Environment: a futuristic view

J. S. Singh

The earth today is experiencing environmental conditions unprecedented in the history of the planet. Biodiversity is the basis of ecosystem services for human well-being. Reports indicate that the earth has indeed entered into a phase of mass extinction, and that the ecological footprint has substantially exceeded the biocapacity of the earth. It is argued that the ecological footprint must be reduced through sustainable development which should keep nature at its core. Anthropogenic activities have led to global environmental change which is adversely affecting human well-being. Global warming may result in a temperature rise of 4–5°C; the world food production may substantially decline, and the sea level may rise by up to 195 cm by 2100, inundating vast coastal areas. Almost four billion people are facing water scarcity. Three of the nine Rockström's planetary boundaries have already been exceeded. However, the encouraging fact is that the nations have agreed to limit global warming to 1.5°C, which gives us hope.

Keywords: Biocapacity, ecological footprint, global warming, planet boundary, societal support, sustainable development.

THE high rate of population growth and consequent exploitation of resources have resulted in a number of environmental problems, such as global warming, sea-level rise, ozone depletion, water scarcity, biodiversity loss, habitat destruction, pollution of air, soil and water, acid rain, desertification, etc. The reports of Intergovernmental Panel on Climate Change (IPCC) and a synthesis of other scientific studies[1] have established beyond doubt that in the present era, human activities are the main driving force for global environmental change. The study and analysis of deceased societies led researchers to suggest that humans have a general tendency to live beyond the capacity of their surrounding environment, and this tendency can result in societal collapse[2,3]. In this article, I will discuss the effects of anthropogenic environmental changes inimical to humanity and also how the nations attempt to come to terms with uncertain environmental changes. But first a little historical background follows.

The book *Silent Spring* authored by Carson[4] in 1962, drew the world attention on rapidly accelerating environmental degradation of marine and freshwater ecosystems, especially from widely promoted and available organochlorine-based pesticides. This book recorded the highly irresponsible destruction of natural habitats by human activities and succeeded in triggering immense international concern.

The ever-increasing degradation of the marine and freshwater environments, and other undesirable changes in the biosphere led the United Nations General Assembly to convene, a Conference on the Human Environment at Stockholm in 1972. U. Thant, the then UN Secretary-General, invited Maurice Strong, a distinguished Canadian politician and diplomat, to lead the Conference. The Stockholm Declaration of 26 'principles' called upon all nations to maintain air, water, land and biological components of the earth in a healthy state. The United Nations Environment Programme (UNEP) was also born at this Conference.

In 1972, at the request of Strong (the then UN Secretary-General), René Dubos (French microbiologist and philosopher) and Barbara Ward (British economist) wrote a background briefing paper[5]. This publication expanded on the phrase 'think globally, act locally' coined by Dubos and the concept of sustainable development presented by Ward[6] in his book *Spaceship Earth*. This book, published in 1966, established the 'only one earth' principle; and 'think globally and act locally' and 'sustainable development' are now frequently used terms in discussions on the environment. The other two terms ubiquitously used are 'greenhouse effect' and 'global warming'.

Revelle and Suess in 1957 stated that as the industrial era progressed, levels of combustion of fossil fuels increased; carbon dioxide also steadily increased in the upper atmosphere; consequently 'it would lower the mean level of back radiation in the infrared and thereby increase the average temperature near the earth's surface'[7]. This observation possibly resulted in the origin of the concept of the 'greenhouse effect'.

Although possibilities of climate change were being vigorously discussed, it was the geoscientist Wallace Broecker[8], who asked the critical question: 'Are we on

J. S. Singh is in the Department of Botany, Institute of Science, Banaras Hindu University, Varanasi 221 005, India.
e-mail: singh.js1@gmail.com

the brink of a pronounced global warming?'. Thus he explicitly used the term 'global warming' for the first time, which has now become a fixture in all environmental discussions. It is believed that Callendar established the carbon dioxide theory of climate change by indicating that anthropogenic emissions of CO_2 into the atmosphere were warming the planet[9].

The concept of 'tipping point' was introduced by Hoegh-Guldberg, in order to attract public attention. As argued by Hoegh-Guldberg *et al.*[10], this is the point when a sequence of undesirable 'actions attain a certain stage' (a critical threshold) 'and begin to initiate changes that become irreversible'. Because it is often difficult to recognize a tipping point, the activities are not moderated or stopped in time, and the ecosystem may slip into an alternative state[10].

The changing planet

The earth is changing rapidly[11]. Some of these changes are: increasing human population, land, ocean and climate transformations, biodiversity loss, overexploitation of resources and pollution, harmful effects of pollution compounded by weakening resilience due to global warming, and increasing atmospheric loading of greenhouse gases (GHGs). It is also recognized that the current rate of change exceeds those in earlier periods, due to climate change associated with fossil fuel-based energy policy[12,13]. It is clear that the ecological footprint or demand has far exceeded the biocapacity of our planet, so that now equivalent to 1.5 earths are needed to meet the current demands of the humanity on nature (Figure 1). Figure 2 shows that during the past 50 years, while the earth's biocapacity has increased from 9.9 to 12 billion gha, the world population has increased from 3.1 to 6.9 billion gha, and thus, per capita ecological footprint has increased from 2.5 to 2.6 gha (Global Footprint Network 2014). Evidently the available planetary resources are under huge stress and thus deteriorating. Scientists feel that 2050 will be a 'crunch time' for humanity in view of the increasing use but diminishing resources[14,15]. CO_2 concentration in the atmosphere has been increasing at an average rate of 2 ppm/yr (Figure 3). However, the current rate is much higher; CO_2 concentration in April 2015 was 403 ppm and in April 2016 it was 407 ppm; i.e. 4 ppm increase in just one year. In 2100, CO_2 concentration is predicted to reach 800 ppm (CO_2e, i.e. CO_2 plus other GHGs to be 1060 ppm, and annual CO_2e emissions to be 130.40 Gt). Consequently, the temperature could rise by 4°C (CO_2 now.org). Methane, another GHG, next in importance after CO_2, was stable for several years up to 2007, but is showing an approximate linear increase afterwards (Figure 4; for details see http://www.esa-ghgcci.org/sites/default/files/documents/public/documents/GHG-CCI_DATA.html).

Lessons from PETM

Climate has always been changing, but the effects of the rapidly increasing atmospheric loading of GHGs may be clear by studying the climatic changes and amplifying feedbacks that occurred during the Palaeocene–Eocene

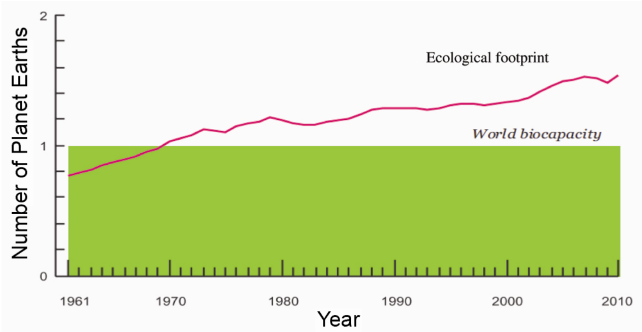

Figure 1. Ecological footprint vis-à-vis world biocapacity (after Global Footprint Network 2014).

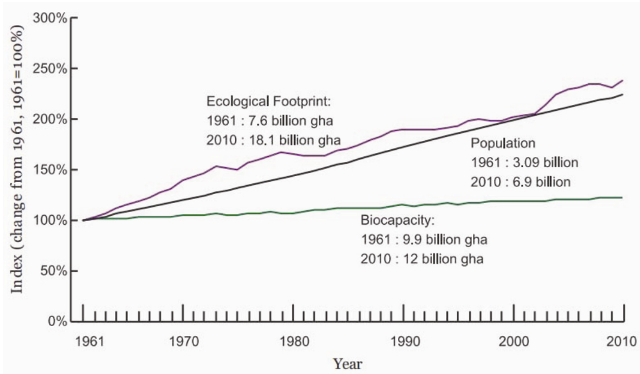

Figure 2. Trends in earth's biocapacity, ecological footprint and world population.

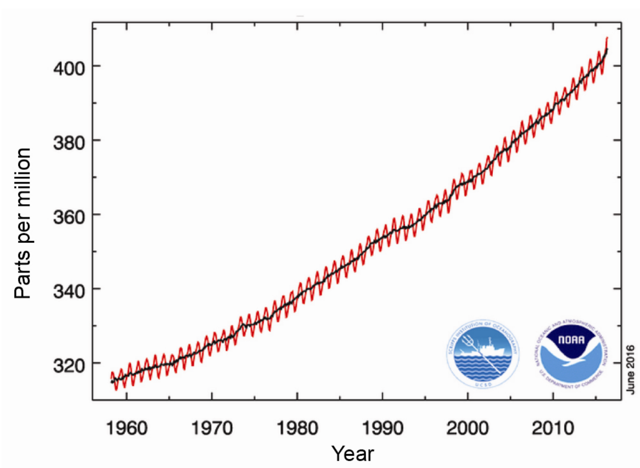

Figure 3. The trend of CO_2 measured at Mauna Loa Laboratory, Hawaii, USA (accessed from http://www.esrl.noaa.gov/gmd/ccgg/trends/full.html, on 7 June 2016).

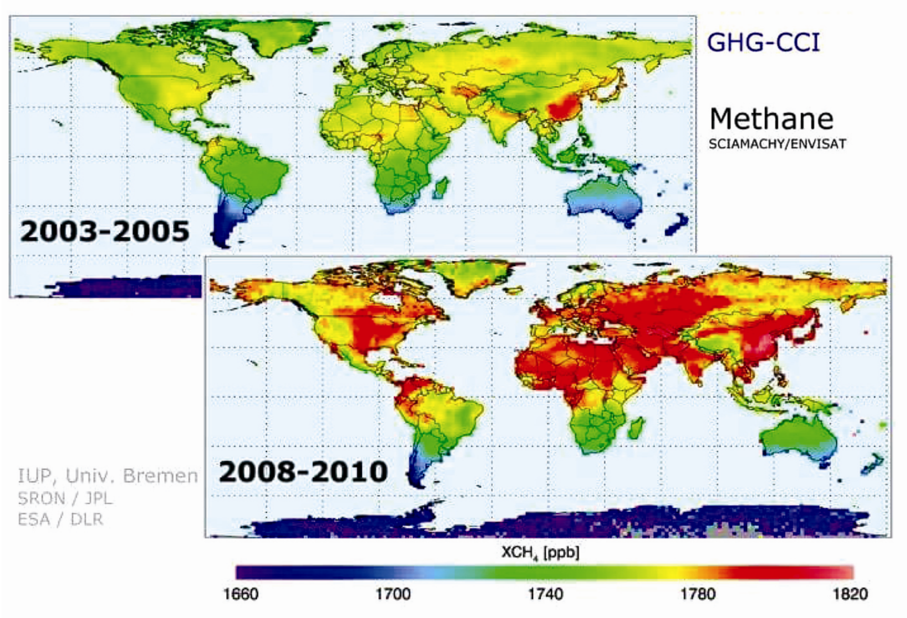

Figure 4. Maps from European satellite ENVISAT-SCIAMACHY showing increased concentrations of methane from 2003 to 2005 and 2008 to 2010 (http://www.esa-ghgcci.org/sites/default/files/documents/public/documents/GHG-CCI_DATA.html).

Thermal Maximum (PETM). It is believed that during PETM (about 55.9 m.y. ago), a large, natural CO_2 release resulted in strong warming[16]; the global temperature rose by about 5°C. Some of the events which took place at that time and which could very well be repeated now are: dwarfing of large animals (due to heat stress or/and reduced nutritional value of food), ecosystem disruptions, soil degradation, water-cycle shifts, enhanced erosion and sediment transport due to increase in hydrological variability, larger or more intense storms separated by longer and drier intervals contributing to regional loss of vegetation, soil carbon and soil fertility[16]. Terrestrial species migrated long distances poleward or upward; some types became extinct, whereas others spread[16]. PETM plant leaf showed heavy damage due to increased insect feeding as higher CO_2 reduced nutritional value of plants, and also invasion by new insects occurred[16]. Up to half of the bottom-dwelling foraminifera species became extinct, or migrated out[16]. Coral reefs were largely lost as functioning ecosystems as the oceans hosted flatter, less complicated structures dominated by foraminifera, and many types of plankton in some coastal tropical oceans were partly or completely lost because of heat or other stresses[16]. An exciting example of dwarfing effect is provided by van Gils *et al.*[17], who showed that due to Arctic warming body shrinkage in the offspring of Arctic wading birds (red knot, *Calidris canutus canutus*) influenced their survival in their tropical wintering range. Shorter bills do not allow the offspring to feed on mollusks buried deep; so they were forced to eat seagrass rhizomes available at shallow depths resulting in reduced fitness and increased mortality.

Planetary boundaries

Rockström *et al.*[12] identified the earth-system processes and tipping points, which, if crossed, could generate irreversible change in the environment. They have recognized nine such processes which require the setting up of critical thresholds: (i) climate change; (ii) rate of biodiversity loss (terrestrial and marine); (iii) interference with the nitrogen and phosphorus cycles; (iv) stratospheric ozone depletion; (v) ocean acidification; (vi) global freshwater use; (vii) change in land use; (viii) chemical pollution; and (ix) atmospheric aerosol loading. These boundaries define the safe operating space within which humanity can continue to develop and thrive (Figure 5). According to Rockström *et al.*[12], three of the earth-system processes – climate change, rate of biodiversity loss, and interference with the nitrogen cycle – have already exceeded their boundaries, and several other boundaries may be crossed soon.

Global risks

The recent global risks report by the World Economic Forum has identified 10 major risks to humanity in the near future. This report defines a global risk 'as an uncertain event or condition that, if it occurs, can cause significant negative impact on several countries or industries within the next 10 years'. According to this report, in accordance with the relative impact, the top four risks are: (i) failure of climate change mitigation and adaptation; (ii) weapons of mass destruction; (iii) water crisis; and (iv) large-scale involuntary migration.

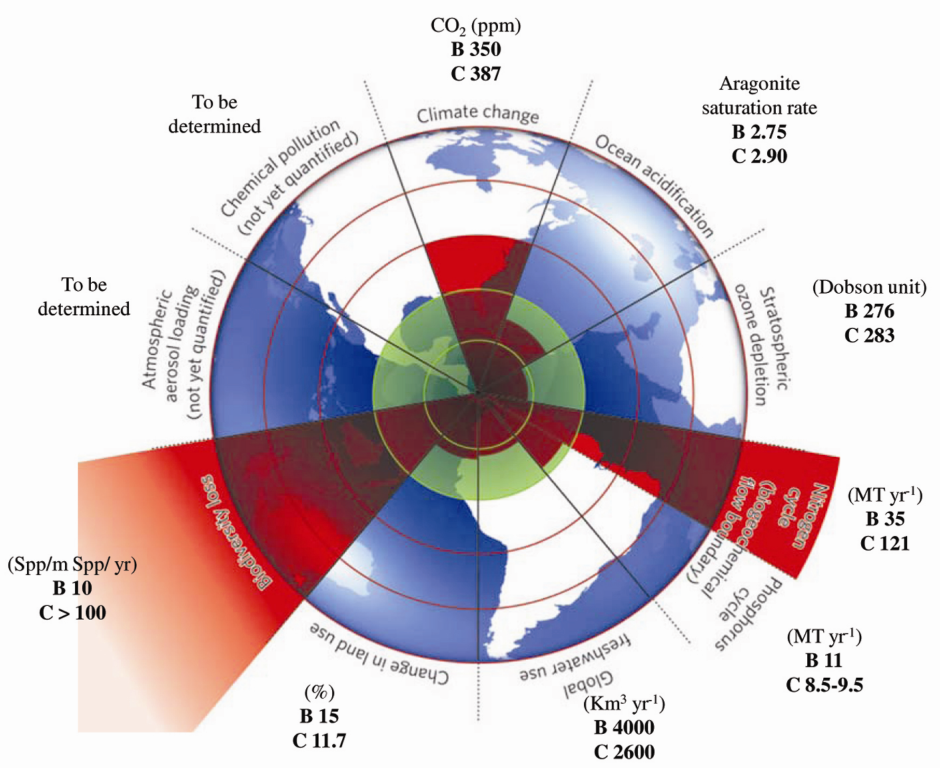

Figure 5. The nine planetary boundaries as safe operating space for humanity (based on Rockström *et al.*[12]). B, Proposed boundary; C, Current status.

Food production

The rising temperatures and changing patterns of precipitation due to global climate change are likely to harm agricultural production. If mitigation or adaptation efforts fail, there will be a pronounced food crisis. Figure 6 shows the predicted world food production for 2050 compared to 2015. Note that, in many regions food production could decline by 20–50%.

Water crisis

According to Mekonnen and Hoekstra[18], 'two-thirds of the global population (4.0 billion people) live under conditions of severe water scarcity during at least a part of the year' (Figure 7). Half a billion people in the world face severe water scarcity all the year round and half of those suffering from water scarcity live in India and China, the world's two most populous countries. In these countries demand of water is higher than its availability.

Sea-level rise

The oceans will continue to rise, given the current rate of warming, and the rise could be anywhere between 75 and 195 cm by 2100. Extreme floods due to sea-level rise are expected to affect 268–286 million people by 2030, and up to 411 million by 2060. High vulnerability to flooding and coastal hazards is predicted for five Asian countries: China, India, Bangladesh, Indonesia and Viet Nam[19].

Massive migration

The report on global risks indicates that 'Global refugee flows have reached a level that is unprecedented in recent history. In 2014, 59.5 million people were forcibly displaced in the world'. Nearly 19.3 million people were forced out of their homes in 2015 by natural disasters alone. People are moving as climate refugees arising from natural disasters, and conflicts over basic resources, extreme events, water crisis, etc. According to the Asian Development Bank, 37 million people from India, 22 million from China and 21 million from Indonesia will be at risk (and therefore may have to migrate) from sea-level rise alone. Migrations create human misery, as the refugees would have often lost their livelihood, family ties and property.

The hottest earth

According to recent reports of NOAA (National Oceanic and Atmospheric Administration), global average temperature is now higher than it has been for the most of the past 11,300 years. In 2015, each month set a new

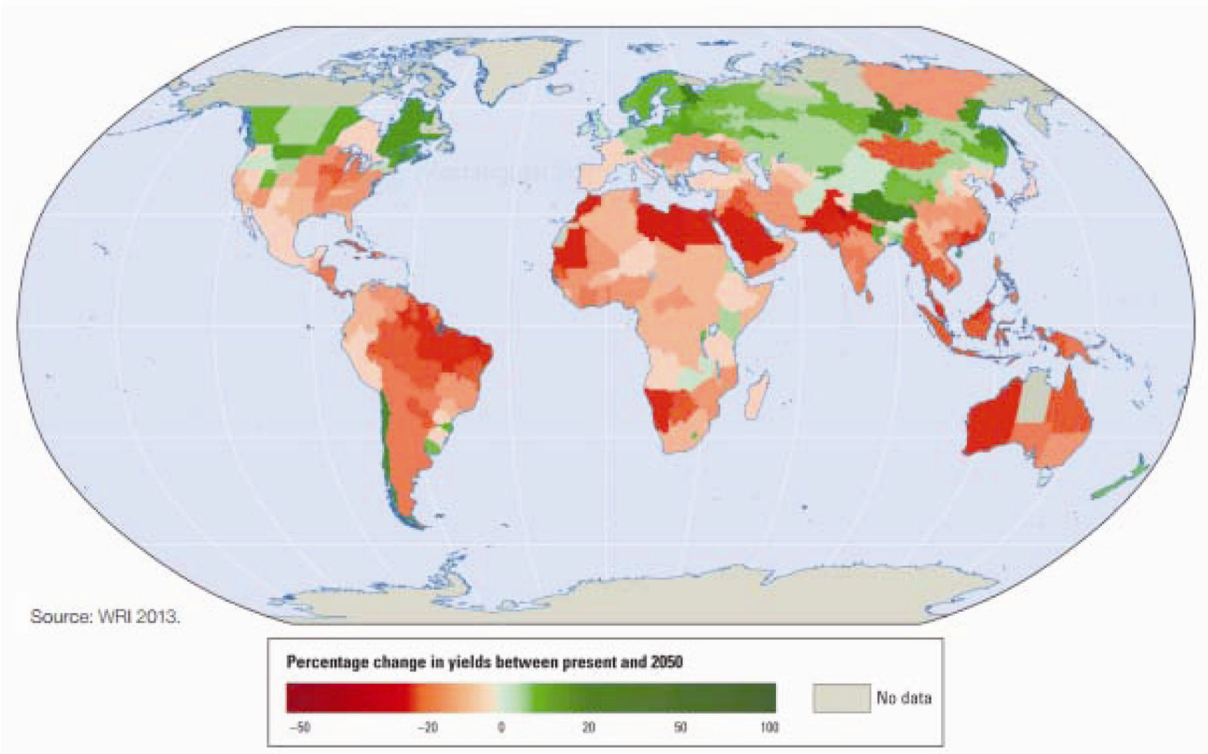

Figure 6. Predicted world food production in 2050 compared to that in 2015 (source: World Resource Institute 2013; World Risks Report 2016).

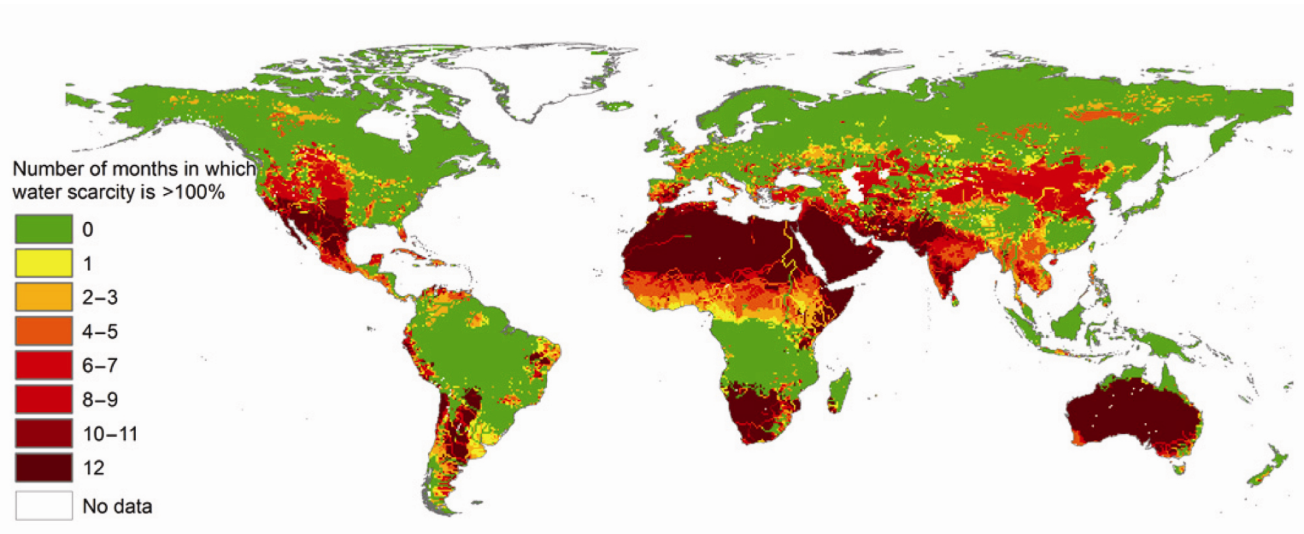

Figure 7. Duration (number of months per year) when blue water is scarce (after Mekonnen and Hoekstra[18]).

temperature record. Studies indicate that several regions of the earth, such as portions of North Africa and the Middle East, would become uninhabitable due to prolonged heat waves and dust storms, forcing people to migrate.

Air quality and pollution

According to a latest report of UNEP, between 2008 and 2013 urban air-pollution level increased by 8%, and 80% of the people living in urban areas experienced pollution levels which exceeded the limits proposed by the World Health Organization (WHO). In Delhi alone, air pollution due to $PM_{2.5}$ (airborne particles smaller than 2.5 μm in diameter) caused as many as 16,000 premature deaths and 6 million asthma attacks annually, cutting about 6 years of the life expectancy of its residents[20]. Aquatic systems are also heavily polluted. For example, in the nine major religious bathing ghats of the Ganga at Varanasi, biochemical oxygen demand (BOD) ranges from 4.8 mg to 62.0 mg/l.

Sustainable development

Most of the environmental evils arise due to unsustainable exploitation of resources and the solution lies in sustainable development. The concept of sustainable development as envisaged by the Brundtland Commission[21] is 'meeting current human needs without compromising needs of future generation'. However, in the post-2015 UN development agenda, nature must be reinstated at the core of 'sustainable development'. The agenda should aim at sustaining nature, rather than reducing it to a resource that feeds our economic system. We must recover the ancient wisdom that economic wealth is not convertible into life, a truth captured graphically in the saying that 'Only when you have felled the last tree, caught the last fish and polluted the last river, will you realize that you can't eat money'[22].

On 25 September 2015, world leaders adopted the declaration on Transforming Our World: the 2030 Agenda for Sustainable Development (UN General Assembly Resolution 70/1). Over 86 of the 169 targets are directly concerned with the environment. Human rights and the environment are inextricably linked through the right of every citizen to a clean, healthy and productive environment[23].

Societal support

Milfont and Schultz[24] highlight evidence, including new analysis of cross-cultural data indicating that an overwhelming majority of the world's population supports environmental protection, and identifies with the value of 'looking after the environment'. This is heartening, as in the absence of societal support no environmental improvement is possible. The society should ask: 'Do we need a human right to a healthy environment?'[25]

Climate change affects billions of people, and interferes with the realization of human rights, such as the right to life, to health, to culture, to food, to self-determination, to property and to development. Few would disagree that every human being deserves access to an environment conducive to health. Therefore, it is imperative to recognize a human right to a healthy environment[25]. The explicit recognition of a fundamental right to a healthy environment might provide new tools for civil society to hold governments accountable for ensuring access to the right[25].

An optimistic vision for 2100

Tollefson[26] presented an encouraging futuristic view and vision for the year 2100, assuming that governments have agreed to limit global warming to 2°C: 'Nearly 8.8 billion people now crowd the planet. Energy consumption has nearly doubled, and economic production has increased more than sevenfold. Vast disparities in wealth remain, but governments have achieved one crucial goal: limiting global warming to 2°C above pre-industrial temperatures.' On this assumption climate modellers charted possible paths by assuming that 'Governments have moved to halt tropical deforestation and to expand forests around the globe. By 2020, plants and soils were stockpiling more than 17 billion tonnes of extra CO_2 each year, offsetting 50% of global CO_2 emissions. Several million wind turbines are installed, and thousands of nuclear power plants were built. The solar industry ballooned, overtaking coal as a source of energy in the waning years of the twenty-first century. Governments have driven emissions into negative territory – sucking greenhouse gases from the skies – by vastly increasing the use of bio-energy, capturing the carbon dioxide generated and then pumping it underground on truly massive scales. Atmospheric CO_2 concentrations peaked in 2060, below the target of 450 parts per million (p.p.m.) and continue to fall'[26]. It may be noted that CCS (carbon capture and storage) technologies are now available and are being further developed[27]. Figure 8 shows the two possible paths as envisaged by the modellers. If global warming can be limited to 2°C, CO_2 concentration would be 475 ppm or CO_2e 485 ppm and CO_2e emission 6.01 Gt (CO_2now.org).

Extremely positive news

The nations of the world (196 signatories) agreed on 12 December 2015 at Paris, to limit global average temperature rise to 'well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels'[28]. This is seen as the end of the fossil fuel era. There are a few indicators of possible phasing out of the fossil fuel: the use of coal decreased from 9 million tonnes in 2005 to 6.44 million tonnes in 2013; more than 208,000 people work in the US solar energy sector alone; a 20% increase over the last year; the alternative energy sources are rapidly developing as shown by massive employment in this sector (Figure 9). When global warming is limited to 1.5°C, CO_2 concentration will be 425 ppm and CO_2e emission 0.92 Gt. Compare these values with actuals in 2014; temperature rise 0.9°C, CO_2 concentration 397 ppm, CO_2e 481 ppm, CO_2e emission 54.96 Gt (CO_2now.org).

As earlier reports of IPCC have considered much higher temperatures for predictions and assessments, it will now take up an in-depth review of the effects of 1.5°C global warming above pre-industrial levels.

On account of the present commitment by the nations to limit global warming to 1.5°C and public activism, the humanity can hope for a better environment than that

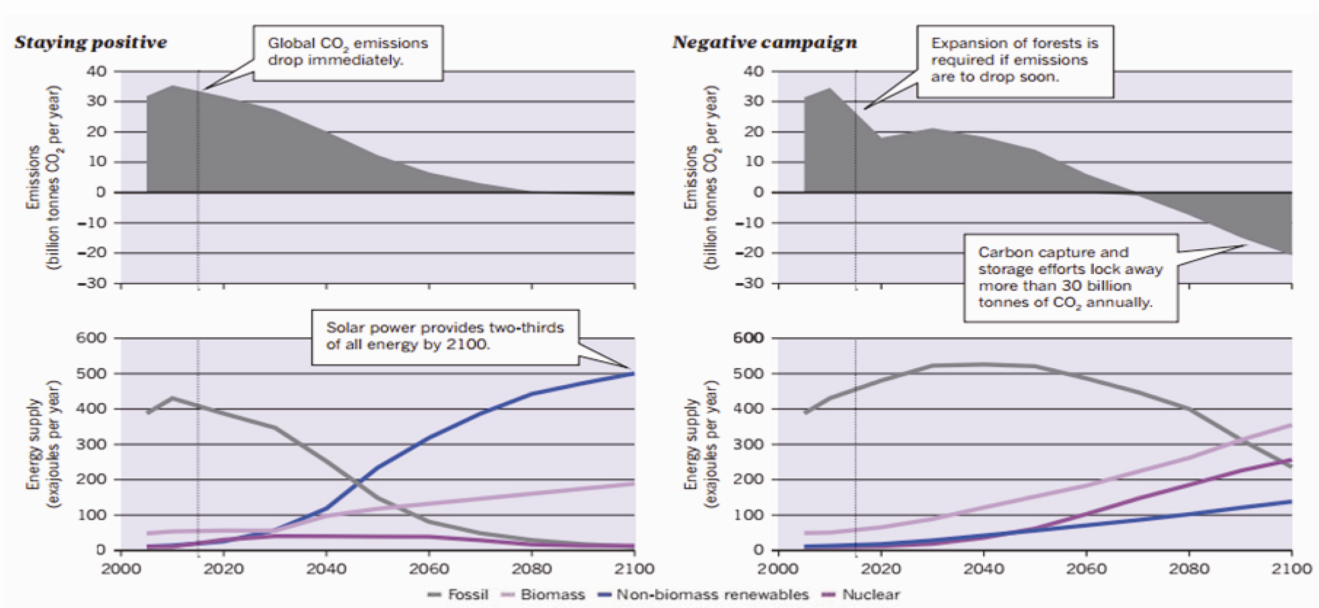

Figure 8. Two possible paths to limit global warming to 2°C. (Left panel) Path 1 fossil fuel use slashed and renewable energy use increased. (Right panel) Path 2 fossil fuel use continued but bioenergy supplies a growing share of energy; carbon from bioenergy industry captured and stored (based on Tollefson[26]).

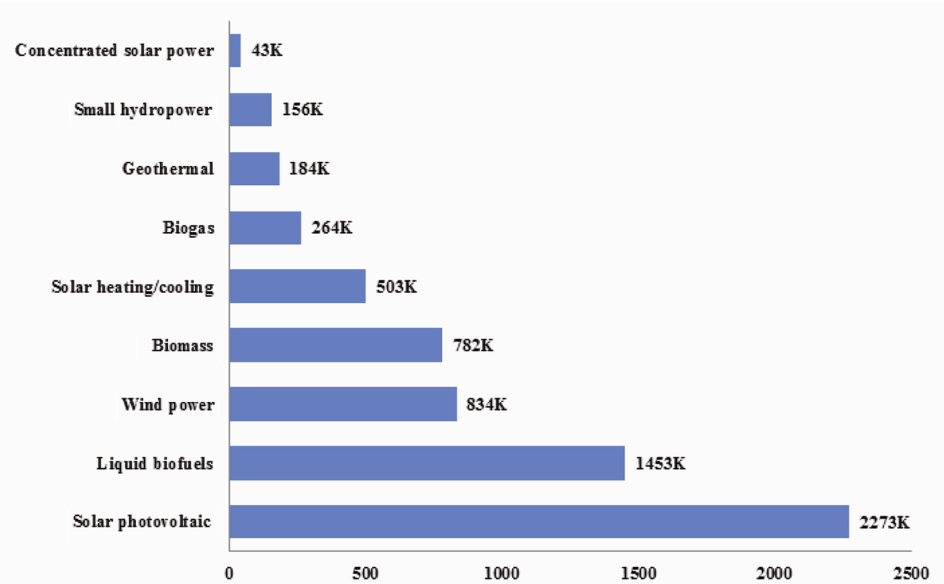

Figure 9. Jobs available in energy sectors other than fossil fuels (6.5 million jobs as of 2013; based on Schaaf[29]).

portrayed by several predictions. Conditions will of course be more difficult than those at present, but humans will be able to adapt to the less intense climate change using available or more innovative technologies, and curb environmental degradation like pollution by applying newer technologies.

1. Cook, J. *et al.*, Quantifying the consensus on anthropogenic global warming in the scientific literature. *Environ. Res. Lett.*, 2013, **8**(2), 024024.
2. Ponting, C., *A New Green History of the World: The Environment and the Collapse of Great Civilizations*, Vintage, London, UK, 2007.
3. Diamond, J., *Collapse: How Societies Choose to Fail or Survive*, Penguin, London, UK, 2011.
4. Carson, R., *Silent Spring*, Honghton Mifflin Co, Boston, MA, USA, 1962.
5. Ward, B. and Dubos, R., Only one earth: the care and maintenance of a small planet. *Atoll. Res. Bull.*, 1972, **166**, 1–10.
6. Ward, B., *Spaceship Earth*, Columbia University Press, NY, USA, 1966.
7. Revelle, R. and Suess, H. E., Carbon dioxide exchange between atmosphere and ocean and the question of an increase of atmospheric CO_2 during the past decades. *Tellus*, 1957, **9**, 18–27.

8. Broecker, W. S., Climate change: are we on the brink of a pronounced global warming? *Science*, 1975, **189**, 460–463.
9. Morgan, R. A., Histories for an uncertain future: environmental history and climate change. *Aust. Hist. Stud.*, 2013, **44**(3), 350–360.
10. Hoegh-Guldberg, O. *et al.*, Coral reefs under rapid climate change and ocean acidification. *Science*, 2007, **318**, 1737–1742.
11. Lindenmayer, D. B. *et al.*, Contemplating the future: acting now on long-term monitoring to answer 2050's questions. *Aust. Ecol.*, 2015, **40**(30), 213–224.
12. Rockström, J. *et al.*, A safe operating space for humanity. *Nature*, 2009, **461**, 472–475.
13. Hooper, D. U. *et al.*, A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature*, 2012; **486**, 105–108.
14. Holloway, J., Hot, crowded, and running out of fuel: earth of 2050 a scary place, 2012; http://arstechnica.com/science/2012/03/hotcrowded-and-running-out-of-fuel-earth-of-2050-a-scaryplace/ (cited 1 November 2013).
15. Fulton, B., Where is Australia headed? Some future projections. The conversation, 2013; http://theconversation.com/where-is-australia-headed-some-future-projections-12403 (cited 5 November 2013).
16. Alley, R. B., A heated mirror for future climate. *Science*, 2016; **352**(6282), 151–152.
17. van Gils, J. A. *et al.*, Body shrinkage due to Arctic warming reduces red knot fitness in tropical wintering range. *Science*, 2016, **352**(6287), 819–821.
18. Mekonnen, M. M. and Hoekstra, A. Y., Four billion people facing severe water scarcity. *Sci. Adv.*, 2016, **2**, e1500323.
19. Neumann, B., Vafeidis, A. T., Zimmermann, J. and Nicholls, R. J., Future coastal population growth and exposure to sea-level rise and coastal flooding – a global assessment. *PLoS ONE*, 2015, **10**(3), e0118571.
20. Subramanian, M., India's capital scrambles to tackle its epic pollution problems. *Nature*, 2016, **534**, 166–169.
21. WCED, *Our Common Future*, Report of the World Commission on Environment and Development, Oxford University Press, Oxford, UK, 1987.
22. United Nations, General Assembly, 68th Session, Item 19 of the provisional agenda, 2013.
23. United Nations Environment Assembly of the United Nations Environment Programme, Delivering on the environmental dimensions of the 2030 agenda for sustainable development: a concept note, 2015.
24. Milfont, T. L. and Schultz, P. W., Culture and the natural environment. *Curr. Opn. Psychol.*, 2016, **8**, 194–199.
25. Bratspies, R., Do we need a human right to a healthy environment? *Santa Clara J. Int. L.*, 2015, **13**, 31–69; http://digital-commons.law.scu.edu/scujil/vol13/iss1/3
26. Tollefson, J., The 2°C dream. *Nature*, 2015, **527**, 436–438.
27. Kintisch, E., New solution to carbon pollution? *Science*, 2016, **352**(6291), 1262–1263.
28. Lewis, S. L., The Paris agreement has solved a troubling problem. *Nature*, 2016, **532**, 283.
29. Schaaf, L., Leading the way. In *Our Planet: Inclusive Green Economy. Building Bridges to a Sustainable Future*, United Nations Environment Programme. Nairobi, Kenya, 2016.

ACKNOWLEDGEMENTS. I thank Dr Manju Sharma, Past President, National Academy of Sciences, India for inviting me to deliver the theme lecture on 'Environment: a futuristic view', on the occasion of World Environment Day at a function, organized by the National Academy of Sciences, India on 5 June 2016. I also thank Professor S. R. Gupta, Department of Botany, Kurukshetra University, Kurukshetra for drawing my attention to latest reports from UN and UNEP, and Rishikesh Singh, Institute of Environment and Sustainable Development, BHU for assistance in the preparation of the manuscript.

Received 26 November 2016; revised accepted 11 January 2017

doi: 10.18520/cs/v113/i02/210-217