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Ram Partap
Dolphin (PG) College of Science and Agriculture. Chunni kalan, Fatehgarh Sahib, Punjab, India

Santosh Kumar
Dolphin (PG) College of Science and Agriculture. Chunni kalan, Fatehgarh Sahib, Punjab, India

Nishant
Dolphin (PG) College of Science and Agriculture. Chunni kalan, Fatehgarh Sahib, Punjab, India

Mannu Kumari
Dolphin (PG) College of Science and Agriculture. Chunni kalan, Fatehgarh Sahib, Punjab, India

Correspondence
Santosh Kumar
Dolphin (PG) College of Science and Agriculture. Chunni kalan, Fatehgarh Sahib, Punjab, India

Impact of global climate change on land degradation and human action

Ram Partap, Santosh Kumar, Nishant and Mannu Kumari

Abstract

Global climate change of the magnitude and rate seen in the past hundred years is a relatively recent, unfamiliar threat to the conditions of the natural environment and human health. It is one of a set of large-scale environmental changes now underway, each reflecting the increasing impacts of human activities on the global environment. These changes, including: stratospheric ozone depletion; biodiversity loss; worldwide land degradation; freshwater depletion; and the global dissemination of persistent organic pollutants have great consequences for the sustainability of ecological systems, food production, human economic activities and human population health. Changes in climate are recognized as one of the major factors responsible for land degradation affecting sustained development. To ensure sustained development, conjunctive efforts based on a sound understanding of the various factors that bestow to land degradation around the world are required. Climate change deteriorates the soil structure are hard to quantify because of the influence of land use and management, hence further research is this area is required for better understanding of the effect of climate change on soil structure The major components and advances in land change are addressed: observation and monitoring; understanding the coupled system—causes, impacts, and consequences; modeling; and synthesis issue. In most cases, changes in soils by direct impact on human action, on-site or off-site (whether intentional or unintended), are far greater than the direct climate-induced effects.

Keywords: Climate change, land degradation, human action

Introduction

Global climate change is a qualitatively distinct, and very significant, addition to the spectrum of environmental health hazards encountered by humankind. Historically, environmental health concerns have focused on toxicological or microbiological risks to health from local exposures. However, the scale of environmental health hazards is today increasing; indeed, the burgeoning human impact on the environment has begun to alter global biophysical systems (such as the climate system). As a consequence, a range of larger-scale environmental hazards to human population health has emerged. This includes the health risks posed by climate change, stratospheric ozone depletion, loss of biodiversity, stresses on terrestrial and ocean food-producing systems, changes in hydrological systems and the supplies of freshwater, and the global spread of persistent organic pollutants. Appreciation of this scale and type of influence on human health entails an ecological perspective — a perspective that recognises that the foundations of long-term good health in populations reside in the continued stability and functioning of the biosphere's "life-supporting" ecological and physical systems.

The main soil changes directly resulting from climatic change would be in soil temperature regimes and soil hydrology. The minor soil temperature increases in the tropics to moderate increases in temperate and cold climates would modify organic matter dynamics, and may increase soil reduction in high latitudes where part of the permafrost would disappear. Increased variability and greater incidence of high-intensity rainfall would entail higher leaching rates in most soils, with more runoff on sloping soils (and increased erosion and sedimentation). There would also be greater extents of periodic soil reduction in humid climates and salinization in semiarid or arid climates. The more rapid leaching, mainly in the tropics and in high latitudes, could accelerate the processes of hydrolysis and cheluviation; larger soil areas becoming periodically reduced could also become subject to ferrolysis. The influence of climate change on soil reaction would be generally minor. Soil changes would be least in a temperate climate. Management measures to increase soil resilience against the effects of climate change should increase vegetative cover and soil faunal activity, with other stresses caused by human agency, which are potentially more damaging than the direct effects of climate change on soils.

Climate change and stratospheric ozone depletion are, today, the best known of the various global environmental changes that have emerged in recent decades. Human societies, however, have had long experience of the vicissitudes of climate. Climatic cycles have left great imprints and scars on the history of humankind. Civilizations such as those of ancient Egypt, Mesopotamia, the Mayans, the Vikings in Greenland, and European populations during the four centuries of Little Ice Age have all both benefited and suffered from nature's great climatic cycles. Historical analyses also reveal widespread disasters, social disruption and disease outbreaks in response to the more acute, inter-annual, quasi-periodic ENSO (El Niño Southern Oscillation) cycle. Climate scientists predict that the increasing emission of anthropogenic greenhouse gases will induce a long-term progressive change in the world's climate. These gases comprise principally carbon dioxide emissions (mostly from fossil fuel combustion and forest clearance) plus various other heat trapping gases such as methane (from irrigated agriculture, animal husbandry and oil extraction), nitrous oxide and various human-made halocarbons.

Indeed, most climate scientists now suspect that the accumulation of these gases in the lower atmosphere has contributed to the strong recent uptrend in world average temperature. In the words of the Third Assessment Report of the Intergovernmental Panel on Climate Change: "There is new and stronger evidence that most of the warm Global climate change – the latest assessment: does global warming warrant a health warning? Global climate change is a qualitatively distinct, and very significant, addition to the spectrum of environmental health hazards encountered by humankind. Historically, environmental health concerns have focused on toxicological or microbiological risks to health from local exposures. However, the scale of environmental health hazards is today increasing; indeed, the burgeoning human impact on the environment has begun to alter global biophysical systems (such as the climate system). As a consequence, a range of larger-scale environmental hazards to human population health has emerged. This includes the health risks posed by climate change, stratospheric ozone depletion, loss of biodiversity, stresses on terrestrial and ocean food-producing systems, changes in hydrological systems and the supplies of freshwater, and the global spread of persistent organic pollutants (Amatekpor, 1989) [8].

Appreciation of this scale and type of influence on human health entails an ecological perspective – a perspective that recognises that the foundations of long-term good health in populations reside in the continued stability and functioning of the biosphere's "life-supporting" ecological and physical systems. RT Watson(A) and AJ McMichael (B) A Director, Environmentally and Socially Sustainable Development Department of Environment World Bank Washington DC, USA e-mail rwatson@worldbank.org B Professor of Epidemiology Department of Epidemiology and Population Health London School of Hygiene and Tropical Medicine London, UK Academic Publishers observed over the last 50 years is attributable to human activities." During the twentieth century world surface temperature increased by approximately 0.6 °C. There were, of course, other natural influences on world climate during the twentieth century. These include an increase in volcanic activity between 1960 and 1991 (when Mount Pinatubo erupted), which induced a net negative radiative forcing for the last two and possibly four decades, and a slight overall increase in solar activity in the first half of the 20th Century (which may have accounted for around one-sixth of the twentieth century's observed temperature increase). Note that the rise in temperature over the past century or so has hugely exceeded the amplitude of natural variations during the preceding nine centuries. The unprecedented prospect of human-induced changes to the global climate, occurring at a rapid rate, has prompted a large international scientific effort to assess the evidence. The IPCC, established within the UN framework in 1988, comprises several thousand experts from many disciplines, charged with advising national governments on the causes and processes of climate change, its likely impacts and their associated costs, and ways of lessening the impacts.

The IPCC's Third Assessment Report (2001) projects an increase in average world surface temperature ranging from 1.4 to 5.8 °C over the course of the twenty-fi rst century [4]. That estimation is based on a large number of different global climate models and plausible scenarios of greenhouse gas and sulphate aerosol precursor emissions. This increase would be much more rapid than any naturally-occurring temperature increase that has been experienced by humans since the advent of agriculture around 10,000 years ago. (IPCC, 2001). The anticipated increases in surface temperature would be greater at higher latitudes, greater on land than at sea, and would affect the daily minimum, night-time, temperatures more than daily maximum temperatures. For example, climate models that project an average global warming of about 3 °C during the twenty-fi rst century suggest that Alaska, northern Canada and northern Siberia could warm by approximately 5-8 °C. Indeed, the temperature increases that have already occurred above the Arctic Circle have apparently disrupted polar bear feeding and breeding, the annual migrations of caribou and the network of telephone poles in Alaska (previously anchored in the ice-like permafrost).

Effects of rainfall and temperature changes in different climates

In the humid tropics and monsoon climates, increased intensities of rainfall events and increased rainfall totals would increase leaching rates in well-drained soils with high infiltration rates, and would cause temporary flooding or water-saturation, hence reduced organic matter decomposition, in many soils in level or depressional sites. This may affect a significant proportion of especially the better soils in Sub-Saharan Africa, for example. They would also give rise to greater amounts and frequency of runoff on soils in sloping terrain, with sedimentation downslope and, worse, downstream. Locally, there would be increased chances of mass movement in the form of landslides or mudflows in certain soft sedimentary materials, discussed below. Soils most resilient against such changes would have adequate cation exchange capacity and anion sorption to minimize nutrient loss during leaching flows, and have a high structural stability and a strongly heterogeneous system of continuous macropores to maximize infiltration and rapid bypass flow through the soil during high-intensity rainfall.

In subtropical and other subhumid or semi-arid areas, the increased productivity and water-use efficiency due to higher CO_2 would tend to increase ground cover, counteracting the effects of higher temperatures. If there would be locally much less rainfall and increasing intra-and inter-annual variability, these could lead to less dry-matter production and hence, in due course, lower soil organic matter contents. Higher temperatures, particularly in arid conditions, entail a higher evaporative demand. Where there is sufficient soil moisture, for example in irrigated areas, this could lead to soil salinization if land or farm water management, or irrigation scheduling or drainage are inadequate. On the other hand, recent experiments by the Salinity Laboratory, Riverside, California, point to increased salt tolerance of crops under high atmospheric CO_2 conditions (E.V. Maas, pers. comm.; Bowman and Strain, 1987) [9].

In temperate climates, minor increases in rainfall totals would be expected to be largely taken up by increased evapotranspiration of vegetation or crops at the expected higher temperatures, so that net hydrologic or chemical effects on the soils might be small. The negative effect on soil organic matter contents of a temperature rise might be more than compensated by the greater organic matter supply from vegetation or crops growing more vigorously because of the higher photosynthesis, the greater potential evapotranspiration and the higher water-use efficiency in a high-CO_2 atmosphere. The temperate zone would thus be likely to have the smallest changes in soils, even in poorly buffered ones, directly caused by the effects of global change. A minor and probably slow, but very visible, change could be a reddening of presently brown soils where increased periods with high summer temperatures would coincide with dry conditions, so that the iron oxide haematite would be stable over the presently dominant goethite. This mineralogical change might decrease the intensity and amount of phosphate fixation. An overview of such changes, with emphasis on temperate climate zones, is given by Buol *et al*. (1990) [5, 14].

In boreal climates, the gradual disappearance of large extents of permafrost and the reduction of frost periods in extensive belts adjoining former permafrost are expected to improve the internal drainage of soils in vast areas, with probable increases in leaching rates. The appreciable increase in period when the soil temperature is high enough for microbial activity would lead to lower organic matter contents, probably not fully compensated by increased primary production through somewhat higher net photosynthesis and the longer growing period. Paradoxically, the extent of soils subject to periodic reduction could well increase in level areas, in spite of the greater leaching, because of increased periods when the soils are water-saturated but also sufficiently warm for microbial activity. Soils most resilient against such effects, including the leaching of nutrients and periodic soil reduction, would have similar characteristics as the most resilient ones in other climates: adequate cation exchange capacity and anion sorption to minimize nutrient loss during leaching flows, a high structural stability and a strongly heterogeneous system of continuous macropores to maximize rapid bypass flow during periods with excess melt water.

Resilience against physical and chemical soil degradation

As discussed, most soils do not have a high intrinsic resilience against physical soil degradation by, for example, high-intensity rainfall. In natural conditions in humid climates, it is the complete soil cover near ground level combined with the perforating activity of the soil fauna that makes the soil-vegetation system resilient against physical degradation.

In the Rhine river plain in the Netherlands, for example, most of the originally calcareous alluvial soils have been decalcified within a millennium or so. Only in small areas on the highest levees of that age that have continually remained under forest, soils are still calcareous, and even have lime pseudo mycelia (filaments) indicative of less humid soil conditions, and abundant vertical macro pores produced by earthworms. In these soils, faunal activity is high because of the adequate litter supply: the resulting macro pores remain open, protected against rain impact by litter and undergrowth: and excess water from heavy rain passes to the substratum through the macro pores without leaching lime from most of the soil mass.

Research to increase resilience of soils against any adverse effects of climate change could be done in conjunction with that on soil resilience against direct adverse human impacts. Until site-specific management procedures have been elaborated, soil and crop (including trees and pasture) management should aim to maintain soil cover and organic matter supply to soil biota, while minimizing mechanical disturbance by heavy traffic, cultivation or excessive grazing intensity. Such kind of management may also help to conserve plant nutrients (in soils not flooded for wetland cultivation) since the stable, heterogeneous system of biopores produced by the soil fauna would favour bypass flow of any excess moisture and thus decrease leaching through the soil mass.

A single management recipe would not be generally applicable in different conditions. Minimizing damage by certain termite species harming crop performance may necessitate a period without residues on the soil, for example; or crop residues may be needed for feed or fuel. Management methods for wetland need to be developed that make optimum use of any increased potential productivity, while minimizing secondary effects such as increased CH_4 or N_2O emission from the reduced soil. Such factors, and others, should be taken into account in designing an optimum management strategy for any specific natural and cultural environment.

Effects of a rising sea level on soils in coastal areas

The probable effects on soil characteristics of a gradual eustatic rise in sea-level will vary from place to place depending on a number of local and external factors, and interactions between them (Brammer and Brinkman, 1990) [3, 4, 10, 12].

In major deltas, such as those of the Ganges-Brahmaputra and the major Chinese rivers, sediment supplies delivered to the estuary will generally be sufficient to offset the effects of a rising sea level. Such deltaic aggradation could decrease, however, under three circumstances: where human interventions inland, such as large dams or successful soil conservation programmes, drastically reduce sediment supply to the delta: e.g., the construction of the Aswan high dam in 1964 has led to coastal erosion and increased flooding of lagoon margins in the Nile delta (Stanley, 1988) [2, 20]; where construction of embankments within the delta interrupts sediment supply to adjoining backswamps, exposing them to submergence by a rise in sea level: e.g., embankments along the lower Mississippi river have cut off sediment supplies to adjoining wetlands which formerly offset land subsidence occurring due to compaction of underlying sediments (Day and Templet, 1989) [15]; where land subsidence occurs due to abstraction of water, natural gas or oil: e.g., as is presently happening in Bangkok and in the northern part of the Netherlands.

The probable response of low-lying coastal areas to a rise in sea level can be estimated in more detail on the basis of the geological and historical evidence of changes that occurred during past periods when sea level was rising eustatically or in response to tectonic or isostatic movements: e.g., around the southern North Sea (Jelgersma, 1988) [17]; in the Nile delta

(Stanley, 1988) [2, 20]; on the coastal plain of the Guyanas (Brinkman and Pons, 1968) [13]; in the Musi delta of Sumatera (Brinkman, 1987) [11]. Contemporary evidence is available in areas where land levels have subsided as a result of recent abstraction of water, natural gas or oil from sediments underlying coastal lowlands. Further studies of such contemporary and palaeo environments are needed together with location-specific studies in order to better understand the change processes, identify appropriate responses and assess their technical, ecological and socio-economic implications (e.g., Warrick and Farmer, 1990) [22].

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