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Asheem Srivastav

The Science and Impact of Climate Change

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The Science and Impact of Climate Change

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Contents

Chapter 1
Earth in Reverse Gear

The environment is everything that isn't me.

Albert Einstein.

Abstract The 1972 Stockholm conference on the Human Environment acknowledged the negative effects of rapid industrialization post World War II. Subsequently, the effect of mining and burning of fossil fuels, manufacture and release of toxic chemicals and pollutants into air and water, destruction of forests, soil erosion, etc., was unambiguously brought on record by the Brundtland Commission in 1987 with a clear warning for humanity to either change its development strategy or be prepared to face the consequences in near future. Unfortunately, the situation has further worsened due to unchecked population growth, consumption pattern, use of fossil fuels and release of greenhouse gases, deforestation and pollution. There are incontrovertible evidences that temperatures today are more than 0.8 °C above pre-industrial levels and the sea level has been rising @3 mm per year. The world is currently witnessing frequent and severe natural disasters including droughts, floods, cyclones, fires and mudslides. Scientists have warned that in the event of temperature rising to 5 °C above pre-industrial levels, 50% of animal and plant species will become extinct, 30% of coastal wetlands would be inundated, terrestrial ecosystems will shift from 'carbon sink' to being 'carbon source', many small island states will suffer from storm surges, and nearly three billion people will be under severe water stress.

Keywords Ozone layer · Fossil fuels · Natural disaster · Acid rain · IPCC
Climate change · Sea level rise · Threatened ecosystems · Receding glaciers
Threatened species · Greenhouse gases · Drought and climate change
Population growth and climate change · Brundtland Commission

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1.1 This Is What the Brundtland Commission Had Said in 1987

- Over the past century, the use of fossil fuels has grown nearly **30-fold**, and industrial production has increased more than **50-fold**. The bulk of this increase, about three-quarters in the case of fossil fuels and a little over four-fifths in the case of industrial production, has taken place since 1950. The annual increase in industrial production today is perhaps as large as the total production in Europe around the end of the 1930s. Into every year, we now squeeze the decades of industrial growth and environmental disruption that formed the basis of the pre-war European economy.
- The impact of growth and rising income levels can be seen in the distribution of world consumption of a variety of resource-intensive produce. The more affluent industrialized countries use most of the world's **metals** and **fossil fuels**. Even in the case of food products, a sharp difference exists, particularly in the products that are more resource-intensive.
- The "greenhouse effect", one such threat to life-support systems, springs directly from increased resource use. The burning of **fossil fuels** and the cutting and burning of forests release carbon dioxide (CO_2). The accumulation in the atmosphere of CO_2 and certain other gases traps solar radiation near the Earth's surface, causing global warming. This could cause sea level rises over the next **45 years** large enough to inundate many low-lying coastal cities and river deltas. It could also drastically upset national and international agricultural production and trade systems.
- Another threat arises from the depletion of the atmospheric **ozone layer** by gases released during the production of foam and the use of refrigerants and aerosols. A substantial loss of such ozone could have catastrophic effects on human and livestock health and on some life forms at the base of the marine food chain. The 1986 discovery of a hole in the ozone layer above the Antarctic suggests the possibility of a more rapid depletion than previously suspected.
- A variety of air pollutants are killing trees and lakes and damaging buildings and cultural treasures, close to and sometimes thousands of miles from points of emission. The **acidification** of the environment threatens large areas of Europe and North America. Central Europe is currently receiving more than one gram of sulphur on every square metre of ground each year. The loss of forests could bring in its wake disastrous erosion, siltation, floods and local climatic change. Air pollution damage is also becoming evident in some newly industrialized countries.
- In many cases, the practices used at present to dispose of toxic wastes, such as those from the chemical industries, involve unacceptable risks. **Radioactive wastes** from the nuclear industry remain hazardous for centuries. Many who bear these risks do not benefit in any way from the activities that produce the wastes'.
- More than 11 million hectares of **tropical forests are destroyed per year**, and this, over 30 years, would amount to an area about the size of India. Apart from the direct and often dramatic impacts within the immediate area, nearby regions are affected by the spreading of sands or by changes in water regimes and increased risks of soil erosion and siltation.
- Chemicals represent about 10% of total world trade in terms of value; some 70,000–80,000 chemicals are now on the market—and hence in the environment. The figure is only an informed estimate because no complete inventory has been done. Some 1000–2000 new chemicals enter the commercial market each year, many without adequate prior testing or evaluation of effects. The negative environmental impacts of industrial activity were initially perceived as localized problems of air, water and land pollution. Industrial expansion following the World War II took place without much awareness of the environment and brought with it a rapid rise in pollution, symbolized by the Los Angeles smog; the

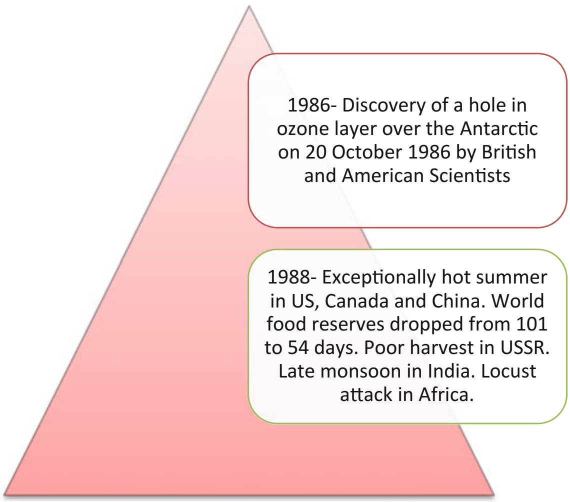

Fig. 1.1 Watersheds in understanding climate change (*Data Source* Ceres 1990 Vol 1, 25 Sept–Oct)

> proclaimed 'death' of Lake Erie; the progressive pollution of major rivers like the Meuse, Kibe and Rhine; and chemical poisoning by mercury in Minamata. These problems have also been found in many parts of the Third World as industrial growth, urbanization and the use of automobiles spread. Industrialized countries still suffer from 'traditional' forms of air and land pollution. Levels of sulphur and nitrogen oxides, suspended particulates and hydrocarbons remain high and in some cases have increased. Air pollution in parts of many Third-World cities has risen to levels worse than anything witnessed in the industrial countries during the 1960s (Brundtland Commission 1987).

It has now been established beyond an iota of doubt by the collective works of thousands of scientists across the globe that the Earth is warming. Two important events have helped in establishing this fact (Fig. 1.1). First was the discovery and confirmation of a hole in the ozone layer above Antarctica by a team of American and British Physicists in 1986 (Monier 1990). The second was summer of 1988 with exceptionally hot and dry weather affecting the food production in the USA, Canada, China, Russia, India and other countries and regions including locust attack in Africa. The food reserves dropped from 101 to 54 days. To avoid scepticism, the United Nations thought it prudent to reconsider the statistical data and compare with the past climate records and prepare forecasting models. The Intergovernmental Panel on Climate Change (IPCC) was asked to prepare a report to this effect. The IPCC submitted its first report in 1990 inter alia with following assertions:

1. Emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: CO_2, methane, CFCs and nitrous oxide. These increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface. CO_2 has been responsible for over half the enhanced greenhouse effect; long-lived gases would require imme-

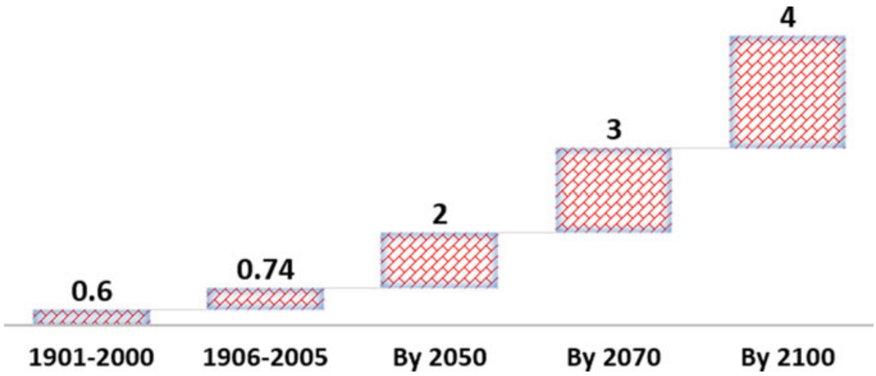

Fig. 1.2 Global average temperature (degree Celsius) changes so far and anticipated. *Source* IPCC 2007

diate reductions in emissions from human activities of over 60% to stabilize their concentrations at today's levels.

2. If we continue living, consuming and producing as we do now, the global temperature increase will be 0.3 °C per decade (ranging from 0.2 to 0.5 °C) from the coming century. This is greater than that seen over the past 10,000 years; warming will be greater on land areas than over the ocean and more pronounced in the northern hemisphere.
3. The rising levels of ocean have been observed in the Maldives and the Guyana coast. A total of 14 island states accounting for 700,000 inhabitants in the Pacific and the Indian Oceans are under the threat of submergence due to sea level rise.
4. There were many uncertainties in the predictions particularly with regard to the timing, magnitude and regional patterns of climate change, due to our incomplete understanding of: sources and sinks of GHGs; clouds; oceans; polar ice sheets.

More than four decades after the Stockholm conference (in 1972), the global environmental scene has worsened as more than three billion people have been added and the cumulative impact of increasing human population, changing consumption pattern, over consumption by some and under consumption by others and the avoidable wastage has begun to produce adverse consequences. Humans currently dominate more than half of biological production through agriculture, forestry, industries and other activities (Fig. 1.3). In doing so, they have increased the release of GHGs on the one hand and have reduced the ability of ecosystems to absorb these gases that are generated as a by-product or end product. As a result, the current global temperatures are higher than they have ever been during the past one thousand years and there are incontrovertible evidences that temperatures today are more than 0.8 °C above pre-industrial levels (Fig. 1.2). The fact that global average temperature continues to increase can be gauged from the recent data which estimates that the average global temperature for 1969–1971 was 13.99 °C that rose to 14.43 °C during 1996–1998, a gain of 0.44 °C (Brown 2000).

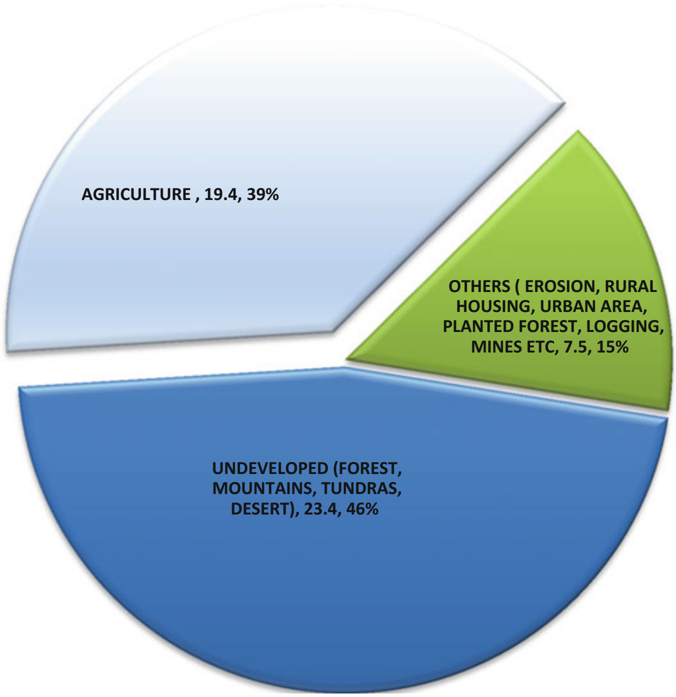

Fig. 1.3 Use of ice-free area of the world (million square miles) (*Data Source* Foley 2014)

The main reason for the current rise in temperature is attributed to high levels of carbon dioxide concentration as well as to some other greenhouse gases such as nitrous oxide, methane and halocarbons that continue to trap infrared radiations in excess vis--vis pre-industrial time and the resulting warming causes long-term climate change. Under normal circumstances, these GHGs act like a blanket to keep the Earth's surface 20 °C warmer for the survival and growth of living entities (Lacis 2010). Unfortunately, the projections, based on current warming trends, indicate that the human actions have already committed the world to a 2 °C warming and any temperature increase beyond this may have disastrous consequences (Schneider 1989). The concentration of carbon dioxide has now been ascertained more accurately for the past 650,000 years from the analysis of Antarctic ice cores. During that time, CO_2 concentration varied between 180 ppm (glacial cold) and 300 ppm (interglacial warm) (Sigman and Boyle 2000). In contrast, the CO_2 concentration shot up by more than 80 ppm in the twentieth century, which would have otherwise taken 5000 years under natural circumstances.

The impacts of this warming are unevenly distributed across the planet. For example, temperature rise is greater at the poles with some regions of the Arctic warming 0.5 °C in last 30 years (World Bank 2010). Snow and ice melting in the Arctic and Greenland have become common; cold days and nights have become less frequent

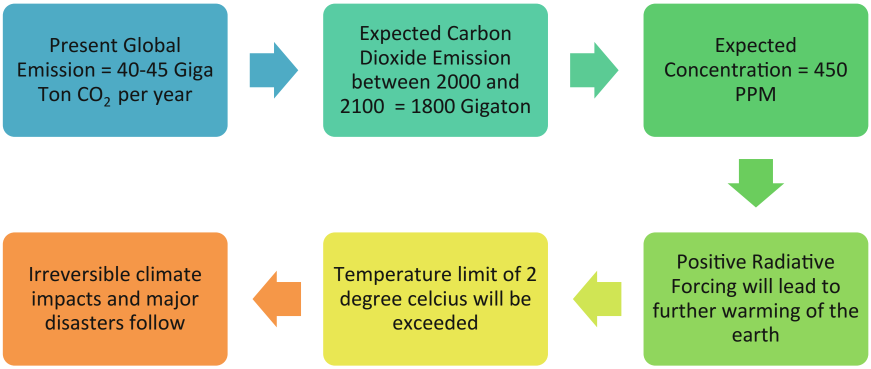

Fig. 1.4 Illustration of CC impacts if carbon dioxide concentration exceeds the limit

while intensity and frequency of heatwaves have increased. Cyclones, droughts and floods occur more frequently in different parts of the world.

The scientific community, while categorizing climate change impacts in five categories, viz.

i. Threatened ecosystems and rare/unique species;
ii. Extreme weather events;
iii. Extent of impacts;
iv. The economic impact;
v. Significant range of discontinuities.

Strongly believes that the future impacts of 2 °C rise (above pre-industrial level) in global temperature will be severe in terms of coastal erosion, water availability (to more than billion people in mid-latitudes and semi-arid low latitudes, mainly in Asia and Africa) (Yoon 2013) and extinction risk (to nearly 25% plant and animal species). In the worst-case scenario of temperature rising to 5 °C above pre-industrial levels, 50% of animal and plant species will become extinct, 30% of coastal wetlands would be inundated, terrestrial ecosystems may shift from 'carbon sink' to being 'carbon source', many small island states will suffer from storm surges, and nearly three billion people will be under severe water stress (Fig. 1.4). Evidences reported in IPCC 2007 indicate that the thawing of Greenland and Antarctic ice sheets as well as that of permafrost and mountain glaciers is faster than expected. It also suggests that the droughts in West Africa and drying of Amazon rainforest may be more likely than thought earlier. While future scenarios are based on past and present data analysis and modelling experiments, in reality the predicted changes in different regions may occur in jumps and shifts. As scientists understand the ambiguities in climate change forces and impacts with better clarity, sudden, intense and unpredictable events continue to occur in different parts of the world.

The instrumental data of sea level change during twentieth century shows an increase of 1.7 mm per year. Similarly, satellite altimetry data gathered since 1993

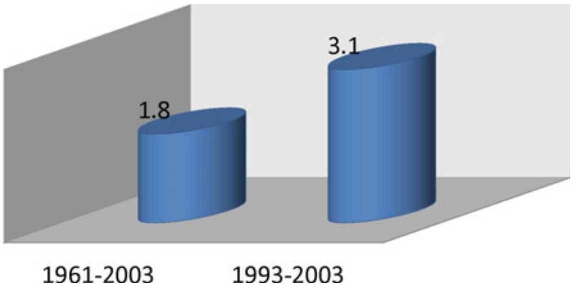

Fig. 1.5 Average sea level rise (in mm) (*Source* IPCC 2007)

indicates that sea level has been rising @3 mm per year which is significantly higher than the average during the previous half century. However, the rise is not uniform around the world and there are sharp variations (IPCC 2007). While in some regions rate of rise is several times higher than average, there are other regions where sea levels are falling. This is mostly due to inconsistent changes in temperature and salinity and the resultant changes in ocean circulation. It is estimated that on average, between 1961 and 2003 thermal expansion contributed about 25% of the observed sea level rise (Fig. 1.5), while melting of snow accounted for nearly 50% (Draper and Kundell 2007). However, during the period between 1993 and 2003, the rise in temperature and melting of ice accounted for nearly 50% sea level rise (IPCC 2007).

Global sea level is predicted to rise further and as per the IPCC report on emission scenario, by the mid-2090s, the global sea level is projected to reach 0.22–0.44 mm above 1990 levels. Scientists have also pointed out that the recent rate of global sea level rise has significantly departed from the average rate of two to three thousand years and is rising more rapidly at one-tenth of an inch per year increasing the vulnerability of millions of people living close to the coastal areas across the globe (Glick 2004). Rising sea levels produce a cascading effect, and it has been estimated that every inch of sea level rise may result in 96 inches or eight feet of horizontal submergence of shoreline with salt water intruding into freshwater aquifers affecting the agriculture and drinking water potential.

With a sharp and sudden population growth from about 1 billion in 1800 to over 7 billion in 2011, the humanity has transited from agriculture-based economy to industrial economy propelled by fossil fuels. The prophecy of Thomas Malthus in 1798 that human population grows faster than the food supplied until war, famine and disease reduce the number has gone wrong. And the credit for this goes to the discovery of fossil fuel, chemical fertilizers, high yielding food plants, pesticides, disease control, improved health and sanitation among other things. Experts also believe that the use of fossil fuel and population explosion are inextricably linked and the present level of human population is attributed to the discovery and exploitation of fossil fuels (Meyerson 2003). While there is no data to prove the foregoing statement, the converse is true. And that is—that the unprecedented of growth of human population has surged per capita fossil fuel consumption from less than 0.01

metric ton to 1.1 metric ton resulting in global emissions of carbon dioxide that grew from 8 million metric tons to 6518 million metric tons between 1800 and 1999, an 820-fold increase (Meyerson 2003).

Besides, the ever-rising footprints of agriculture has caused tremendous loss of several natural ecosystems including the prairies of North America, rainforests of Brazil, boreal forest and tropical forests. Hunger of land for agriculture and development has led to diversion of precious and irreplaceable natural forests. On a global scale, nearly 60 per cent of recent deforestation is attributable to agriculture sector (*farming is among the largest contributors to global warming emitting more GHGs than transport sector*), 20% to logging (including mining and petroleum) and 20% to household sector for fuel-wood, all GHG-enhancing activities (Population, Environment and Development 2001). Farming sector has also sucked up underground water supply, dried up several perennial rivers through damming and canal for irrigation, caused salinity ingress in coastal areas and polluted water bodies with run-off fertilizer, insecticides and pesticides.

The double whammy of increasing population and prosperity is driving the world crazy for high energy diet that mainly comes from egg, chicken, fish, pigs, lamb and beef. At present, only 55% of the world's crop is being fed directly to the people, about 36% is fed to the livestock, and the rest 9% goes into biofuels and other industrial products (Foley 2014). How the world will feed 9 billion mouths in 2045 is a dilemma for which there is no solution at present especially considering the fact there is a trend towards consumption of animal protein and therefore food production will have to far outpace population growth particularly in developing world where per capita protein demand will increase by 103.6% by 2050. We do not realize the fact that for every kilo calorie of grain that is fed to the animals, only 40% is converted into of milk or 22% is converted into eggs or 12% into chicken or 10% into pork or only 3% into beef. In other words, the loss of energy from grain to meat conversion is extremely high, and scientists and policymakers will have to work on new ideas to ensure minimization of wastage (Fig. 1.6) and efficient use of grain for undernourished people of the world.

The overall impact[1] of climate change is, nevertheless, different in developed world though the direction of impact varies. A rapidly growing rich global consumer society of 1.7 billion is currently responsible for the over use of biological products, fossil fuels, minerals and metals and other diverse products and services than ever before, while 2.8 billion poor struggle to survive on less than USD 2 per day. Affluent nations like USA, Canada, Britain, France, Germany, Japan and Italy represent only a tenth of global population but consume over 40% of Earth's fossil fuels as well as most of the world's commodities (Fig. 1.7) and forest products. With every dollar increase in per capita GDP, there is 1.4 kg increase in per capita CO_2 emissions (Olivier et al. 2014). In other words, higher socio-economic status has equal or more detrimental impact on the environment. The ecological footprint of an individual in a high-income country is at least six times higher than in low-income countries.

[1] Impact $= f$ {Population × Affluence(or Poverty) × consumption pattern × Technology}.