Volume 92 Number 879 September 2010

INTERNATIONAL
REVIEW
of the Red Cross

Climate change and its impacts: growing stress factors for human societies

Martin Beniston

Professor Martin Beniston is director of the Institute for Environmental Sciences, University of Geneva, Switzerland.

Abstract

The realization that human beings need to be concerned about the only 'life-support system' that the Earth and its environment provides stems perhaps in part from the fact that, until fairly recently, the evolution of humankind was largely dependent on the quality of the environment and the resources it provides in terms of water, food, and favourable health conditions. These are as vital as ever, despite current levels of technology and apparent resilience in the face of often degraded environments in many parts of the world. Today, the conditions for human sustainability (i.e. water quality and quantity, food security, and health) are potentially under threat as a result of numerous human-induced factors; among these, climate change is certainly one of the more durable aspects of anthropogenic disruptions to natural resources. This article will therefore focus on the possible evolution of climate in the course of the twenty-first century and on a number of key climate impacts that may determine the future course of human societies, as well as issues that may confront them such as rivalries over natural resources and possible environmentally driven conflicts and migrations.

: : : : : : :

Human activities in most parts of the world are transforming the global environment. Among the numerous factors that contribute to global environmental change, mention can be made of land-use change, desertification and deforestation, loss of biodiversity, air pollution, ozone depletion, and climate change. Changes in average and extreme patterns of weather and climate are capable of putting vital resources under pressure. Ecosystems become more susceptible to the

doi:10.1017/S1816383110000342

emergence, invasion, and spread of opportunistic species. Many of these environmental pressures act in a synergistic manner, thereby compounding the stress situation and the adverse effects that a degraded environment may have on human activities and the carrying capacity of a particular region.

Humans are not only the receptors of environmental change but are also in numerous instances the drivers of change. Over-exploitation of resources in the industrialized world and unsustainable economic policies have given rise to many of the factors generating global change. In less developed countries, high population growth is linked to environmental degradation because local inhabitants attempt to maintain or improve their resource base and economic level through the over-exploitation of their environment.[1] This takes place in general without any long-term environmental management strategy; resources can thus become rapidly depleted or ineffective.

Through technological advances and seemingly adequate resources, the industrialized world in particular lives under the impression that basic life-supporting resources (i.e. water, food, health, and shelter) are abundant and quasi-unlimited. There are, however, frequent acute reminders that famine and disease are still widespread in many parts of the world and that, at the end of the twentieth century, over 550 million people did not have access to clean drinking water.[2] Moreover, even in technologically advanced societies, water, food, and health all constitute basic, interrelated needs for human survival. These elements are all highly dependent on environmental factors such as climate, and are sensitive to shifts in existing environmental conditions. Such changes may upset the delicate balance even in those countries that enjoy reliable food security, water quality and quantity, and sanitary conditions.

Climate change in the twenty-first century

When the climate change debate began in the late 1980s, estimates of the amplitude of warming according to greenhouse-gas scenarios suggested that global average temperatures could rise by 1.5–5 °C by the end of the twenty-first century. Over two decades later, with climate models that have become much more detailed, the plausible range of global atmospheric temperature increase remains essentially unchanged: 1.5–5.8 °C according to the Intergovernmental Panel on Climate Change (IPCC).[3] It is also remarkable to note that, as early as 1897, Svante Arrhenius, a distinguished Swedish physical chemist and Nobel Prize laureate,

---

[1] Barry Commoner, 'Rapid population growth and environmental stress', in *International Journal of Health Services*, Vol. 21, No. 2, 1991, pp. 199–227; Anne R. Pebley, 'Demography and the environment', in *Demography*, Vol. 35, No. 4, 1998, pp. 377–389.

[2] UNESCO, *International Conference on World Water Resources at the Beginning of the 21st Century*, Paris, 3–6 June 1998; United Nations, *Millennium Development Goals Report 2009*, New York, 2009, 60 pp.

[3] Susan Solomon *et al.* (eds), *Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press for the Intergovernmental Panel on Climate Change (IPCC), Cambridge, 2007, 996 pp.

made the first calculation of the possible effect of greenhouse gases on the temperature of the Earth and came to the conclusion that a doubling of CO_2 in the atmosphere would lead to a 4 °C warming, a figure that is still well within the bounds of the most sophisticated climate model results today.

In the various suites of IPCC reports published in 1996, 2001, and 2007, climate models of varying complexity have been applied to assess the response of the climate system to anthropogenic forcing in the twenty-first century. They include fully coupled ocean–atmosphere models, atmospheric general circulation models, and simpler models designed to investigate a particular element of the system such as the global carbon cycle, or to integrate much further ahead in time than the more computationally resource-intensive general circulation models. In order to capture the limits of uncertainty of the model results, and to investigate the variability inherent to the climate system, 'ensemble simulations' have been undertaken. These involve the use of a set of different models that employ the same forcing scenario but with slightly different initial conditions.[4] Small perturbations of initial conditions result in an internally generated climate variability that produces different results for the different members of the ensemble simulations. These can be considered to reflect the natural variability of the system, upon which the strong anthropogenic signal is superimposed. The ensemble approach provides a more coherent strategy for climate simulations and has shown skill in reproducing the observed distributions of pressure, temperature, and precipitation under current climate conditions, as reported by Lambert and Boer.[5]

Figure 1 shows the possible range of global warming in response to a number of greenhouse-gas emission scenarios developed by Nakićenović *et al.* for the IPCC.[6] The range illustrated in this figure is not simply a result of the uncertainty in climate model simulations, but reflects the spread of possible socio-economic futures. These are based on subtle combinations of demography, economic growth, technological choice, and policy options that lead to varying levels of carbon in the atmosphere. The strength of the response of the climate system by 2100 will of course be directly related to the cumulative levels of atmospheric carbon between now and the end of this century.

Results from coupled ensemble ocean–atmosphere general circulation models allow the geographical distribution of change to be mapped. Results based on the IPCC SRES A2 scenario[7] are shown here in order to emphasize what could

---

[4] E.g. Cedo Branković and Tim N. Palmer, 'Seasonal skill and predictability of ECMWF PROVOST ensemble', in *Quarterly Journal of the Royal Meteorological Society*, Vol. 126(B), No. 567, 2000, pp. 2035–2067; Francisco J. Doblas-Reyes, Michel Déqué, and Jean-Philippe Piedelievre, 'Model and multi-model spread and probabilistic seasonal forecasts in PROVOST', in *Quarterly Journal of the Royal Meteorological Society*, Vol. 126(B), No. 567, 2000, pp. 2069–2089; Jacques Derome *et al.*, 'Seasonal predictions based on two dynamical models', in *Atmosphere-Ocean*, Vol. 39, No. 4, 2001, pp. 56–68.

[5] Steven J. Lambert and George J. Boer, 'CMIP1 evaluation and intercomparison of coupled climate models', in *Climate Dynamics*, Vol. 17, No. 2–3, 2001, pp. 83–106.

[6] Nebojsa Nakićenović *et al.*, *IPCC Special Report on Emissions Scenarios*, Cambridge University Press, Cambridge, 2000, 599 pp.

[7] *Ibid.*

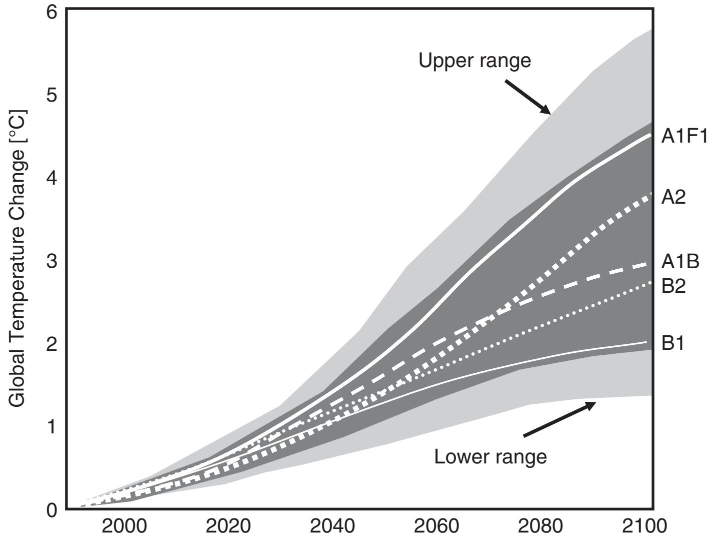

Figure 1. Global warming futures according to various greenhouse-gas emission scenarios developed by the Intergovernmental Panel on Climate Change (Source: IPCC, 2007).

be the response of the climate system to one of the strongest greenhouse-gas forcings. The A2 scenario assumes a high level of emissions in the course of the twenty-first century, resulting from low priorities on greenhouse-gas abatement strategies and high population growth in the developing world. The said scenario leads to atmospheric CO_2 levels of about 800 ppmv (parts per million by volume) by 2100 – that is, about three times their pre-industrial values – and provides an estimate of the upper bound of climate futures discussed by the IPCC (2007).

Figure 2 shows the difference in temperatures between the baseline climate (1980–1999) and the scenario climate (2080–2099). The shifts in temperature are greatest in the high latitudes; the changes that are expected in terms of snow cover and sea ice in the Arctic Ocean are likely to modify very substantially the energy balance at the surface, in terms of albedo (reflectivity), in particular. High-latitude regions would therefore exert a very much stronger positive feedback on the climate system than the tropics, where the essential characteristics of the surface are not expected to change quite as much. One exception to this are regions where tropical deforestation is widespread and where the albedo and the thermal and humidity characteristics of the ground are altered by the presence of managed crops and trees that replace the areas previously occupied by rainforests, thus modifying regional- and continental-scale climates. Temperature change is also of greater amplitude over the continents than over the oceans, because of the much higher heat capacity of water.

Precipitation changes broadly exhibit a dual mode. The distinctive features include the drier conditions on average over the mid-latitude ocean areas and the boundaries of the continents concerned, the drier inter-tropical zone, and the

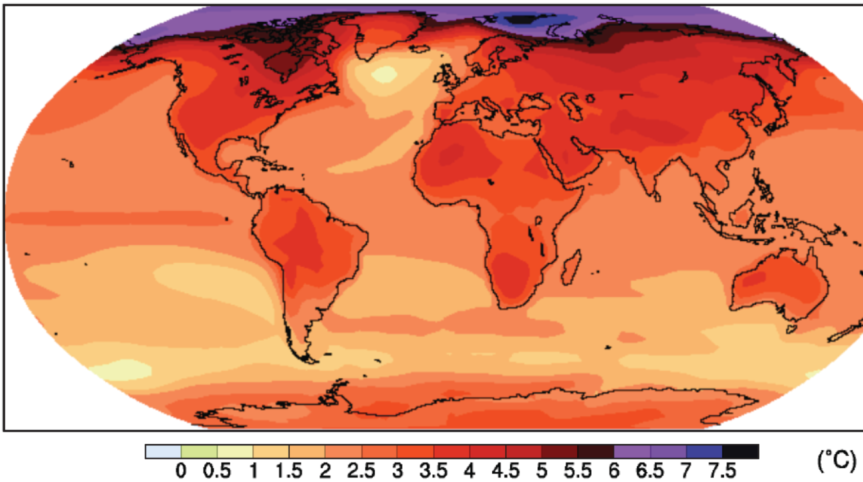

Figure 2. Changes in temperature between current (1980–1999) and future (2080–2099) climates based on ensemble model simulations (Source: IPCC, 2007).

enhanced precipitation in the mid- and high latitudes. The Mediterranean Basin experiences substantial reductions in average precipitation levels in the future climate, from North Africa into Central Europe and beyond to the Middle East. Because of the reduction of the equator-to-pole temperature difference, the activity of rain-bearing systems diminishes. The possibility remains, however, that short-lived but very intense systems may increase in the future.

At higher latitudes of the Northern Hemisphere, increases in precipitation are simulated by the models, in response to the enhancement of the hydrological cycle in a warmer climate and the shift in storm trajectories. Mountain regions, which are the source of over half the world's surface water, will also experience contrasting levels of change according to geographical location.[8] In mid-latitudes, wintertime precipitation may occur more as rainfall than as snow, compared to today, with the potential for significantly changing runoff regimes in river basins originating in mountainous areas, in terms of both quantity and seasonality. These changes would, in turn, substantially modify the availability of water for the more populated lowlands located downstream of the mountain ranges.[9] In other regions, for example in the tropical cloud forest regions, a sustained rise above the current condensation levels would have a devastating effect on the specific ecosystems that depend on clouds for their moisture, and in turn on other environmental regimes such as the quantity and quality of surface runoff.

---

[8] Martin Beniston, 'Climatic change in mountain regions: a review of possible impacts', in *Climatic Change*, Vol. 59, No. 1–2, 2003, pp. 5–31.

[9] Martin Beniston, *Climatic Change and Impacts: A Review Focusing on Switzerland*, Kluwer Academic Publishers, Dordrecht and Boston, 2004, 296 pp.

Impacts of climate change

One of the more visible and global consequences of climate change is sea-level rise, which is the result of the combined effects of thermal expansion of water and the additional influx of fresh water to the oceans from melting mountain glaciers and ice sheets. Depending on the amplitude of warming, estimates of sea-level rise by the end of the century are in the range of 50–100 cm. If the two largest planetary ice caps, Antarctica and Greenland, were to melt completely, the world's oceans would rise by over 120 m. Although recent observations suggest that ice-cap dynamics are faster today than hitherto anticipated (particularly in Greenland), a strong sea-level rise is not expected to take place in coming decades, because of the very long lag times involved in cryosphere–climate interactions, and especially because Antarctica is expected to expand in volume in coming decades – a warmer climate may trigger additional precipitation falling there in the form of snow, thus increasing the ice volume on that continent.

The consequences of sea-level rise for many low-lying coastlines may be one of the most important impacts of climate change for societies and economies. A large proportion of the world's population live on or close to a seashore and often within the critical metre above sea level, as in island states such as the Maldives in the Indian Ocean, the Marshall Islands in the Pacific, certain parts of Bangladesh in the Ganges delta, or Indonesia, to name but a few examples.

Water resources will most probably come under mounting pressure because of changing temperature and precipitation regimes, but also because of heterogeneous population trends around the globe. Significant shifts in climate conditions will affect demand, supply, and water quality. In countries that are currently sensitive to water stress, particularly in arid and semi-arid regions, any shortfalls in water supply will increase competition for water use for a wide range of economic, social, and environmental applications. In the future, such competition will be accentuated as a result of larger populations, which will lead to a heightened demand for irrigation and perhaps also industrialization, often at the expense of drinking water.

Projections of annual per capita water availability by the 2020s suggest a declining trend in all parts of the world, including those that are considered to have ample water resources.[10] In many countries, shifting precipitation belts account for only a fraction of the projected reduction in water availability; rapid population growth, urbanization, and economic expansion place additional strain on water supply. In some regions, population pressures may have a greater impact on per capita water availability than climate change itself, while the reverse may be true elsewhere. The worst-case scenarios are projected to occur in some of the poorest countries of the world, in a context where population growth and climate change will act together to sharply diminish water availability. The sharing of water across international borders, which is already a source of rivalry and conflict in many

---

[10] S. Solomon *et al.*, above note 3.

places today (e.g. the Nile, the Jordan, the Tigris, and the Euphrates), will certainly be exacerbated by climate change that will alter the balance of power between upstream and downstream neighbours of a given hydrological basin.

Food security is also threatened by climate change, both directly by changing temperature and precipitation patterns, and indirectly through losses of agricultural land due to sea-level rise, greater wind and water erosion, pests, and disease. In addition, human-induced land-use change linked to deforestation and desertification has already reduced the agricultural potential of many parts of the world.[11]

The world food system involves a complex dynamic interaction of producers and consumers, interlinked through global markets. Although agricultural productivity has increased to keep pace with the growing world population over the last century, there are still close to one billion people who are undernourished. Furthermore, agriculture is probably the most vulnerable of all human activities to weather and climate variability; the chief controls on agricultural yields include temperature, precipitation, soil moisture, carbon dioxide levels, and disease and pests (themselves largely climate-dependent). Any changes in one or more of these controlling factors may have profound, non-linear effects on productivity. The Food and Agricultural Organization (FAO) has warned that by 2020 agricultural yields will need to almost double, compared to 1990 levels, in order to keep up with demographic trends and the diversification of consumption patterns.[12] It is unlikely that the 'green revolution' of the twentieth century will be repeated, even if new technologies such as genetic engineering are taken into account, because competition for land and climate change may negate all or part of the progress made in agricultural productivity.

Agricultural production will be affected by the severity and rate of climate change. If change is gradual, there will be time for political and social institutions to adjust. Slow change may also enable natural biota to adapt. Many untested assumptions lie behind attempted projections of the potential influence of climate change on crops. Besides the magnitude and rate of change, the stage of growth during which a crop is exposed to drought or heat is important. Moreover, temperature and seasonal rainfall patterns vary from year to year and region to region, regardless of long-term trends in climate. Temperature and rainfall changes induced by climate change will probably interact with carbon dioxide levels, fertilizers, insects, plant pathogens, weeds, and the soil's organic matter to produce unanticipated responses. In many parts of the world, generally warmer temperatures and longer hot periods will impose additional stress on certain crops. Corn, for example, has a stress limit of about 35 °C; temperatures above this for any length of time can do irreversible physiological damage to the plant. The United States Midwest, one of the world's principal cereal-producing regions, could be particularly vulnerable to prolonged heat, heightening the potential for crises in the

---

[11] *Ibid.*

[12] FAO, *The State of Food and Agriculture*, FAO Agriculture Series, Rome, 2000, 329 pp.

global food supply. The 1988 drought in the Midwest resulted in severe shortfalls in corn yields, and for the first time since World War II the US was a net importer of cereals rather than an exporter. A warmer and drier climate at critical times of the year could augment the frequency of crop failures.

Rainfall, however, remains the major limiting factor in the growth and production of crops worldwide. Adequate moisture is critical for plants, especially during germination and fruit development. Any changes in rainfall patterns will also reduce soil water content. In certain semi-arid and arid zones, the soil moisture often enables plants to survive a short drought period; a warmer climate, accompanied by more evaporation, lower precipitation, and associated reductions in soil moisture recharge, would spell disaster for regions where agriculture is only just viable today.

A wide range of extreme weather events, which may increase in frequency and severity in certain parts of the world, may compound the stress effects of a warming *average* climate. Drought, fire, and heat waves are one category of extremes that needs to be considered, while heavy precipitation and hail are another category that can adversely affect agricultural production. These events may be offset to some extent in colder regions by a lower frequency of spring frosts, which are often damaging to plants at the beginning of their growth cycles.

Vulnerability to climate factors is lower in regions where agriculture is well adapted to current climate variability, or where market and institutional factors allow a redistribution of agricultural surpluses to make up for shortfalls. In order to plan ahead and reduce the impacts of climate change on agriculture, long-term agricultural policy options should be implemented in parallel to addressing other concerns, such as erosion, loss of topsoil, salinization, and soil and water pollution. Furthermore, improved water management and irrigation practices should be put into effect to help reduce the adverse effects of droughts and heat waves that are likely to be on the increase in a warmer global climate.

Forecasting the impacts of climate change on a third determinant for human well-being, namely human health, is complex because populations have different vulnerabilities to change and susceptibility to disease. These depend on the general levels of hygiene practices, clothing, housing, and medical and agricultural traditions. Adaptation to the spread of disease is determined by the economic level of a given population, the quality and coverage of medical services, and the integrity of the environments.[13] Thus human biological and psychological factors are primary determinants, but ecological and global systems are also involved, as are economics and access to health care, which shape the vulnerability of societies to disease. Shifts in environmental conditions, interacting with the biology of disease agents, can exert profound effects. Changes in how land is used affect the distribution of disease carriers, such as rodents or insects, while climate influences

---

[13] Anthony J. McMichael and R. Sari Kovats, 'Climate change and climate variability: adaptations to reduce adverse climate change impacts', in *Environmental Monitoring and Assessment*, Vol. 61, No. 1, 2000, pp. 49–64.

their range and affects the timing and intensity of outbreaks. Changing social conditions, such as the growth of multimillion-inhabitant cities in the developing world and widespread ecological change, are today contributing to the spread of infectious diseases.

The occurrence of vector-borne diseases such as malaria is determined by the abundance of vectors and intermediate and reservoir hosts, the prevalence of disease-causing parasites and pathogens suitably adapted to the vectors, and the human or animal hosts and their resilience in the face of the disease.[14] Local climate conditions, especially temperature and moisture, are also determinant factors for the establishment and reproduction of the *Anopheles* mosquito.[15] The possible development of the disease in mountain regions thus has relevance, because populations in uplands where the disease is currently not endemic may face a new threat to their health and well-being as malaria progressively invades new regions under climate conditions favourable to its development.[16]

The occurrence of vector-borne diseases is widespread, ranging from the tropics and subtropics to the temperate climate zones. With few exceptions, they do not occur in the cold climates of the world, and are absent above certain altitudes even in mountain regions of the tropical and equatorial belt.[17] At elevations above 1,300–1,500 m in Africa and tropical Asia, the *Anopheles* mosquito can currently neither breed nor survive; as a result, malaria is almost totally absent from many highlands of the tropical zone.[18]

Vectors require specific ecosystems for survival and reproduction. These are influenced by numerous factors, many of which are climatically controlled. Changes in one or more of these factors will affect the survival and hence the distribution of vectors.[19] Projected climate change may thus have a considerable impact on the distribution of vector-borne diseases. A permanent change in one of the abiotic factors may alter the equilibrium of the ecosystem, resulting in the creation of either more or less favourable vector habitats. At the present limits of vector distribution, the projected increase in average temperature is likely to create more favourable conditions, in terms of both latitude and altitude, for the vectors, which may then breed in larger numbers and invade formerly inhospitable areas.

The infection rate for malaria is an exponential function of temperature;[20] small increases in temperature can lead to a sharp reduction in the number of days

---

[14] Anthony J. McMichael and Andrew Haines, 'Global climate change: the potential effects on health', in *British Medical Journal*, Vol. 315, No. 7111, 1997, pp. 805–809.

[15] Paul R. Epstein *et al.*, 'Biological and physical signs of climate change: focus on mosquito-borne diseases', in *Bulletin of the American Meteorological Society*, Vol. 79, No. 3, March 1998, pp. 409–417.

[16] Pim Martens *et al.*, 'Climate change and future populations at risk of malaria', in *Global Environmental Change*, Vol. 9, Suppl. 1, 1999, pp. 89–107.

[17] World Health Organization (WHO), *World Health Report 1999*, WHO, Geneva, 1999, 121 pp.

[18] Marlies H. Craig, R.W. Snow, and David LeSueur, 'A climate-based distribution model of malaria transmission in Africa', in *Parasitology Today*, Vol. 15, No. 3, 1999, pp. 105–111.

[19] Brian H. Kay *et al.*, 'Rearing temperature influences flavivirus vector competence of mosquitoes', in *Medical and Veterinary Entomology*, Vol. 3, No. 4, 1989, pp. 415–422.

[20] WHO report, above note 17.

of incubation. Regions at higher altitudes or latitudes may thus become hospitable to the vectors; disease-free highlands that are found in parts of Ethiopia and Kenya today, for example, may be invaded by vectors as a result of an increase in annual temperature. If this were to occur, then the number of persons infected by malaria would rise sharply.

The response of malaria to changing climates is seen in the intensification of the disease observed in Colombia during episodes of El Niño, when temperatures increase and precipitation decreases in comparison to normal conditions.[21] Such links between abrupt but significant changes in climate and the annual cycle of malaria development and transmission may help further our understanding of the relationships between environmental and epidemiological factors, both in the short term (ENSO cycles) and the longer term (climate change).

While Africa is often cited in terms of the incidence of malaria, it is not the only continent to be affected by the increase in vector-borne diseases; in certain countries where the disease had been eradicated in the course of the twentieth century, particular strains of malaria are reappearing. There are reports from various low- to medium-elevation upland sites in Turkey, the Middle East, and Central Asia that malaria is being transmitted in rural populations.[22]

It is often difficult to associate any particular change in the incidence of a particular disease with a given change in a single environmental factor. The environment-related health hazards need to be placed in a population context, such as age, level of hygiene, socio-economic level, and health status.[23] These phenomena could contribute to migration from one rural region to another and from rural to urban areas, and thus to the spread of disease.[24] In addition, if climate change were to be accompanied by an increase in the intensity of certain forms of natural hazard, such as cyclones, floods, or drought, these would compound the effects on human health. Moreover, such catastrophes can generate large refugee and population movements, with a need for resettlement in what are often already densely populated areas.[25]

Conclusions

Projections of population growth, increasing pressure on resources, and persistent inequalities in resource access in coming decades imply that scarcities will affect many environmentally sensitive regions on a scale and with a severity and speed

---

[21] Germán Poveda *et al.*, 'Coupling between annual and ENSO timescales in the malaria–climate association in Colombia', in *Environmental Health Perspective*, Vol. 109, No. 5, 2001, pp. 489–493.

[22] M.L. Wilson *et al.*, *Vector-borne Disease Associated with Irrigation, Agriculture, and Environmental Change in Southeastern Turkey: Application of Satellite Image Analysis*, Yale-New Haven Medical Center Report, 2001.

[23] A.J. McMichael and R.S. Kovats, above note 13.

[24] Norman Myers, 'Environmental refugees in a globally warmed world', in *BioScience*, Vol. 43, No. 11, 1993, pp. 752–761.

[25] A.R. Pebley, above note 1.

unprecedented in history, largely because of a rapidly changing climate. Many countries lack the social institutions that are essential to provide the social and technical solutions needed to face up to problems of scarcity. Population displacement in response to significant external stress often indicates the breakdown of social resilience. In the context of food security, for example, displacement and coping strategies are an extreme manifestation of vulnerability. Coping strategies generally represent short-term adaptations to extreme events; they are usually involuntary, and rarely pave the way for reducing a population's vulnerability to future famine situations.

Dwindling resources in an uncertain political, economic, and social context are capable of generating conflict and instability, but the causal mechanisms are often indirect. Scarcities of cropland, fresh water, and forests constrain agricultural and economic productivity. Such situations are capable of generating population movements.[26] In extreme cases, these can contribute to local or regional conflicts, which may increase over time as environmental scarcities worsen. While such internal, resource-based conflicts may not be as conspicuous as wars at an international level, there is nevertheless a potential for significant repercussions upon the security interests of both the developing and the industrialized countries, for they can affect international trade relations, produce humanitarian disasters, and lead to growing numbers of refugee flows.[27]

With regard to the complex issues that may result in the migration of populations in the twenty-first century, it will be increasingly necessary to distinguish between voluntary and forced migration. Voluntary migration can occur for a number of reasons, particularly economic and political or ideological. Forced migration, on the other hand, has several root causes also to be found in political and economic domains, in particular war and ethnic strife. In this context, environmental factors for migration can be considered an indirect consequence of decisions taken in the political and/or economic arenas. While sea-level rise is an obvious environmental driver that may significantly affect many low-lying coastal regions around the world and thus lead to population migrations, it is a consequence of a warming global climate, itself in part the result of economic and industrial policies leading to enhanced greenhouse-gas emissions.

In conclusion, there will be numerous interacting root causes, from politics and economics to profound changes in the environment (sea-level rise, deforestation, soil degradation, and climate change), that are likely to impact heavily upon the key determinants of human survival: water, food, and human health. The extent to which the reductions in water supply and shortfalls in agricultural yields, or changing patterns of disease, may actually force extensive out-migration is a matter of debate. Almost twenty years ago, Myers was already predicting that about 150 million 'environmental refugees' may constitute one

---

[26] N. Myers, above note 24.

[27] Michael J.G. Parnwell, *Population Movements and the Third World*, Routledge, London, 1993, 194 pp.

of the direct consequences in the 'greenhouse world' of the twenty-first century.[28] There is no certainty associated with this particular figure, and it may be an overstatement. But it helps to raise awareness of these issues and to stimulate thought and action in order to prepare, institutionally and legally, for refugees in larger numbers than those hitherto experienced.

---

[28] N. Myers, above note 24.