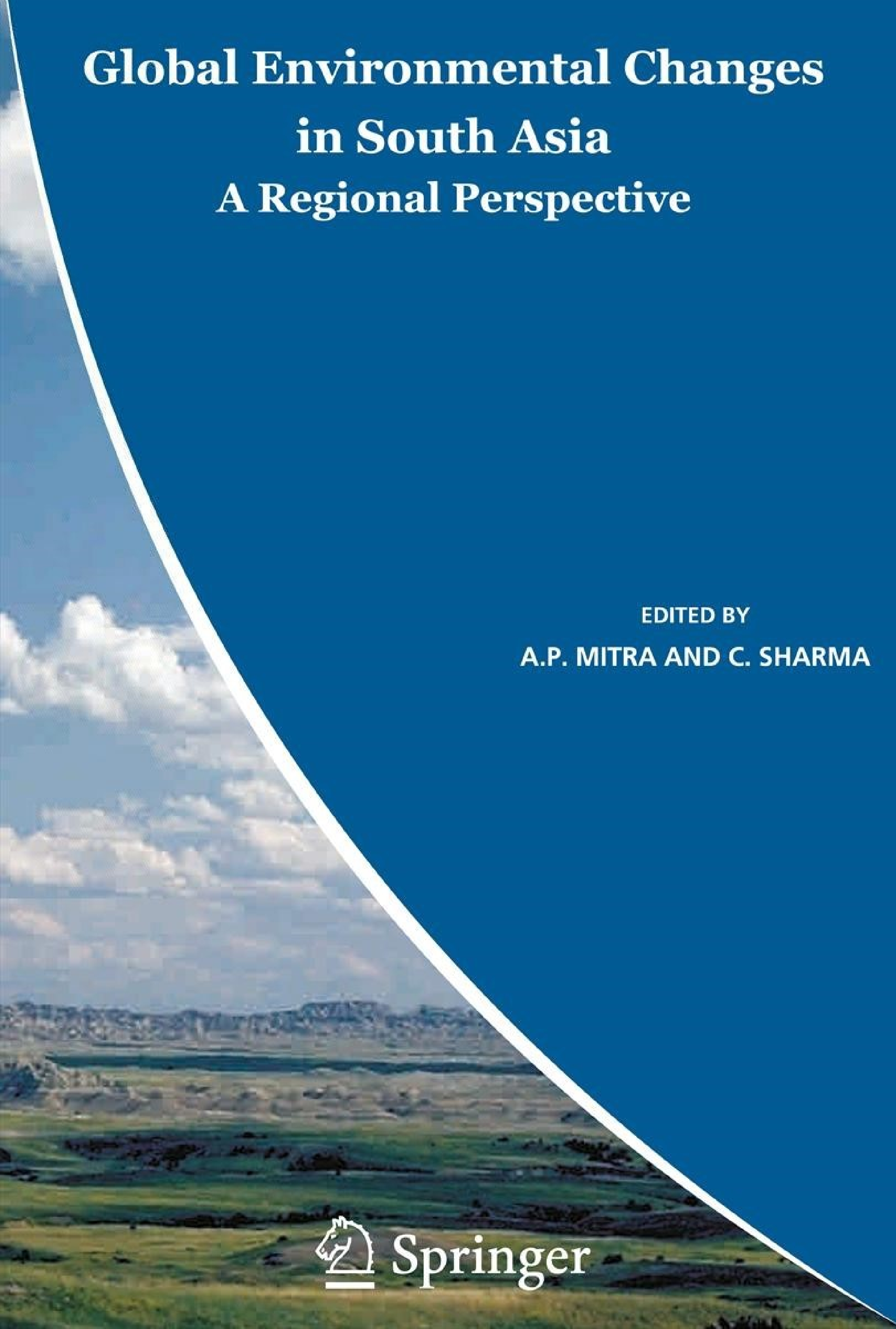
Global Environmental Changes in South Asia

A Regional Perspective



EDITED BY

A.P. MITRA AND C. SHARMA

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Edited by

A.P. Mitra (deceased)

and

C. Sharma

National Physical Laboratory
New Delhi, India

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Foreword

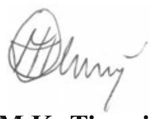
The Fourth Assessment Report of IPCC having clinched in 2007 the evidence of global warming on account of anthropogenic activities, backed with scientific data gathered and analyzed globally, has made it mandatory world over to focus efforts on delineation of the anticipated adverse impacts of global warming on regional temperature and moisture regimes and the linked hydrologic, climatic and biospheric processes. First and foremost is the requirement to understand vulnerability to food and livelihood security in various ecosystems—on mainland, mid-range and high mountains as well as coastal areas including CEZs. The projected global temperature rise of the order of about two degrees or more and further rise at a decadal rate of around 0.2°C is sufficient to make grievous changes in sea surface level and submerge many low lying coastal areas around the world thereby possibly causing unprecedented losses to human habitat and livelihood in the coming years. A rise in climate variability is also becoming increasingly evident with potential direct impact on agricultural performance, on water accessibility and on weather extremes.

Developing countries due to their poor infrastructure, limited resources and large impoverished population are likely to face more intense and widespread adverse impact of climate change than the developed world and also have limited adaptation capacity. Keeping this in view the Global Change System for Analysis Research and Training (START), of which the South Asian START Regional Centre (SAS-RC) operated by National Physical Laboratory at New Delhi is an organ, had initiated in 2003, with cooperation of its member countries, an exercise under their MAIRS project to enable Rapid Assessment of the present state of the environment in the developing regions of Asia and highlight vulnerability of the prevalent human systems, of the deliverables from various sectors and the livelihood security. The objective of the exercise was to assess and later facilitate to build or enhance the existing capacities in these countries needed to adequately understand and tackle the extent of likely impact of climate change on ecosystems.

Possible pathways to adapt to upcoming climate variability in order to minimize damages to human support systems were also to be explored in different sectors. The Regional Centres of the three Asian networks within START, namely, the South Asian Regional Network, the Temperate East Asian Regional Network and the South-East Asian Regional Network undertook this exercise beginning 2003. The Asia Pacific Network for Global Change Research (APN) facilitated this by sponsoring scoping meetings of Rapid Assessment activity.

The NATCOM exercise implemented by the Indian Ministry of Environment and Forest for the purpose of submitting in 2004 the First National Communication to UNFCCC from India also succeeded in establishing an extensive country-wide network of experts and knowledge bases for vulnerability assessment. This network has continued to strengthen in the following years with NATCOM-II programme currently underway. This and similar experience of the other countries of the South Asian Region has made the Rapid Assessment exercise initiated feasible. The result is the present book "Global Environmental Changes in South Asia". The "Introduction" and the first chapter of the book titled "Human Dimensions of Changing Environment", record well the vision of the leader of this cooperative effort, Dr. Ashesh Prasad Mitra, who is no more with us. He was the founder Director of SAS-RC and the first Chairman of its Planning Committee, SASCOM and has edited several chapters of this book. Dr. Chhemendra Sharma, his long term associate and co-editor of this publication, has gathered vast experience in various assessment exercises linked with climate change including budgeting of greenhouse gases as well as vulnerability to various sectors. The authors of other chapters of the book are all well established in their respective areas. Many of them have led internationally significant initiatives. They have addressed all the significant issues in the book, such as reliability of the monsoon system, altering C&N pools in quickly transforming lands, floods and droughts frequency, deteriorating air quality in the urban regions, changing oxidizing capacity of the atmosphere, impact on mangrove biotic structure, limited denitrification capacity of the Bay of Bengal, etc. The need for quickly implementing new sustainable development pathways are also elaborated upon.

This book is a true amalgamation of the region's capabilities to capture environmental changes of a global nature in the region and its vulnerability to climate change. It is indeed possible based on this publication to identify important capacity gaps in adapting to climate variability, bridging of which over a period of time is necessary in the region.



New Delhi
November 2009

M.K. Tiwari
Director
South Asian START Regional Centre (SAS-RC)
National Physical Laboratory, New Delhi, India

Introduction

THE SOCIO-ECONOMIC SETTINGS

South Asia is a unique region of the world. The land area of this region is only 3% of the world but the 1990 population was 21.3% and 2025 population is expected to rise to nearly 24% of the world. It is one of the most densely populated regions of the world ranging from 250 persons/km^2 in Nepal to over 800 persons/km^2 in Bangladesh. The scenario for 2025 is further alarming: as much as over 1300 persons/km^2 in Bangladesh and between 300-400 persons/km^2 in other countries in the subcontinent. A positive aspect of this increasing population is, however, the increasing dominance of the youth. People of the age of 60+ range from 5% in Bangladesh to 9.5% in Sri Lanka in 2001. In comparison the developed countries in eastern half of the globe has larger share of 60+ age group population (e.g. 24% in Japan, 16.5% in Australia and 16% in New Zealand).

Urbanization in South Asia – a major source for emissions of trace gas and aerosol emissions – is rapidly increasing. From 1995 to 2005, the rise has been from 27 to 45% in India, 18 to 40% in Bangladesh, 22 to 43% in Sri Lanka and 14 to 34% in Nepal. The middle class in this region is mainly professional and is a major consumer shaping the developmental pathways of the region. In India, the 200-250 million professional middle class is at the base of industrial transformation and, also as a result, of conspicuous consumptions. The major socio-economic features of South Asia are country-wise summarized in Table 1.

THE GEOPHYSICAL SETTINGS

The key geophysical features of the South Asia (Table 2) are (a) the presence of mountains in the north, (b) the Indo-Gangetic Plains which is

Table 1: Socio-economic features of South Asia

	Bangladesh	*Bhutan*	*India*	*Nepal*	*Pakistan*	*Sri Lanka*
GDP (current US$) (billions)	56.6	0.7	691.2	6.7	96.1	20.1
Population, total (millions)	139.2	0.9	1079.7	26.6	152.1	19.4
Per capita GDP (US$)	406.6	777.8	640.2	251.9	631.8	1036.1
GNI per capita, Atlas method (current US$)	440	760	620	250	600	1010
Population under poverty line (% of total population)	49.8	-	28.6	30.9	32.0	22.0
Life expectancy at birth, total (years)	63.5	63.5	63.5	62.2	64.9	74.4
Population growth (annual %)	1.9	2.5	1.4	2.0	2.4	0.9
Surface area (thousands sq. km)	144.0	47.0	3287	147.2	796.1	65.6

Table 2: Major physical parameters

	India	*Pakistan*	*Bangladesh*	*Sri Lanka*	*Nepal*
Population (Millions)					
1990	853	123	112	17	19
1995	929	130	120	18	22
2001	1025	145	140	19	24
2025 (Projected)	1442	267	235	25	35
Annual Growth Rate (1901-2001)	1.8	2.6	22	1.0	2.4
Population density (per sq km)					
1990	287	159	888	266	140
1995	285		836	380	256
2025	423	345	1362	382	289
P.C. of population aged 60^+ (2001)	7.7	5.8	5.0	9.5	5.9
EEZ ('000 km^2)	2015	319	77	517	-
Length of coast (km)	12700	1046	580	1340	-
EEZ/land (%)	68%	41%	59%	795%	-

bread-basket of the region, (c) the perennial river system which is under threat now due to increasing stress from population and climate, (d) large expanses of wetlands and coral reef providing eco-system services to the region, (e) the large area under Exclusive Economic Zone (EEZ) and (f) the seasonal alteration of the atmospheric flow patterns associated with the monsoons – the key parameter influencing the food security issues of the region. The EEZ for the region totals around 29,25,000 km^2 compared to land area of 44,30,000 km^2 which is as much as 66%. However there is a wide variation for different countries in South Asia e.g. while Sri Lanka's EEZ is as high as 795% and Nepal is a land-locked country. EEZ is, therefore, a major natural resource for this region.

The mountains in the North are dominated by the Himalayas. The Himalayas extend from 35°N, 74°E to 30°N, 95°E stretching over 2400 km and over an area of 460,000 km^2. This region is rich in biodiversity, a storehouse of unique gene pool, is provider of a large fraction of water to the rivers Indus and Ganges, isolates the subcontinent geographically and meteorologically. Its rich forests have in recent years been greatly depleted catalyzing large sediment flow, floods and climate events. The physical and socio-cultural parameters of the Himalayas are given (K.L. Shrestha, Personal Communication) in Table 3.

The Indo-Gangetic Plain (IGP) region is the bread-basket of this region (Fig. 1) but it is also a major emitter region of nearly all the climate forcing gases and particles: CO_2, CH_4, N_2O, CO, NO_x, BC and OC. The extended urban sprawl in this region merges with that of the Mekong delta and eastward combining with the Yangtse river delta; it provides a massive sprawl over the entire Asian region dominating industrialization, urbanization, city growths, and is the home of some of the most populated megacities of the world.

Table 3: Physical and socio-cultural parameters of Himalaya region

Description	*Western Himalayas*	*Central Himalayas*	*Eastern Himlayas*
Latitude	37°N	28°N	28°N
Longitude	72°E	81°E	97°E
Snowline	4,800 m	5,000 m	4,900 m (3,500 m)
Treeline	4,000 m	3,900 m	4,200 m
Predominant species (lower elevation)	Pinus variety	Shorea to Pinus	Shorea Robusta
Vegetation regime	Xerophytic	Transitional	Hydrophytic
Annual average precipitation	700-2000 mm	3500 mm	
Main river system	Indus	Ganges	Brahmaputra
Drainage area	1,263,000 sq.km	1,075,000 sq.km	940,000 sq.km
Average annual runoff	3,850 cu. M/s	15,000 cu.m/s	20,000 cu.m/s
Specific Runoff	3.05	13.95	21.28
Number of Languages	Indo Aryan: 11 Tibeto Burman: 9	Indo Aryan: 5 Tibeto Burman: 11	Tibeto-Burman:11
Culture	Caucasoids	Mixed	Mongoloids

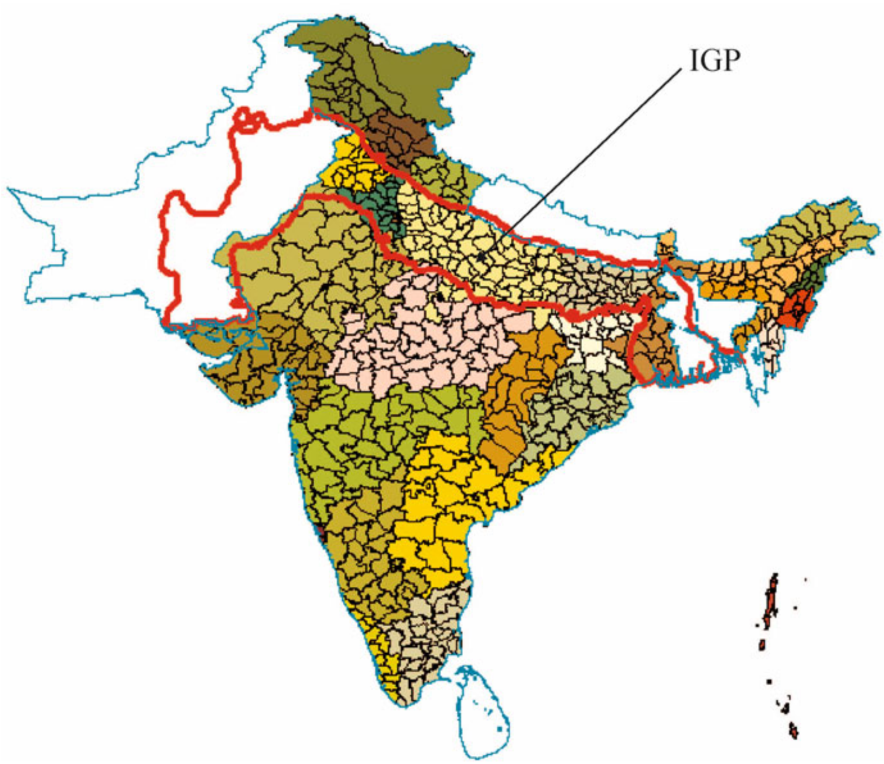


Fig. 1: Indo-Gangetic Plain (IGP) region of South Asia.

Monsoon is the major dominating factor for agriculture sustainability in this region. The seasonal alteration of the surface wind flow is associated with monsoon. The inter-tropical convergence zone (ITCZ – the so-called meteorological equator) moves from its northern location in summer to the south location to around 5^{o}S in winter. The movements and locations of the ITCZ vary from year to year and not only respond to climate change but also contribute to it. The position of ITCZ determines the nature and direction of transport to and from the India land mass. Another special feature is that rainfall is principally confined to four months in a year.

One of the special features is the presence of large wetlands including coral reefs in the region. There is a rich variety of as many as 3959 coastal wetland sites in India alone. Of these, the most important is the Sunderbans, stretching over an area of 10,000 km^2 which is the largest mangrove in the world and an UNESCO heritage area but now heavily degraded. About 38% of Sunderbans area is in West Bengal (India) and the rest is in Bangladesh. Coral reefs, in six major regions in the Indian coast, are also undergoing changes from anthropogenic pressures from fishing, mining, sedimentation, invasion by alien species, exploitation and deforestation of islands.

Other features include presence of appreciable arid and semi-arid areas, of high sedimentation rate, of a warm pool in the Indian Ocean, of differing rainfall patterns in different areas and of frequent occurrences of floods and droughts.

THE DRIVERS

The key drivers sourcing from the developmental paths chosen by the institutions of governance are influenced by the historical path, culture, dominant ideologies and political will in almost all the setup. This is also true for the South Asian region. The key direct and indirect drivers responsible for the developmental pathways steering the consumption and production patterns, influence the key sectors like energy, industries, landuse change and forestry and waste sectors. These sectors are responsible for emissions of greenhouse gases and other pollutants which are responsible for climate change. These emissions, in turn, also impact the aforementioned sectors.

The major drivers operating in the South Asian region are population, consumption pattern and changing atmosphere. Historical analysis shows that the developmental processes in the South Asia over past century has been guided by regimes and institutions that led to development trajectory which are no different from predecessors and thus converging (unless intervened) towards high energy intensive emission loaded pathways. However in recent years, the governance is undergoing rapid changes as governance has lost its territories and Millennium Development Goals are dominating the developmental agenda. The global common framework for policy thoughts and action is allowing the nations to adjust national policies to global regimes. Despite this upward movement in institutional convergence, attempts to streamline local micro institutions towards management of local resources are also a predominant trend in South Asia.

The changing atmospheric composition comes from a variety of sectors: energy, industrial processes, agriculture, forests and landuse changes and waste. These contribute to the climate forcing gases and particles which can be classified in three categories: Long-lived gases (CO_2, CH_4, N_2O principally), short-lived gases (O_3, CO, NO_x, VOC, SO_2) and aerosols (two types; scattering aerosols and absorbing aerosols). The short-lived gases (SLG) and aerosols have life times of a week or so, and have in the past been considered mainly as health hazard pollutants. Their role in climate change has been recognized only recently. Ozone forms a category of its own. It is a greenhouse gas. CO, NO_x , HC and VOCs are precursor gases that contribute to photochemical production of ozone. Although because of their short life-times their immediate impact is sub-regional or regional, the life-times are long enough for transboundary transport across countries and sometimes across continents.

In past years, efforts for estimation of emissions from the various sectors for South Asian countries have been made which included the following efforts:

India	First Inventory in 1992; ALGAS; MAC 98 (for methane) INDOEX, National Communication to UNFCCC
Bangladesh	National Communication to UNFCCC; ALGAS
Pakistan	National Communication to UNFCCC; ALGAS
Sri Lanka	National Communication to UNFCCC; ALGAS

Except for India, in most other South Asian countries, the emission inventories were limited to CHGs only. In estimating South Asian emissions for other pollutants, provisional estimates have been earlier made by National Physical Laboratory, India using emission factors derived for India.

The key points which emerged from South Asian region are:

(i) Although this region is inhabitated by more than 20% of population of the world, the greenhouse gas emissions are small. In fact these are considerably lower: around 2.7% for CO_2 (all sources) and 7% for CH_4 (all sources). For fossil fuel alone, the emission from this region is 3% (of the order of 175 Tg/Yr) and is expected to rise to 11-12% (690-800 Tg/Yr) in 2025 under baseline scenario. A point to note is that the per capita emission is much lower than the global average of 1.2 T/capita for all cases. For several South Asian countries it is unusually low (0.05 T/capita for Bangladesh, 0.06 for Sri Lanka, and 0.016 for Nepal).

(ii) For some countries, the CH_4 role is dominant. The CO_2 equivalent value of CH_4 emission is 21 times that of CO_2 for Nepal, 1.4 times in Sri Lanka and 0.63 times for India. Thus for mitigation measures CH_4 emission needs special attention especially emissions from rice and animals which are major sources of CH_4 emission.

(iii) The agricultural sector is a source of major emissions. In terms of CO_2 equivalent values, agricultural sector emissions are 50% of the energy and industry sector for India, as large as 126% for Bangladesh and 325% for Sri Lanka. Thus policy approach should be appropriately re-oriented.

(iv) Atmospheric SO_2 loading from anthropogenic sources is no longer negligible for this region. Also this loading has been growing rapidly.

(v) It is important to note that aerosols as well as ozone-precursor gases like CO, NO_x, NMVOC can travel long distances, several thousand kilometres specially in northern winter.

(vi) From INDOEX Programme carried out in 1998 and 1999, an aerosol model for the tropical Indian Ocean during Northeast Monsoon, prepared by Satheesh et al., shows largest contribution coming from non-sea salt sulfates and ammonia (29%), sea salt and nitrates (17%), missing organics (20%), dust (15%) and soot (11%). A surprising element is the presence of a large haze cloud in winter over North India Ocean and in East Asia, and its transport. The MODIS data show large AOD values in South Asian region (Fig. 2).

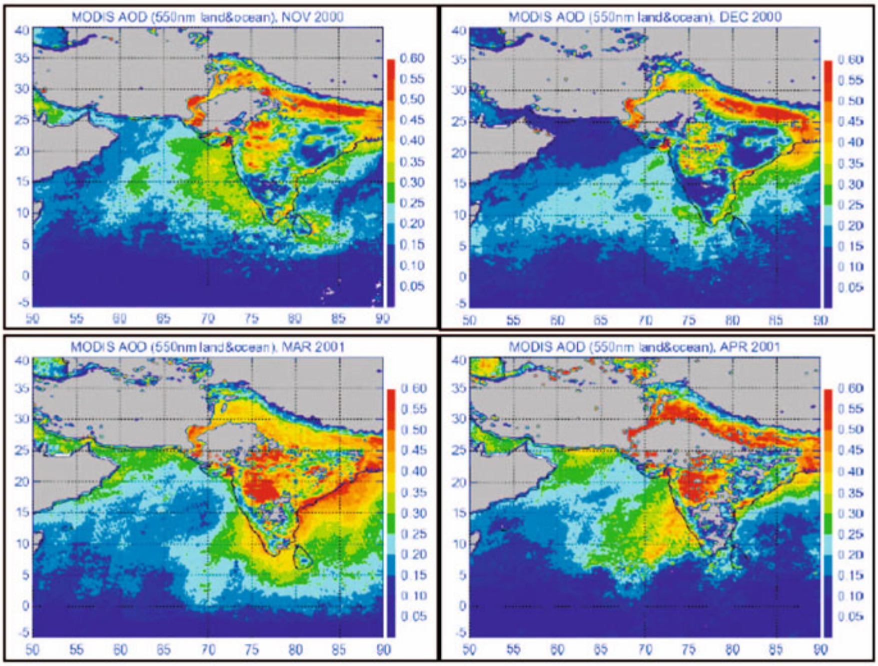


Fig. 2: The MODIS data showing large AOD values in South Asian region.

(vii) One of the special observation which emerged from the INDOEX study is the presence of large amount of carbonaceous aerosols which are absorbing in nature and thus contribute to the changing radiations budget in the region.

(viii) Various regions of South Asia experiences high climate variability, both spatially and temporally. The hydrological regime of major parts of the region is predominantly influenced by monsoon, which brings 70-80% of total annual rainfall during early June to September. The post-monsoon months become dry and there is hardly any appreciable rainfall during winter months (December to February). Moreover, the western parts of Bangladesh and India generally receive significantly lower amounts of rainfall compared to the eastern parts of both the countries, which is a manifestation of high spatial distribution of rainfall. Rainfall in Nepal is also higher in the eastern part compared to the western region. Topographically, in the Terai region with flatter topography along the Indian border, rainfall is very high. In a warmer climate in future, the overall pattern of rainfall/precipitation is expected to change spatially as well as temporally. Water resources of the South Asia region, however, are highly sensitive to climate variability and change. Therefore, an anticipated change in climate system – as a consequence of global warming and subsequent sea level rise –

could considerably affect both the hydrological cycle as well as distribution, which in turn would affect the lives and livelihoods of hundreds of millions of inhabitants.

(ix) A matter of special interest, for atmospheric chemistry, is the large OH concentration in this region. This means a large rate of CH_4 destruction.

(x) The ozone problem is quite different for this region. The problem is not of stratospheric ozone depletion (there has been virtually no change over the last decade, see Fig. 3), but of tropospheric ozone increase principally from CO and NO_x injection into the atmosphere due to vehicular emissions and biomass burning. UV-B effects are, therefore, only of academic interest, but consequences of tropospheric ozone changes on agriculture and health assume importance. In this the region itself is a contributor.

(xi) The changing oxidising capacity of the tropical atmosphere is of great concern. The increased emissions of NO_x and non-methane hydrocarbons from combustion, along with higher penetration of UV radiation tend to increase the ozone and OH concentrations in the tropical-free troposphere. On the contrary, the increased emission of CO from biomass and fossil fuel burning tends to reduce the OH concentrations. Also an increase in methane emission due to increase in natural gas usage, cattle and paddy field also contribute to a reduction in the global OH concentration. Model estimates, on the decrease in OH concentration since the pre-industrial era, differ anywhere between 5 and 30%. Future changes in the oxidising or the cleansing capacity of our atmosphere is going to depend critically on the future anthropogenic emissions.

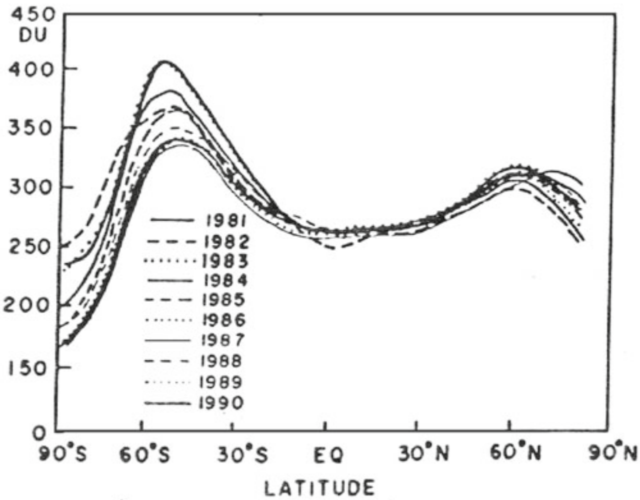


Fig. 3: Average October ozone amounts (1981-1990).

(xii) The two northern basins of the North Indian Ocean – the Arabian Sea and the Bay of Bengal – though situated at similar latitudes and subject to similar physical processes, exhibit widely differing biogeochemical features. Processes like upwelling during summer monsoon and convective mixing during winter make the Arabian Sea one of the most productive regions in the world. High biological production at surface causes heavy fluxes of organic matter and, consequently heavy oxygen demand in intermediate waters, leading to formation of the intense oxygen minimum layer. Renewal of oxygen is slow due to the high rates of respiration, aided by moderately slow water circulation and lower oxygen content of the source waters. Presence of a 5 m thick low salinity lens at the surface in the coastal waters of eastern Arabian Sea, caused by the heavy freshwater flux during monsoon, prevents vertical mixing in the water column. Aided by the high biological production, this leads to anoxia in subsurface waters and emission of H_2S, N_2O, CH_4 and DMS gases to the atmosphere at rates, which are highest ever recorded in the oceans. Similarly, the upwelling areas of coastal and central Arabian Sea give rise to high fluxes of these gases, especially CO_2, round the year, thus making the Arabian Sea, on the whole, a perennial source of atmospheric CO_2.

(xiii) The Bengal delta is formed by the continued deposition of sediment by the Ganga-Brahmaputra-Meghna (GBM) river system. Its hydrology is characterized by "too much water" during monsoon followed by "too little water" in dry season giving rise to extreme temporal distribution of flows posing a complex hydrological challenge of managing both flood and drought in one hydrological cycle. The delta is prone to high intensity floods as well as droughts and low-flow induced salinity ingress. In addition to surface water, its ground water is a major source of water for agriculture, industry and municipal uses. The delta is morphologically very active, e.g., the Sylhet basin is subsiding at 1-3 $mm.y^{-1}$ while the coastal plains exhibit both accretion and erosion. Until recently, there was only one predominant land use – paddy cultivation – which formed the main economic activity. Urban centres started flourishing since 1970s leading to gradual change in pattern of land use. Large cities, including the two megacities of Kolkata and Dhaka, having high population densities, are built either on river banks or along main roads.

(xiv) Sunderbans, with its land area shared between India (38%) and Bangladesh (62% or about 577,000 ha) is the largest single patch of mangroves in the world. Located at the fag end of the Ganges basin, it receives fresh water and sediment from a number of distributaries of Ganges. About 1/3 of the forest consists of water bodies like rivers, channels and tidal creeks. The present geomorphological features were formed over millennia due to continuous deposition of weathered materials by the river system. Mudflats along the rivers are subject to direct wave action, flow and turbulence of water currents. During high tides the lower parts of mudbanks remain submerged with brackish water. Gradual sediment deposition along the river banks gives rise to formation of ridges and levees. It is influenced by semi-diurnal tides with tidal variation ranging from 3.5 to 5.0 m. The soil is saline due to tidal interactions. The soil salinity influences the floral distribution. It hosts one of the richest natural genepools for forest flora and fauna species in the world. It is also endowed with a number of commercially important mangrove species. In addition to the Bengal Tiger, it supports a variety of wild animals, birds, reptiles, sweet and brackish water fish, shrimps, crabs, mollusks, shellfish, turtles and snakes including the King Cobra and Vipers. The creeks serve as nurturing grounds for shrimp larvae and fries. Giant estuarine crocodiles, wild boars and the Indian Otters are also found. The forest provides about 0.3 million tons of fuel wood annually.

(xv) Major mangrove formations in South Asia occur in the deltaic regions of Indus, Mahanadi, and Sunderbans, in the Gulf of Kutchchh and Andaman & Nicobar group of islands. In Sri Lanka they are found in Jafna peninsula and along the west coast. These ecosystems are at serious risk due to rise in sea levels as a result of global warming. Additionally, individual components of the habitat may change their response pattern to the increased temperature and CO_2 levels, and alterations of the hydrological regime in the ambience. Among the various types of biota associated with the ecosystem, the soft bodied animals and bivalves will be the most adversely affected by rise in temperature and salinity. While the biota with specific tolerances within the tidal spectrum will migrate farther landward, in regions with limited land margins there will be no scope for further expanse in response to the sea level rise and change in the hydrological regime of the ambience.

(xvi) For most of the climate parameters, the South Asian region is highly vulnerable. The low capacity of this region to really have a sufficient adaptability to such climate impacts makes this region further vulnerable.

THE KEY REGIONS

The key region in South Asia is the Indo-Gangetic Plains, cutting across Pakistan, India, Nepal and Bangladesh, the bread-basket of the region, and the one which has gone through much changes, especially in landuse, in the last century principally from human activities. The cumulative CO_2 today from landuse change from this region from 1850 to 1985 is as much as half of that from fossil fuel. Although, endowed with mighty rivers (Ganga, Brahmaputra, Indus etc.), abundant natural resources, and biodiversity, with intense human activities and excessive intensification of agriculture, IGP ecosystem has degraded drastically and poses a major environmental threat not only for itself but for the entire region.

The IGP region stretches from the Arabian Sea to the Bay of Bengal and from the Himalayan foothills to the Indian peninsula (Fig. 1). For India, the region covers 21% of the geographical area; for Nepal 14% of its area; for Pakistan it covers 24% and for Bangladesh 100%. Population residing in this region is high: 40% of Nepal's population, 40% of India's, and 86% in Pakistan. The dominant landuse is agriculture: 70% in India, and 60% in Nepal.

The IGP region affects the climate drivers in a number of ways:

(i) From forestry changes and landuse: Large scale deforestation contributing to a reduction in its capacity to serve as a "sink".

(ii) Agricultural practices contribute to atmospheric loading of CH_4 and N_2O: the key sector are rice production and inadequately fed ruminant animals. This is the single most important contributor to CH_4.

(iii) The large urban sprawl that constitutes the IGP is replete with many large cities. This sprawl extending to the Mekong urban sprawl and that of the Yangtse river is one of the largest sprawls in the world (Fig. 4). Urbanization is the key driving factor. We have in this sprawl the mega cities of Karachi in Pakistan, Mumbai, Delhi and Kolkata in India, Kathmandu in Nepal and Dhaka in Bangladesh. The estimated CH_4 emission from this region constitutes over 50% of the GHG emissions for the entire South Asia. Cities in South Asia included several amongst world's largest cities in 1995. These are also some of the most polluted ones in the world.

THE CHANGING SCENARIO

In South Asia, the origin of agriculture and domestication of animals have been linked to changes in the monsoon precipitation, which in turn would have driven the beginning of agriculture and human civilizations in the region. As the arid phase (weak summer monsoon) began ~5,000 cal yrs BP, the societies in India migrated to more productive areas to the east and south and some may have developed mechanisms of adaptation to climate change. This can be viewed from the presence of ponds, tanks, and artificial reservoirs constructed during the late Holocene across India when the monsoon reached its Holocene minimum, and we find correlation between heightened historical human efforts for adaptation and the most recent minima in the monsoon that occurred during the Maunder Minimum (1600 AD). The monsoon record supports an emerging paradigm that at least in the tropics, the largest climate changes and societal responses were driven by changes in precipitation rather than surface temperature. A key factor for the agriculture is the prediction of

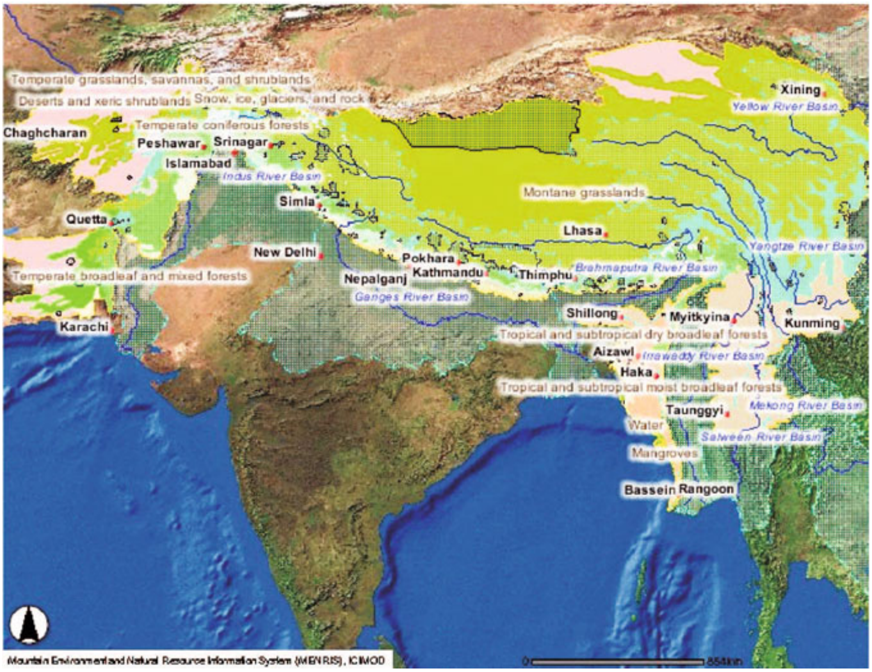


Fig. 4: The urban sprawl extending from Ganges to Yangtse river basins

the onset date of monsoon and distribution of rainfall. These factors determine the agricultural yield.

The land use change pattern is undergoing a rapid phase of transition. The increasing urbanization in South Asia is putting immense pressure primarily on agriculture land and, thus catalyzing a change in socio-economic character of the region which has been historically agrarian. But now the agriculture's share in national GDP is gradually declining with other sectors like service/industries picking up. The urbanization has altered the carbon-flow in the society.

The atmospheric properties in the South Asia are also changing very significantly. While the ambient air quality – especially in many urban and industrial areas – have assumed chronic proportion, the oxidizing capacity of the atmosphere is also being altered due to significant increase in emissions of various gases and particulates in recent years. The anthropogenic activities in this region is also responsible for the significant winter-time clear sky aerosol radiative forcing at the surface in the range of 23-27 W/m^2 over the polluted ocean region and a sufficiently large atmospheric absorption, in the range of 16-20 W/m^2.

Water resources availability in South Asia is highly sensitive to climate. Monsoon contributes maximum share to the annual runoff. However, high runoff availability is more or less useless as the water cannot be stored for dry season. There is simply not enough water in the dry season to meet present demands of various economic sectors. The paucity of water has led to inter-nation and intra-nation water conflicts. Many of the South Asian nations have drafted their national water plans or water policies. Unfortunately, however, the very issue of climate change has not been featured in the plans/ policies in an appreciable manner. It is important to take notice of the changes in climate system and find correlation between climate parameters and timely availability of water resources of a country in order to avoid future complications.

The changing climate has significant bearing on the coastal and marine ecosystems in the South Asian region as well, and the rising atmospheric CO_2 levels influences the sea surface temperature (SST) and sea level.

The South Asia is one of the most vulnerable areas of the world. The vulnerability of climate change and more specifically from extreme climatic events is further exacerbated due to low coping capacity and adaptability of the region. Although policies for coping with the extreme climatic changes in South Asian region exist but the same remain by and large ineffective due to reasons like apathy, uncoordinated institutional approach, improper dissemination of relevant information to the stakeholders and non-availability of impact assessment information. Therefore, the region requires a shift from policy to action by development of adequate realistic adaptation plans that are integrated into existing development initiatives.

The present efforts by regional scientists of South Asia to synthesize the current understanding of various issues of global change relevant for the region has been undertaken under the auspices of STARTS MAIRS programme in which regional scientists of different disciplines pooled up their own resources and intellect which is reflected in the chapters in this book.

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About the Editors

Late Dr. A.P. Mitra, a Fellow of Royal Society of London, was born on 21 February, 1927 in Kolkata, India. He obtained his D.Phil. in 1955 from University of Calcutta. Dr Mitra was an outstanding scientist and began his research career in the area of ionospheric and related atmospheric research and became the doyen of upper atmospheric research in India. Over the last one and a half decade, he had concentrated on the scientific aspects of global environmental hazards of human activities. His scientific contributions to ozone problem, to the atmospheric chemistry and measurement of greenhouse gases in India, and to global environmental chemistry have had international impacts. He led the global change science programme in India and South Asia and was instrumental in the initiation and execution of several regional collaborative global change research programmes in Asia-Pacific region. Dr Mitra was the Fellow of all the three Academies of India and Fellow of Third World Academy of Sciences (TWAS) and of the International Academy of Astronautics. He was also the Past President of the National Academy of Sciences. He was also the honorary president of International Union of Radio Science (URSI). He had over 200 publications to his credit and also written and edited several books and monographs. Dr Mitra had been bestowed with several awards and medals including the Padma Bhushan by Government of India.

Dr. C. Sharma, is presently working as a scientist at the National Physical Laboratory, New Delhi. Dr Sharma's research interests include climate change, vulnerability and adaptation studies, measurements of greenhouse and other trace atmospheric gas emissions, emission inventory preparations and air quality measurements and impacts. Dr Sharma has extensively worked for the generation of country specific emission factors of various greenhouse and other trace gases from different sources like agriculture, biomass burning, landfill etc. He has participated in a number of international and national global-change related projects and has published more than 80 research papers in various national and international journals. Dr Sharma has contributed to the Intergovernmental Panel on Climate Change (IPCC) process as well and has been provided the recognition certificates by the IPCC as well as by the Prime Minister of India for his contribution to the work of IPCC, which co-shared the Nobel Peace Prize 2007.

Contributors

A. Jayaraman
National Atmospheric Research Laboratory, Department of Space
Govt of India
Gadanki 517 112, India
jayaraman@narl.gov.in

A.K. Singhvi
Physical Research Laboratory
Ahmedabad 380 009, India
singhvi@prl.res.in

A.P. Mitra (Late)
National Physical Laboratory
Dr. K.S. Krishnan Marg
New Delhi 110 012, India

A. Velmurugan
Indian Institute of Remote Sensing (NRSA)
4, Kalidas Road
Dehradun 248 001, India
vels@iirs.gov.in

A. Hassan
Center for Environmental Geographic Information Services (CEGIS)
House 6, Rd. 23/C, Gulshan-1
Dhaka 1212, Bangladesh

Ahsan Uddin Ahmed
Centre for Global Change (CGC)
12-Ka/A/1 Shaymoli Second Lane
Dhaka 1207, Bangladesh
ahsan.ua@gmail.com

A. Bhattacharyya
Birbal Sahni Institute of Palaeobotany
53, University Road
Lucknow 226 007, India

A.K. Gupta
Department of Geology & Geophysics
Indian Institute of Technology
Kharagpur 721 302, W.B., India
anil_k_gupta1960@yahoo.co.in

Anoja Wickramasinghe
Dept. of Geography
University of Peradeniya
Peradeniya, Sri Lanka
niluwick@slt.lk>niluwick@slt.lk

Arshad M. Khan
Global Change Impact Studies Centre (GCISC)
National Centre for Physics (NCP) Complex
Quaid-i-Azam University Campus
Islamabad, Pakistan
arshad.khan@gcisc.org.pk

A.B. Shrestha
International Centre for Integrated Mountain Development (ICIMOD)
Khumaltar, Lalitpur, Nepal
abshrestha@icimod.org

Brenna Enright
Department of Civil Engineering
University of Toronto
35, St. George St.
Toronto, ON, M5S 1A4
brenna.enright@gmail.com

C. Venkataraman
Department of Chemical Engineering
Indian Institute of Technology Bombay, Powai
Mumbai 400 076, India
chandra@iitb.ac.in

Chetana Chaudhuri
Jawaharlal Nehru University
New Delhi

C. Sharma
Radio and Atmospheric Sciences Division
National Physical Laboratory
Dr. K.S. Krishnan Road
New Delhi 110 012, India
csharma@mail.nplindia.ernet.in

Chhonda Bose
Department of Economics
La Martiniere for Boys
11 Loudon Street
Kolkata 700 017, India
chhonda_bose@yahoo.com

D.A. Quadir
Apt B-1, House 62, Road 4-A, Dhanmondi R/A
Dhaka 1209, Bangladesh
dquadir@yahoo.com

G. Beig
Indian Institute of Tropical Meteorology
Dr. Homi Bhabha Road, Pashan
Pune 411 008, India
beig@tropmet.res.in

J. Ashraf
Global Change Impact Studies Centre (GCISC)
National Centre for Physics (NCP) Complex
Quaid-i-Azam University Campus
Islamabad, Pakistan
javeria.ashraf@gcisc.org.pk

Joyashree Roy
Department of Economics
Jadavpur University
188, Raja S.C. Mallik Road
Kolkata 700 032, India
joyashreeju@gmail.com

K. Rupakumar
World Climate Applications and Services Division
Climate Prediction and Adaptation Branch
Climate and Water Department
World Meteorological Organization
7bis, Avenue de la Paix
Case Postale No. 2300
1211 Geneva 2, Switzerland
RKolli@wmo.int

L.P. Devkota
Central Department of Hydrology & Meteorology
Tribhuvan University
Kathmandu, Nepal
devkotalp@hotmail.com

M.D. Kumar
National Institute of Ocenography
Dona Paula, Goa 403 004, India
dileep@nio.org

M.S. Chauhan
Birbal Sahni Institute of Palaeobotany
53, University Road
Lucknow 226 007, India
mschauhan_2000@yahoo.com

M.R. Ray
Neuroendocrinology Department
Chittaranjan National Cancer Research Institute, Kolkata, India

Manaswita Konar
HM Treasury (Labour market policy team)
I Horse Guards Road
London SW1A 2HQ, UK
manaswita.konar@gmail.com

Md Rashed Chowdhury
Pacific ENSO Applications Climate Center
Affiliate Faculty - Urban and Regional Planning
University of Hawaii at Manoa
2525 Correa Road (HIG 350)
Honolulu, HI 96822, USA
rashed@hawaii.edu

M. Thamban
National Centre for Antarctic & Ocean Research
Headland Sada, Vasco-da-Gama, Goa 403 804 India
meloth@ncaor.org

Mitali Dasgupta
Resources and Global Security Division
The Energy and Resources Institute (TERI)
741, Jessore Road
Kolkata 700 028
mitalipal@gmail.com

M. Monirul Qader Mirza
Adaptation and Impacts Research Division (AIRD)
Environment Canada
c/o Department of Physical and Environmental Sciences
University of Toronto at Scarborough, 1265 Military Trail
Toronto, ON M1C 1A4, Canada
monirul.mirza@utoronto.ca

Moumita Roy
Economics Department
Krannert School of Management
Purdue University, Krannert Center
425 West State Street
West Lafayette, Indiana 47907

M. Adnan
Global Change Impact Studies Centre (GCISC)
National Centre for Physics (NCP) Complex
Quaid-i-Azam University Campus
Islamabad, Pakistan
m.adnan@gcisc.org.pk

M.M. Sheikh
Global Change Impact Studies Centre (GCISC)
National Centre for Physics (NCP) Complex
Quaid-i-Azam University Campus
Islamabad, Pakistan
munir.sheikh@gcisc.org.pk

N.R. Phadtare
Palynology Laboratory
Wadia Institute of Himalayan Geology
33 GMS Road
Dehradun 248 001, India
phadtarenr@wihg.res.in

N. Manzoor
Global Change Impact Studies Centre (GCISC)
National Centre for Physics (NCP) Complex
Quaid-i-Azam University Campus
Islamabad, Pakistan
naeem.manzoor@gcisc.org.pk

O.N. Dhar
Indian Institute of Tropical Meteorology
Pashan, Pune 411 008, India

O.S. Chauhan
National Institute of Oceanography
Dona Paula, Goa 403 004, India
onkar@nio.org

P.D. Roy
Departamento de Geoquimica
Instituto de Geología
Universidad Nacional Autonoma de Mexico, Ciudad Universitaria
C.P. 04510
Coyoacan, Mexico D.F., Mexico
p_debajyotiroy@yahoo.com

R.R. Yadav
Birbal Sahni Institute of Palaeobotany
53, University Road
Lucknow 226 007, India
rryadav2000@gmail.com

Ranjan Bose
Energy and Transport Specialist
Energy Sector Management Assistance Program (ESMAP)
World Bank, Washington DC
1818 H Street, NW

Rucha Ghate
SHODH: The Institute for Research and Development
106, K.T. Nagar, Katol Road
Nagpur 440 013, India
www.shodh-research.org

S.K. Satheesh
Centre for Atmospheric & Oceanic Sciences
Indian Institute of Science
Bangalore 560 012, India
satheesh@caos.iisc.ernet.in

Saikat Sinha Roy
Jadavpur University
188, Raja S.C. Mallick Road
Kolkata 700 032, India
saikat@ris.org.in

Sarmistha Das
Jadavpur University, Kolkata
188, Raja S.C. Mallick Road
Kolkata 700 032, India

S. Nandargi
Indian Institute of Tropical Meteorology
Dr. Homi Bhabha Road, Pashan
Pune 411 008, India
nshobha@tropmet.res.in

Shobhakar Dhakal
Global Carbon Project
National Institute for Environmental Studies
16-2, Onogawa
Tsukuba, Japan 3058506
shobhakar.dhakal@nies.go.jp

S.N. de Sousa
Goa State Pollution Control Board
Dempo Tower (1st floor)
EDC Plaza, Patto, Panjim, Goa
simao@rediffmail.com

S. Sardessai
National Institute of Oceanography
Dona Paula, Goa 403 004, India
sugandha@nio.org

Sumana Bhattacharya
NATCOM Project Management Cell
Ministry of Environment and Forests, Government of India
Winrock International India
S-212, Panchsheel Park
New Delhi 110 017
sumana@winrockindia.org

S. Chakravorty
Climatology and Hydrometeorology Division
Indian Institute of Tropical Meteorology
Dr Homi Bhabha Road, Pashan
Pune 411 008, India
supriyo@tropmet.res.in

T.G. Jagtap
National Institute of Oceanography
Dona Paula, Goa 403 004, India
tanaji@nio.org

T. Lahiri
Neuroendocrinology Department
Chittaranjan National Cancer Research Institute, Kolkata, India

U.C. Kulshrestha
School of Environmental Sciences
Jawaharlal Nehru University
New Delhi 110 067, India
umesh@mail.jnu.ac.in

V.K. Dadhwal
Indian Institute of Remote Sensing (NRSA)
4, Kalidas Road
Dehradun 248 001, India
vkdadhwal@iirs.gov.in

V.S. Kale
Department of Geography
University of Pune, Pune 411 007
India
vskale@unipune.ernet.in

Contents

1 Human Dimensions of Changing Environment

A.P. Mitra

1. INTRODUCTION

There is an increasing global concern resulting from human activities affecting not only the human development but also endangering the planet earth. One of the important component of this hazard is that of its environment. It is interesting to investigate how it has been changing in the past before human activities began to alter it and how it is changing now and the extent to which recent changes have been contributed by human activities. These changes are caused by and in turn influence other components of the earth system – land, atmosphere, oceans – and the processes that relate them. There are concerns about human well-being and the earth system stability. Global change programme has now been redesigned to cover this entire earth system. This connectivity is shown in Fig. 1.

Global change and human society are interlinked. The linkages have several aspects:

- Human societies are part of ecosystem but also more than ecosystems,
- Human societies do not change via Darwinian mechanism alone, but depends also on human choice.
- Carrying capacity of the earth is determined not only by the number of people on Earth that drives global change but also per capita levels of resource consumption.
- Collapse of societies: Societies choose to fail or survive.
- There are reverberations of such changes in the responses of the Earth System. Figure 2 shows the reverberations of fossil fuel combustion through the earth system. This is only one of the examples.

The responses include:

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