHAPTER 2

BIODIVERSITY AND ITS RELATIONSHIP WITH CLIMATE CHANGE

2.0 BIODIVERSITY AND CLIMATE CHANGE

Changes in the climate of the India and the rest of the world have accelerated in the 20th century, as increasing amounts of greenhouse gas, particularly carbon dioxide, were released into the atmosphere by humankind. Virtually all scientists and decision makers now accept that climate change is accelerating due to human activity at a rate far in excess of natural processes\(^1\). Climate is one of the most important factors that influence the behaviours, abundance and distribution of species, as well as having a strong influence on the ecology of habitats and ecosystems. Changes in the behaviours, abundance and distribution of species are already being observed and linked to climate. Over time these and other changes are likely to become increasingly profound.\(^2\)

\[\text{Figure 1: Drax coal-fired power station}\]


\(^3\) Credit: Natural England, Photographer: Paul Glendell
2.1 BIODIVERSITY

The term biological diversity was coined by Thomas Lovejoy in 1980, while the word “biodiversity”, shorter version of “biological diversity”, was coined by the entomologist E.O. Wilson in 1986, in a report for the first American Forum on biological diversity organised by the National Research Council (NRC), to replace biological diversity, considered to be less effective in terms of communication.

Biological diversity has no standard definition. A simple definition of biodiversity defines it as the totality of genes, species, and ecosystems of a region. An advantage of this definition is that it seems to describe most instances of its use, and one possibly unified view of the traditional three levels at which biodiversity has been identified.

- Biodiversity may be defined as the totality of different organisms, the genes they contain, and the ecosystems they form.
- The Convention on Biological Diversity defines biodiversity as the variability among living organisms from all sources including, among other things, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

Biodiversity may be considered at three levels: genetic diversity, species diversity, and ecosystem diversity.

- Genetic Diversity

Genetic diversity refers to the variations of genes within species. It includes genetic variability within and between the populations of the same species. Species diversity encompasses the variety of living organisms-plants, animals and other forms of life existing in a region. It refers to the number of different species that constitute the entire biological spectrum on Earth. Genetic variation allows species to evolve in response to diseases, predators, parasites, pollution, and climate change. In addition to traditional breeding, advances in genetic engineering have allowed scientists to

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4 S.S. Negi “Biodiversity & its Conservation in India”, Indus Publishing Co., 1993, pp 1-12
5 Ibid 4
introduce beneficial genes from one species to another. For example, diabetics used to depend on insulin from human cadavers, or from cows or pigs. Human insulin was expensive, and non-human insulin could cause allergic reactions. Now we can isolate the gene that codes for human insulin, insert it into bacterial cells, and let the bacteria produce large quantities of human insulin. Other notable feats in genetic engineering include the introduction of genes that enhance the nutritive value of food, create crop resistance to insect pests, induce sheep to produce a protein for treating cystic fibrosis disease, and alter bacteria so that they can clean up toxic mine wastes through their metabolic activities. Many other genetic manipulations are currently in development.

- **Species Diversity**

![Image of species diversity](image)

**Figure 2: Species Diversity**

Species diversity is the basic component of biodiversity which refers to the variety of living species within a geographic area.

- **Ecosystem Diversity**

![Image of ecosystem diversity](image)

**Figure 3: Ecosystem Biodiversity**

Ecosystem diversity refers to the diversity of ecological complexes or biotic communities found in a given area (e.g. forests, water bodies, grasslands). An
ecosystem comprises of a biotic community (an interrelated and interacting community of plants, animals and microorganisms) along with its abiotic (soil, water, air) habitat with some identifiable boundary. However, the most reliable definition of “Biodiversity” can be found in Article 2 of the Convention on Biological Diversity.

![Figure 4: Illustrations of various levels of biodiversity](image)

### 2.1.1 Need to Conserve Biodiversity

From a selfish point of view, humans should be concerned about saving biodiversity because of the benefits it provides us—biological resources and ecosystem services. However, nature provides social and spiritual benefits as well.

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6 Ibid 4& see also, P Pushpangadan, “Biodiversity and Emerging Benefit Sharing Arrangements-Challenges and Opportunities for India”, Proceedings of Indian National Science Academy(PINSA) B68 No.3 pp. 297-314

7 Article 2 of Convention on Biodiversity defines biodiversity. "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."
Biological Resources

Figure 5: The tensile strength of spider silk provided inspiration for engineering a similar synthetic fabric.

This large female Argiope trifasciata spider has a male suitor, and dinner waiting in her silken web. (Courtesy of Jeffry Mitton)

Biological resources are those products that we harvest from nature. These resources fall into several categories: food, medicine, fibers, wood products, and more. For example, over 7,000 species of plants are used for food, although we rely heavily on only 12 major food crops. Most of the human population depends on plants for medicines. In the developed world, many of our medicines are chemicals produced by pharmaceutical companies, but the original formulas were often derived from plants. For example, opiate pain relievers are derived from poppies, aspirin is derived from willows, and quinine for treating malaria comes from the *Chinchona* tree. The rosy periwinkle (*Vinca rosea*) and Pacific yew (*Taxa brevifolia*) both provide substances used in chemotherapy to inhibit the cell division of cancerous cells. Fibers for clothing, ropes, sacking, webbing, netting, and other materials are provided by a large number of plants, including cotton plants, flax plants (linen), hemp (cordage and sail canvas), *Agave* plants (sisal), *Corchorus* plants (jute), bamboo and palms. Trees provide the wood products used in making homes, furniture, and paper products.

In addition, living organisms provide inspiration for engineers seeking better and more efficient products. The field known as bio mimicry is the study of natural
products that provide solutions to human needs. For example, shark skin provided the model for hydrodynamic swimming suits. The glue used by Sandcastle worms (*Phragmatopomacalifornica*) to cement together their sand particle shells was the inspiration for glue that mends fractured bones in the aqueous internal environment of the body. Finally, scientists are using the chemical nature of spider’s silk to design strong, lightweight fibers (Figure 4).

- **Ecosystem Services**

Ecosystem services are processes provided by nature that support human life. These services include the decomposition of waste, pollination, water purification, moderation of floods, and renewal of soil fertility. Ecosystem processes are often overlooked, and are not generally valued as part of the economy until they cease to function. When economic value is assigned to these services, it is often startlingly high. For example, insect pollinators help produce many commercially important fruits such as almonds, melons, blueberries, and apples. The global economic value of pollination services performed by insects has been valued at $217 billion per year (Gallai *et al.* 2009).

How does a process like water purification work? Rain water is filtered by soil and by microbes that can break down nutrients and contaminants, and reduce metal ions, slowing their spread into the environment. Wetland and riparian plants absorb nitrogen, and trap sediments that decrease water quality.

Human construction and development disrupt natural environments, but most habitats have an extraordinary ability to recover when given the chance. This is because dormant seeds in the soil can germinate, stabilize the soil, and initiate successional events that restore vegetation which provides food and structure for other colonizing organisms. Native plants like fireweed can help revegetate an area after fire.

- **Social and Spiritual Benefits**

Throughout most of human history, conservation has involved protecting nature for the spiritual gifts it provides, and protecting sacred places in the local landscape. Stories of indigenous people incorporate detailed knowledge of the animals and plants that make up their world. The heterogeneity of the world’s mythology, folk art, and
folk dances show the effects of biodiversity on cultural development, and contribute to the richness of global arts and literature (Figure 5)

Figure 6: The costumes and stances of these dancers illustrate cultural differences in depicting birds through dance.

Figure 7: People flock from around the world to see the bull elk bugling and displaying during mating season at Rocky Mountain National Park. Courtesy of Jeffry Mitton.
Different cultures developed in different landscapes that influenced activities, occupations, diet, language, and architecture. Cultures adapted to local environmental challenges by growing local domestic crops, developing irrigation and terracing systems, hunting, fishing, and gathering. Biodiversity provides a sense of place. Countries and states have flagship animals and plants that are a source of pride and highlight the uniqueness of each habitat (Figure 6). Travel, which provides great pleasure to many people, is motivated by the desire to see this combination of cultural, landscape and biological diversity.

Ecotourism is travel with the desire to view, sustain, and support natural ecosystems and local cultures. Support from ecotourism can reduce habitat destruction, preserve species that suffer from poaching and illegal trade in the pet market, plus provide jobs for the local economy. For example, the Wasini Island Project in Kenya has been a major ecotourism success story. Coral reefs and mangrove forests were suffering degradation from development, agriculture, and from exploitation of reef species. Support from the Biodiversity Conservation Programme made it possible for the local community to build boardwalks and other features that facilitate viewing wildlife.

2.1.2 The Value of Biodiversity

The loss of biological diversity is a growing area of concern and is of immediate relevance to the vast majority of India’s population. This population, in particular tribal and other traditional communities – farmers, fishers folk, pastoralists, and hunter gathers—are heavily dependent on biodiversity and biological resources for their survival and livelihood. India’s biodiversity is severely threatened; wildlife populations, traditional cultures, geological cycles, and a range of other attributes are being destroyed. There are a variety of reasons for this, but climate change plays big role to threaten biodiversity. The loss of biodiversity often reduces the productivity of ecosystems, thereby shrinking nature’s basket of goods and services, from which

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8 http://www.nature.com/scitable/knowledge/library/conservation-of-biodiversity-13235087, Last accessed on 30/09/2012 at 8.45 pm
9 The term biological resources is defined in Section 2(a) of the Biological Diversity Act 2002, See Annexure I
11 According to CBD secretariat “Goods and Services” provided by ecosystems include : Provision of food, fuel and fibre, Provision of shelter and building materials, Purification of air and water, Detoxification and decomposition of wastes, Stabilization and moderation of the Earth’s climate,
we constantly draw. It destabilizes ecosystems, and weakens their ability to deal with natural disasters such as floods, droughts, and hurricanes, and with human – caused stresses, such as population and climate change.

- **Soil formation and maintenance of soil quality**
The activities of microbes and animal (bacteria, algae, fungi, millipedes, etc) condition soils, break down organic matter, form soil and prevent soil erosion.

- **Maintain air quality**
Plants purify the air and regulate the composition of the atmosphere, by taking in CO2 during photosynthesis and liberating oxygen in the atmosphere.

- **Maintain water quality**
Trees and forest soils purify water; prevent siltation of rivers and reservoirs arising due to soil erosion and landslides.

- **Pest control**
Conserving biodiversity can control 99% of potential crop pests.

- **Detoxification and decomposition of wastes**
About 130 billion metric tons of organic waste (including industrial wastes) is processed every year by earth’s decomposing organisms.

- **Pollination and crop production**
Without plant and animal (bees, butterflies, bats, birds) interactions, no pollination will be possible and hence would lead to decline in crop yield.

- **Climate stabilization**
Oceans, soil and vegetation are huge carbon sinks and help reduce the CO2 in atmosphere. In rainforests the surface temperature is maintained by regular rains, while in cold regions the temperature is regulated by forests acting as insulators and windbreaks.

- **Prevention and mitigation of natural disasters**
Ecosystem biodiversity (forest, salt marshes, and mangrove) prevents erosion, nutrient loss, landslides, floods and impacts of storms.
- **Provision of food security**

  Biodiversity in terms of plants and animals is the ultimate source of food, fiber, fuel and shelter. Biodiversity conservation will lead to strengthening of ecosystem resilience and will improve the ability of ecosystem to provide important services during increasing climate pressures\(^\text{12}\).  

2.1.3 **Economic Values of Biodiversity**

Biodiversity offers several direct and indirect economic benefits to mankind. It performs two important functions. One is it sustains the stability of the biosphere, which in turn leads to the stability of climate, water regime, soil fertility, quality of air and overall health of the biosphere. And the other one is, biodiversity is the source from which human race depends for food, fodder, fuel, fiber, shelter, medicine and raw materials for industrial goods. Biodiversity is thus the biological capital of our planet and it reforms the foundation upon which human civilization is built. The history of human civilization and development of economic systems and thoughts are all inherently and inveterately interwoven with the biological resources. All economic activities of humankind directly or indirectly derive its sustenance form the environmental resources including biological resources\(^\text{13}\).

**Some important economic commodities that biodiversity supplies to humankind are\(^\text{14}\):**

- Biodiversity provides food: crops, livestock, forestry and fish;
- Biodiversity has a role in mediation. Wild plant species have been used for medicinal purposes since before the beginning of recorded history. For example, quinine comes from cinchona tree (used to treat malaria), digitals from the foxglove plant (chronic heart trouble), and morphine from the poppy plant (pain relief). According the National Cancer Institute, over 70% of the promising anti-cancer drugs come from plants in the tropical rainforests. Animal may also play a role, in particular in research, it is estimated that of


\(^{13}\)Supranote7

\(^{14}\)Supranote4
the 250,000 known plant species, only 5000 have been researched for possible medical applications.\(^{15}\)

- **Industry:** For example fibers for clothing, wood for shelter and warmth. Biodiversity may be a source of energy (such as biomass). Other Industrial products are oils, lubricants, perfumes, fragrances, dyes, paper, waxes, rubber, latexes, resins, poisons and cork can all be derived from various plant species. Supplies from animal origin are wool, silk, fur, leather, lubricants, waxes. Animals may also be used as a mode of transport.

- **Tourism and recreation:** Biodiversity is a source of economical wealth for many areas, such as many parks and forests, where wild nature and animals area source of beauty and joy for many people. Ecotourism in particular, is a growing outdoor recreational activity.

Economic arguments for protecting biodiversity are criticized for being too utilitarian and human-centered. While there are hundreds of examples of known economic and aesthetic benefits of biodiversity, biologists and other scientists frequently outline that more is unknown for the benefit of the humankind and they cannot be discovered if they disappear before discovery.

### 2.1.4 Biodiversity Profile of India

India is the seventh largest country in the world and Asia’s second largest nation with an area of 3,287,263 square km. It has a land frontier of some 15,200 kms and a coastline of 7,516 km. India, known for its rich heritage of biological diversity, has so far documented over 91,200 species of animals and 45,500 species of plants in its ten bio-geographic regions. Besides, it is recognized as one of the eight Vaviloviancentres of origin and diversity of crop plants, having more than 300 wild ancestors and close relatives of cultivated plants, which are still evolving under natural conditions. India is also a vast repository of Traditional Knowledge (TK) associated with biological resources. India ranks among the top ten species-rich nations and shows high endemism. India has four global biodiversity hot spots (Eastern Himalaya, Indo-Burma, Western Ghats and Sri Lanka, and Sunderland). The varied edaphic, climatic and topographic conditions and years of geological stability have resulted in a wide

range of ecosystems and habitats such as forests, grasslands, wetlands, deserts, and coastal and marine ecosystem. Inventories of faunal diversity in India are being progressively updated and analyzed with several new discoveries. So far, nearly 91,212 of faunal species (7.43% of the world’s faunal species) have been recorded in the country. Endemic rich Indian fauna is manifested most prominently in Amphibia (61.2%) and Reptilia (47%). Likewise, Indian fish fauna includes two endemic families and 127 monotypic genera. As per the International Union for Conservation of Nature (IUCN) Red List (2008), India has 413 globally threatened faunal species, which is approximately 4.9% of the world’s total number of threatened faunal species. Continuous surveys and explorations have added new discoveries – 41 plant species in 2007 by Botanical Survey of India (BSI) alone. The unique features of the plant diversity, among others, include 60 monotypic families and over 6000 endemic species. As estimates indicate the presence of over 256 globally threatened plant species in India. India is one of the top twelve mega diversity countries and has two of the total eighteen “biodiversity hotspots” in the biodiversity rich areas of the Western Ghats and the Eastern Himalayas. In opinion of a Ministry of Environment and Forest Report, the country is estimated to have over 49,219 plant species and 81,251 animal species representing 12.5% of the world’s flora and 6.6% of its fauna. High incidence of endemism and occurrence of several endemic centers are characteristic features of India’s biodiversity. Among plants, species endemism is estimated at 33%. Endemism among mammals and birds are relatively low. Only 44 species of Indian mammal and 55 bird species have a range that is confined entirely to within Indian territorial limits. Endemism in the Indian reptilian and amphibian fauna is high. There are around 187 endemic reptiles, and 110 endemic amphibian species.

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16 The mega diversity country concept recognizes that, of all the countries on Earth, only a small handful account for a major portion of life on Earth, including terrestrial, freshwater and marine life. Dr. Russell Mittermeier first developed this concept in 1988, based on preliminary analysis of primate conservation priorities. Subsequent analysis of other mammals, birds, reptiles, amphibians, plants and selected groups of insects led to the conclusion that 17 countries qualified for mega diversity status. These 17 countries by themselves accounted for more than two-thirds of all life forms and for the vast majority of tropical rainforests, coral reefs and other priority systems. Life forms and for the vast majority of tropical has increased it to twenty five.

17 The conservation International has increased it to twenty five.

Eight amphibian genera are not found outside India\textsuperscript{19}. To protect these, India has got 89 national parks, 497 wildlife sanctuaries covering an area of 1.56 lakh square kilometers and 27 Tiger Reserves with an area of 37,761 square kilometers\textsuperscript{20}. Likewise, India’s contribution to crop biodiversity has been impressive with repositories of over 50,000 varieties of rice, 5,000 of sorghum, 1,000 varieties of mango, etc. The National Genebank, primarily responsible for ex-situ conservation of unique germplasm on long-term basis, holds 3,66,933 unique accessions of plant genetic resources. India is also endowed with vast and diverse forms of domesticated animal genetic resources, e.g., cattle, buffalo, sheep, goat, pig, camel, horse, donkey, yak, mithun, duck, goose, quail, etc. Besides, a rich diversity of wild relatives of domesticated animals exists here. The molecular characterization has been undertaken so far only in a few animals such as cattle, sheep, pig and poultry, using internationally recommended DNA markers. India, endowed with vast inland and marine bio resources, is the third largest producer of fish in the world. A database on 2,182 fishes found in Indian waters has been developed, which includes 327 freshwater species listed in IUCN threat categories and 192 endemic fishes. A macro level fish occurrence map of India has been prepared and DNA barcodes of 100 Indian marine fish species developed\textsuperscript{21}.

- **Impact of Climate Change on Biodiversity of North East India**

The highly bio diverse but fragile mountain ecosystems of North East India have diverse vegetation types encompassing from the subtropical, submontanne, montanne, subalpine to alpine systems. North East India is nestled in the globally recognized biodiversity hotspot and an Eco region and renowned for its high species diversity and endemism. It is also recognized as one of the centers of origin of cultivated plants. The dependence of the population on forest's resources is high which provides livelihood to more than 225 tribal groups native to the region.

The predicted increase in the precipitation in the forest areas in the Indian subcontinent is higher than that of the non-forest area. Climate models predict 20 -

\textsuperscript{19}Biodiversity Profile of India, available at http://www.wcmc.org.uk/igcmc/main.html last accessed on 30/09/2012 at 5.45 p.m

\textsuperscript{20}Supranote 3

\textsuperscript{21}Supranote 18
3.50°C increase in temperature and 250 - 500mm increase in precipitation in the North Eastern region. Increase in rainfall may not have significant impact on the forest areas of North East which are already experiencing high rainfall but change in temperature regime may cause severe impact and significant changes.  

2.2 GLOBAL WARMING (CLIMATE CHANGE)

Before the Industrial Revolution, human activities released very few gases into the atmosphere and all climate changes happened naturally. After the Industrial Revolution, through fossil fuel combustion, changing agricultural practices and deforestation, the natural composition of gases in the atmosphere is getting affected and climate and environment began to alter significantly.

Over the last 100 years, it was found out that the earth is getting warmer and warmer, unlike previous 8000 years when temperatures have been relatively constant. The key greenhouse gases (GHG) causing global warming is carbon dioxide. CFC’s, even though they exist in very small quantities, are significant contributors to global warming. Carbon dioxide, one of the most prevalent greenhouse gases in the atmosphere, has two major anthropogenic (human-caused) sources: the combustion of fossil fuels and changes in land use. Net releases of carbon dioxide from these two sources are believed to be contributing to the rapid rise in atmospheric concentrations since Industrial Revolution. Because estimates indicate that approximately 80 percent of all anthropogenic carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate.

The term climate change refers to long-term changes in temperature, humidity, clouds and rainfall and not to day-to-day variations. Regional climate change is caused by both local and global factors. This difference is very important because if a regional climate change occurs on account of local factors then these changes can be

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23 “Global Environmental Concerns”, pdf file available at http://www.emea.org/Guide%20Books/Book-1/1.9%20Global%20Environmental%20Concerns.pdf, last accessed on 18/10/2012 at 4.01 pm

mitigated by local actions. If a city is getting warmer because of too many concrete buildings, then this can be altered by local laws that require some greenery between buildings. On the other hand, if a city is warming because of global increase in carbon dioxide then the action to reduce CO2 emission has to be initiated through global negotiations.\(^{25}\)

The Intergovernmental Panel on Climate Change (IPCC) was created by the United Nations to enable scientists from all parts of the world to provide an authentic summary of our present understanding of the climate change induced by human beings and indicate the ways to mitigate this climate change or adapt to it.\(^{26}\)

2.2.1 Observed Changes in Climate Change

Observational evidence demonstrates that the composition of atmosphere is changing [e.g., the increasing atmospheric concentrations of greenhouse gases such as CO2 and methane (CH4)], as is the Earth’s climate (e.g., temperature, precipitation, sea level, sea ice, and in some regions extreme climatic events, and droughts). Because of their observed and potential effects on biodiversity are summarized below. For example, the concentration of CO2 atmosphere affects the rate and efficiencies of both photosynthesis and water use, thus can affect both the productivity of plants and other ecosystem processes. Climatic factors also affect plant and animal productivity and other ecosystem functions.\(^{27}\)

\(^{25}\)climatechange.worldbank.org/.../Turn_Down_the_heat_Why_a_4_degree., Last accessed on 10/12/12 at 11.00 am.


Global Atmospheric Concentration of the principal well-mixed anthropogenic greenhouse gas:

![Graph showing CO₂ concentration and radiative forcing over time.](image)

Figure 8: Records of past changes in atmospheric composition over the last millennium demonstrate the rapid rise in CO₂ concentration that is attributable primarily to industrial growth since the year 1750. Early sporadic data taken from air trapped in ice (Symbols) matches up with continuous atmospheric observations from recent decades (Solid line). CO₂ is well mixed in the atmosphere, and its concentration reflects emissions from sources throughout the globe. The estimated positive radioactive forcing resulting from the increasing concentration of CO₂ is indicated on the right-hand scale.

2.2.2 Sources of Greenhouse Gases

Some greenhouse gases occur naturally in the atmosphere, while others result from human activities. Naturally occurring greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Certain human activities, however, add to the levels of most of these naturally occurring gases. Carbon dioxide is released to the

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atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products are burned\textsuperscript{29}.

![Pie chart showing the share of greenhouse gases.](image)

**Figure 9: Share of Greenhouse Gases\textsuperscript{30}**

Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from the decomposition of organic wastes in municipal solid waste landfills, and the raising of livestock. Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.

Very powerful greenhouse gases that are not naturally occurring include hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulfur hexafluoride (SF6), which are generated in a variety of industrial processes.

Often, estimates of greenhouse gas emissions are presented in units of millions of metric tons of carbon equivalents (MMTCE), which weights each gas by its Global Warming Potential or GWP value.

\textsuperscript{29}Supranote 18
\textsuperscript{30}Supranote 28
Figure 10: Changes in GHG emission excluding LULUCF  

Figure 11: Changes in GHG emission including LULUCF 

31 http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php, last accessed on 25/10/2012 at 8.15 am.  
32 Ibid
2.2.3 Global Warming Potentials

Although there are a number of ways of measuring the strength of different greenhouse gases in the atmosphere, the Global Warming Potential (GWP) is perhaps the most useful.\(^\text{35}\)

GWPs measure the influence greenhouse gases have on the natural greenhouse effect, including the ability of greenhouse gas molecules to absorb or trap heat and the length of time, greenhouse gas molecules remain in the atmosphere before being removed or broken down. Each greenhouse gas differs in its ability to absorb heat in the atmosphere. HFCs and PFCs are the most heat-absorbent. Methane traps over 21

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33 Ibid
34 Ibid
35 Supranote 18
times more heat per molecule than carbon dioxide, and nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide. Conventionally, the GWP of carbon dioxide, measured across all time horizons, is 1. The GWPs of other greenhouse gases are then measured relative to the GWP of carbon dioxide. Thus GWP of methane is 21 while GWP of nitrous oxide is 270. Other greenhouse gases have much higher GWPs than carbon dioxide, but because their concentration in the atmosphere is much lower, carbon dioxide is still the most important greenhouse gas, contributing about 60% to the enhancement of the greenhouse effect\textsuperscript{36}.

2.2.4 Global Warming (Climate Change) Implications

- **Rise in Global Temperature**

  Observations show that global temperatures have raised by about 0.6 °C over the 20th century. There is strong evidence now that most of the observed warming over the last 50 years is caused by human activities. Climate models predict that the global temperature will rise by about 6 °C by the year 2100\textsuperscript{37}.

- **Rise in Sea Level**

  In general, the faster the climate changes, the greater will be the risk of damage. The mean sea level is expected to rise 9 - 88 cm by the year 2100, causing flooding of low lying areas and other damages.

- **Food Shortages and Hunger**

  Water resources will be affected as precipitation and evaporation patterns change around the world. This will affect agricultural output. Food security is likely to be threatened and some regions are likely to experience food shortages and hunger.

- **Loss of Biodiversity**

  Biodiversity refers to the variety of life on earth, and its biological diversity. The number of species of plants, animals, microorganisms, and the enormous diversity of genes in these species, the different ecosystems on the planet, such as deserts,

\textsuperscript{36} Ibid 31
\textsuperscript{37} Supranote 18
rainforests and coral reefs are all a part of a biologically diverse earth. Biodiversity actually boosts ecosystem productivity where each species, no matter how small, all have an important role to play and that it is in this combination that enables the ecosystem to possess the ability to prevent and recover from a variety of disasters. It is now believed that human activity is changing biodiversity and causing massive extinctions. The World Resource Institute reports that there is a link between biodiversity and climate change. Rapid global warming can affect ecosystems chances to adapt naturally. Over the past 150 years, deforestation has contributed an estimated 30 percent of the atmospheric build-up of CO₂. It is also a significant driving force behind the loss of genes, species, and critical ecosystem services.

2.3 LINK BETWEEN BIODIVERSITY AND CLIMATE CHANGE

- Climate change is affecting species already threatened by multiple threats across the globe. Habitat fragmentation due to colonization, logging, agriculture and mining etc. are all contributing to further destruction of terrestrial habitats.
- Individual species may not be able to adapt. Species most threatened by climate change have small ranges, low population densities, restricted habitat requirements and patchy distribution.
- Ecosystems will generally shift northward or upward in altitude, but in some cases they will run out space – as 1°C change in temperature correspond to a 100 Km change in latitude, hence, average shift in habitat conditions by the year 2100 will be on the order of 140 to 580 Km.
- Coral reef mortality may increase and erosion may be accelerated. Increase level of carbon dioxide adversely impacts the coral building process (calcification).
- Sea level may rise, engulfing low-lying areas causing disappearance of many islands, and extinctions of endemic island species.
• Invasive species may be aided by climate change. Exotic species can out-compete native wildlife for space, food, water and other resources, and may also prey on native wildlife.

• Droughts and wildfires may increase. An increased risk of wildfires due to warming and drying out of vegetation is likely.

• Sustained climate change may change the competitive balance among species and might lead to forests destruction

2.3.1 The Response of Biodiversity to Climate Change

Detailed knowledge of how climate change affects biodiversity is still very limited, but no of studies have identified a number of areas where changes from warming are evident. One is what ecologists call ecosystem boundaries. These are the transition zones that separate, say, a prairie made up primarily of tall grasses from one containing mixed grasses. Changes in precipitation and temperature can cause these boundaries to move, allowing some ecosystems to expand into new areas, while others diminish in size as the climate becomes inhospitable to the species they contain.38

From a broader perspective, climate change may lead to a sharp increase in rates of extinction. Focusing on five regions of the world, if the climate continues to warm it could dramatically increase the number of species going extinct. Mid-range predictions suggest that 24 per cent of species in these regions will be on their way to extinction by 2050 due to climate change. This study also indicates that for many species, climate change poses a greater threat to their survival than the destruction of their natural habitat.39 Climate change also affects species at the level of cells and genes. Changes in the genetic makeup of species are expected as organisms adapt to new climatic conditions, and increases in temperature can also lead to increases in the rate at which cells use energy. Other observed impacts of climate change include


changes in the timing of reproduction in certain species; in the length of the growing season in many regions; in the abundance of different species; and in the frequency of pest and disease outbreaks. For example, higher temperatures have led to an increase in the number of eggs laid by the spruce budworm, already one of the most devastating pests in North America’s boreal forest. This could in turn contribute to more severe outbreaks of this pest.\textsuperscript{40}

The impacts of climate change on biodiversity will, of course, vary considerably from region to region, partly because changes in temperature and precipitation will differ among regions. The most rapid changes in climate are expected in the far north and south of the planet, and in mountainous regions. Unfortunately, these are also the regions where species often have no alternative habitats, a factor that prevents them – unlike animals and plants in some temperate regions – from migrating or spreading elsewhere to survive.

Other species are vulnerable in different ways. Corals and other organisms living in coral reefs, for example, have already shown devastating losses as a result of increased water temperatures. Species restricted to small areas, or in small populations, are also particularly vulnerable. A catastrophic event such as disease or drought, for example, can kill off a small population. And populations in small, isolated habitats are unlikely to be replenished once decimated by outbreaks of fire or other catastrophes.

A number of direct key impacts of climate change upon biodiversity have been identified:

- changes in the timings of seasonal events, leading to loss of synchrony between species and the availability of food, and other resources upon which they depend
- shifts in suitable climate conditions for individual species leading to change in abundance and range

\textsuperscript{40}Gitay, H. et al (2002) Climate Change and Biodiversity. Intergovernmental Panel on Climate Change Technical Paper V.
• changes in the habitats which species occupy
• changes to the composition of plant and animal communities
• Changes to habitats and ecosystems, such as altered water regimes, increased rates of decomposition in bogs and higher growth rates in forests. In the view of some scientists, the greater frequency of extreme weather events is likely to have as much impact upon biodiversity as overall trends in temperature and precipitation.

Indirect impacts may become just as significant as a result of climate-induced changes in land use having knock-on effects on biodiversity. For example, growing new crops, increases in summer watering and geographical shifts in arable and livestock production could well occur, but how these indirect changes may affect biodiversity remains less certain.

2.3.2 Observed Changes

Both for the India and the rest of the world, there is a large and increasing body of information about the ecological impacts of climate change. Five types of information illustrate the impacts of climate change on wildlife:

• Vegetation

The vegetation is exhibiting the following changes;

  o Migration of vegetation towards a higher altitude: In Nainital, species such as Berberisasiatica, Taraxacumofficinale, Jasminumofficinaleetc have shifted from 1000 to 2000m height. Teak dominated forests are predicted to replace the Sal trees in central India and also the conifers may be replaced by the deciduous types. According to climatologists and palynologists, temperature change of 3°C may lead to forest movement.

41Supranote 2
42Supranote 2

- **Invasive species:** Invasive species (Lantana camara, Parthenium hysterophorous, Ageratum conyzoides) are a threat to native species being more tolerant to climatic variations.\footnote{Supranote 42}

- **Changes in phenological behaviour:** Climate/season affects the normal life cycle (bud, leaf fall, flowering, fruiting, fertilization time and production) of the plant. The crops show early flowering and maturation which has shortened their grain fill period and yield.

- **Forest fires** have increased in number due to high temperature conditions.

- **Increase in the pest attacks:**
  
  Due to climate change, pests have increased in number. Variation in temperature and precipitation patterns can result in more frequent droughts and floods making indigenous plants more vulnerable to pests and diseases.\footnote{J. Tibbetts (2007). Health effects of climate change Environmental Health Perspectives, 115: 196-203.}

- **Animals**

  Sensitivity of the species to even a slight change in the climate leads to their extinction as in case of the golden toad. Polar bears are in danger due to reduction in Arctic ice cover. North Atlantic right whale may become extinct, as planktons, its main food have shown decline due to climate change. The sex of sea turtle depends on temperature and more female turtles are produced as a result of high temperature. Some threatened species (frogs, toads, amphibians, tigers and elephants) are vulnerable to the impacts of climate change like sea level changes and longer drier spells. Changes in ocean temperature and acidification may lead to loss of 95% of the living corals of Australia’s Great Barrier Reef.\footnote{Anonymous (2007) Biodiversity and Climate Change Convention on Biological Diversity www.biodiv.org , last accessed on 24/10/2012 at 7.10pm.}
• Ecosystem
  
  o **Polar ice/ Glaciers** they are diverse ecosystem facing extremes of the cold temperature with the flora (planktons) and fauna (migratory birds, whales) and Arctic people modified to such conditions.\(^{48}\) Climate change has resulted in an increase in -the temperature to about 5°C to the normal and has resulted in the melting of the ice, increase in sea level which is threatening the endemic species (polar bears, walruses, seals, emperor penguins, krill, and ringed seal). Studies show a decline in the weight of the polar bears from 325 kg in 1980 to 253 kg in 2004.\(^{49}\) Biodiversity loss has impacted the fishing and hunting practices by Igneous people (Saamiand Inuit of Canada) posing an implication on their only source of food.\(^{50}\)

  o **Marine and Coastal:** 70% of the Earth’s surface is covered by oceans comprising some of the world’s most diverse and unique ecosystems (mangroves, coral reefs, sea grass beds).\(^{51}\) Climate change is leading to sea level rise, increased coastal erosion, flooding, higher storm surges, sea salinity ingress, increased sea-surface temperatures, ocean acidification, coral bleaching, mangroves and millions of climate change refugees. Species composition and distribution will surely be affected by such changes. Indian coastal areas vulnerable to climate change are Sundarbans, Maharashtra, Goa and Gujarat (Rann of Kutch).\(^{52}\) The distribution and composition of the species is bound to be effected.

  o **Island ecosystem:** Islands are the most fragile with rich biodiversity and a high economic importance. 23% of island species are at present endangered. Islands have small and endemic species (corals)\(^{53}\) sensitive to

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\(^{48}\) Ibid


\(^{50}\) Supranote 46


the changing climate. Climate change leads to an increase in the sea level, frequency and intensity of storms, variability in rainfall and intolerably high temperatures affecting the endemic species and hence economic loss in the tourism sector.

- **Inland water ecosystem:** Inland water systems include the fresh water systems and are only 0.01% of the world's water source comprising 0.8% of the Earth's surface, but support 6% of the total species

  They are rich source of food, income, employment and biodiversity. Changing rainfall patterns will lead to change in the course of the streams affecting breeding and food habits of many species. The ice cover is bound to decrease causing an increase in the number of flood and drought. This would further lead to changes in the phenology, physiology and migration trends of some organisms like migratory birds.

- **Forest:** Forest area is about one-third of the Earth’s surface and comprises two-thirds of all the known terrestrial species. They are also rich biodiversity hotspots. Half of the original forest cover has been cleared up till now. The increased level of CO2 has led to increase in the growth of some forest. Increased temperature (even 1°C) has resulted in significant migration of tree species, increased attack of pest, invasive species and wild fires, hence modifying the composition of forest. Many animals, primates and 9% of all known tree species (woody trees, white spruce) are at risk of extinction.

- **Agriculture:** About one-third of the world’s area is under cultivation. Climate change leads to variability in rainfall patterns, heat stress, spread of pests and diseases and shortening of the crop cycle and affecting plant growth and production.

- **Dry lands and Grassland:** They support 35% of the world population and comprise of the arid and semi-arid areas, grasslands and savannahs. They have localized species (wild ass, Kutch etc) and have varied crops and livestock. The desertification is expanding and so is the temperature

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54 Ibid
55 Supranote 46
making them drier and intolerable for the threatened species. The risk of wild fire is increasing which could change the species biodiversity. Climate change is a threat to the diverse hotspots.

- **Mountain:** One–third of the Earth’s surface is covered by the mountains which supports one-third of the world population. Many species are very specific and endemic to this ecosystem and are rich natural reservoirs of goods. Climate change is leading to the glacier retreat, change in the course of rivers, and migration of the tree species northward and subsequent extinction of some species.

- **Phenology**

This is the study of the change in timing of seasonal events, such as flowering and migration. There has been a general trend towards spring and summer events taking place earlier in the year. These include earlier first leafing dates of trees (e.g. oak leafing has advanced three weeks in the last 50 years), flight times of moths and butterflies, egg-laying dates in birds, first spawning of amphibians and first appearance of hoverflies and earlier fruiting of species such as blackberry. Autumn events are more complex, with delayed leaf fall and bird migration reported for some species.\(^{56}\) The conservation implications of such changes are starting to emerge. Of greatest importance may be that interdependent species no longer have life cycles that are synchronised. There is, for example, good evidence that some populations of the pied flycatcher(*Ficedula hypoleuca*) are declining because birds are now breeding after the time of peak caterpillar abundance, which has become earlier.\(^{57}\)

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- **Species Abundance**

Species are increasing and decreasing their abundance at sites in ways correlated with climate change. This has been shown by long-term monitoring of butterflies and moths, and plants in woodlands and grasslands, changing the composition of plant and animal communities\(^{58}\).

- **Habitat Preference**

Recent studies of the silver spotted skipper butterfly (Hesperia comma) have revealed a change of habitat, so that it now breeds in cooler, taller grasslands. There is contrasting evidence that other butterfly species which over-winter as eggs and larvae are being excluded from grasslands, due to rapid plant growth early in the year which, paradoxically, creates a cooler spring micro climate in the sward\(^{59}\).

![Silver-spotted skipper butterfly](image)

**Figure 14: Silver-spotted skipper butterfly**


Credit: Natural England, Photographer: Michael Hammett
2.3.4 How Biodiversity Affects Climate

The process is not one-way. Just as climate change alters the state of biodiversity, so changes in biodiversity can also affect the world’s climate. Perhaps most significantly, changes in land use that lead to a loss of biodiversity can lead to increased greenhouse gas emissions.

Take forests. These are a major store of carbon. Carbon dioxide is released into the atmosphere whenever there are forest fires, or when forests are cut down. It is estimated that one-third of the carbon dioxide released into the atmosphere between 1850 and 1998 came from land-based sources, predominantly the destruction of forests. Forests also help to regulate moisture in the atmosphere and can reduce temperatures. So felling them can cause changes in atmospheric moisture and higher temperatures.

Peat lands or mires are another major store of greenhouse gases. As they hold roughly one-third of the carbon contained in soil worldwide, greenhouse gases are released into the atmosphere every time wetlands or peat lands are burned, drained, converted to agriculture or degraded. A dramatic example of this was the peat land forest fires that occurred in Indonesia during 1997. These fires released amounts of carbon dioxide equivalent to 40 per cent of the world’s average yearly carbon emissions from fossil fuels.

There are also feedback mechanisms at work between biodiversity and climate change. For example, some species of ocean algae release a chemical into the atmosphere known as dimethyl sulfate (DMS). When ocean temperatures rise – an effect of global warming – more DMS is released. But DMS is also associated with the formation of clouds. This means that a boom in populations of some algal species – due to increased water temperatures – and a resultant boost in DMS levels, may actually help reduce temperatures because extra cloud cover reduces the amount of heat that reaches the Earth’s surface.61