Ecology and environmental science in the universities

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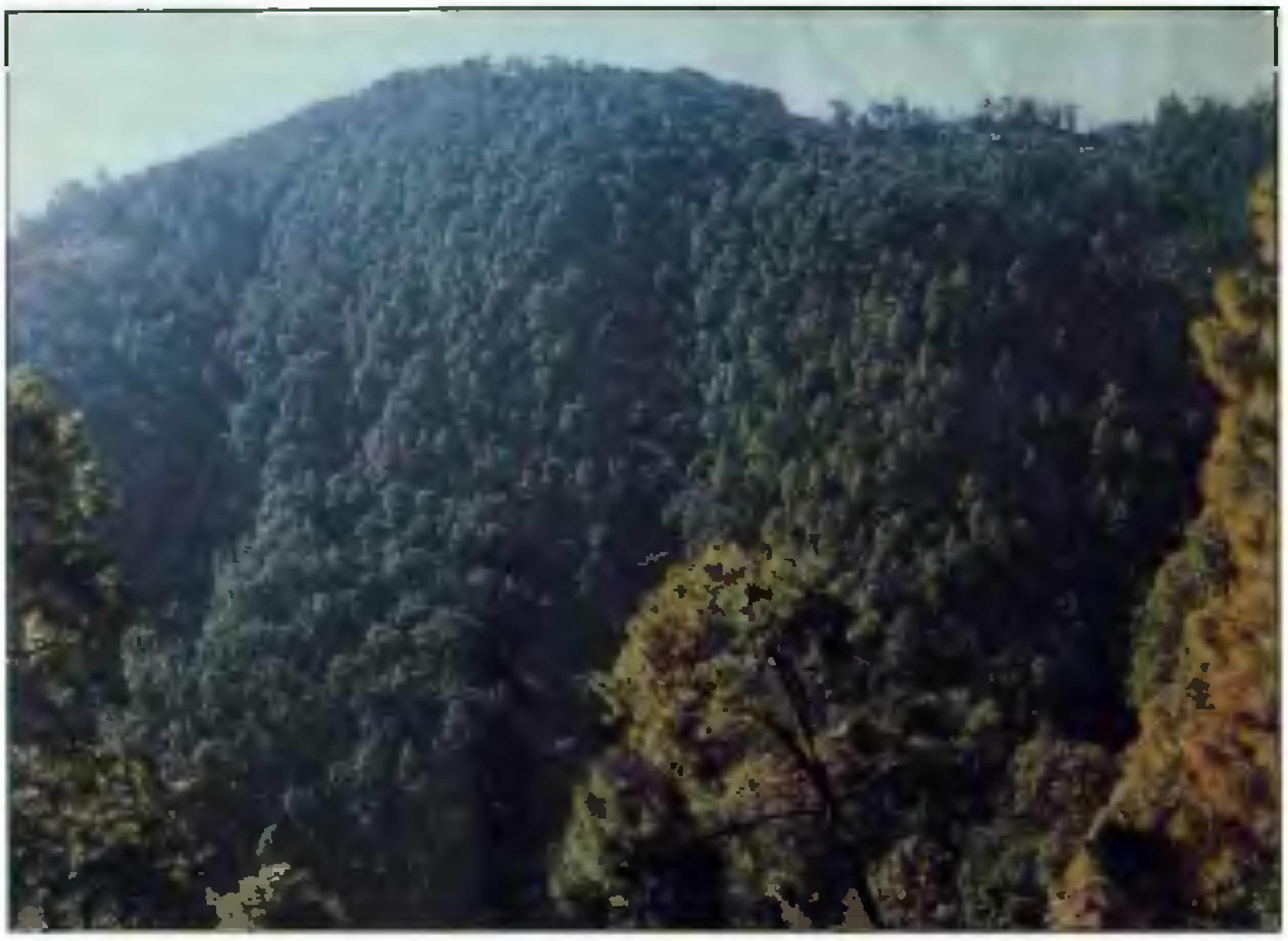
Solutions to the increasing environmental problems of today call for trained ecologists. Universities must create centres for ecology and environmental science for such training and for research.

Never before has the transition from one century into another meant entering a period of global crisis. The cumulative impacts of the series of environmental perturbations unleashed by the growth in human numbers and consumerism on the biosphere are collectively exceeding all but the greatest upheavals of the geological past. During the present century the human population has increased three-fold, consumption rate of fossil-fuel energy has increased 12-fold, and growth in the global economy has increased 29-fold (refs. 1, 2). In the next three or four decades human numbers will double, consumption of food and fibre will triple, energy demand will quadruple, and economic activity will quintuple[3]. The carrying capacity of Earth would be saturated by the middle of the next century. Not only do we stand to lose species and genetic strains of potential medical, agricultural, and industrial importance, but we will greatly impair natural ecological processes crucial to our well-being and destroy much of the evolutionary potential of these systems to respond to future perturbations[4].

Burgeoning problems

It is difficult to foresee all environmental problems that mankind will face in the future. However, on the basis of contemporary information, I focus on four major groups of them. I do not list them here in any order of priority because they are interdependent and synergistic.

Loss of biological diversity



Top: A dense forest with high biological diversity. *Bottom*: Overexploitation has reduced forest cover and diversity.

We seem to be entering into a phase of mass extinction. Today we are losing at least one higher-plant species per day from tropical forests alone[1]. Estimates indicate that, from ten hot-spot localities in tropical forests (300,000 km^2) alone, some 17,000 endemic plant species and 350,000 endemic animal species could well be eliminated shortly[5]. If the present trend continues, about 25% of the total 250,000 higher-plant species will be lost in the next few decades and another 25% by the end of the twentyfirst century. Further, we can expect the demise of 20–60 animal species per plant species lost[1,6]. Mass extinctions (25–>70% of extant species each time) have occurred in the past at geologic-time boundaries, such as Frasnian/Fammennian, Ordovician/Silurian, Permian/Triassic, Triassic/Jurassic and Cretaceous/Tertiary. There were a fewer species at stake then, however. There were around 25,000 species of flowering plants some 125 million years ago, by the Late Cretaceous this number had swelled to 100,000, and today there are some 200,000 species of these plants on Earth[7]. Additionally, while the past extinctions occurred each time over a span of a million years or less, and plant species were largely spared as the general nature of vegetation remained the same on both sides of the boundary[4], the present mass extinction may well occur within a short period of about 200 years, and plants (which make up the base of the food chain) will be equally or worse affected. In India alone, it is feared that 15–20% (i.e. over 2500 species) of the total vascular flora now fall in one or the other category of threatened species[8].

Degradation of ecosystems

The rate at which ecosystem degradation has occurred globally during the present century is alarming. Significant areas have already been profoundly altered, depleted, eroded or contaminated by toxic substances[9]. Anthropogenic forcing and exploitation of already shrinking resources in future would further ravage the land, water and biota. Current estimates indicate that 3 to 15 million hectares of tropical forests[10] are being cleared per year (about 1 acre per second!). Disruption of natural vegetation and subsequent, often faulty land-use management, causes serious damage to the system. Drastic disturbances such as surface mining for natural resources disrupt ecosystems entirely. The problem of land degradation is going to be specially acute for developing countries in the face of their shrinking productive land base, polluted and meagre water resources, and increasing human and livestock populations. For India, estimates indicate that more than half of the land mass of the country is already degraded in some way, out of 143 million hectares of agricultural land 56% is degraded due to bad agricultural practices[11], and now dense forest cover has been reduced to only 11% of the geographical area[12]. The situation is frequently so bad that even cessation of abuse will no longer necessarily lead to self-correction of the natural system.

Environmental pollution and contamination

Estimates indicate global sulphur dioxide (SO_2) and nitrogen-oxide (NO_x) emissions to be 65 million and 20 million tons of S and N respectively for 1980, and 205 million and 65 million tons of S and N respectively for the year 2030 (ref. 13). Increases in these anthropogenic gases as well as in carbon monoxide (CO), methane (CH_4), and non-methane hydrocarbons in the troposphere have implications also for tropospheric concentrations of phytotoxic oxidants, such as ozone and hydrogen peroxide[13]. The acid-rain problem, thus far primarily confined to Europe and North America, is now causing concern in other regions as well, including China[14]. India cannot expect to remain unscathed. Few would be aware that ambient SO_2 levels in the industrialized Gangetic Plains are now similar to those of the industrialized regions of Europe and the northeastern US[15]. Calculated loading rates of trace metals, such as Cd, Cu, Ni, Pb, Cr, Zn, and Hg, in air, water and soils demonstrate that human activities now have major impacts on the global and regional cycles of most of the trace elements[16]. There is significant contamination of freshwater resources[17] (as well as artificial eutrophication of lakes and reservoirs) and an accelerating accumulation of toxic metals in the human food chain. (See also ref. 18 for a survey of pollution problems.)

Global change

Increase in atmospheric abundance of radiatively important trace gases, such as carbon dioxide (CO_2), nitrous oxide (N_2O), CH_4 and chlorofluorocarbons (CFCs), is occurring at a high rate. There are unmistakable evidences that this increase in greenhouse gases is going to raise global temperatures, to disturb rainfall pattern, and to cause sea-level rise within the next few decades[19]. At the same time, decreasing concentration of ozone in the stratosphere is resulting in increased UV radiation on Earth. Thus, within a few decades, Earth is likely to be much warmer; mean global temperatures would have increased by 2–4.5°C; sea levels would have risen by 30–50 cm, inundating vast coastal areas and causing ingress of salinity inland; UV radiation harmful to most organisms would have increased[20]; and warmer sea temperatures would affect the monsoon pattern of circulation, which was established over India some 11 million years ago, increasing the frequency of extreme events. Certain biomes (major regional ecological communities) will begin to migrate or begin to be reconstituted[21]. The consequences of these global-change phenomena are many, and alarming.

Responsibilities of the Indian university system

Two major roles of a university, *inter alia*, are generation of knowledge and creation of trained manpower who can use this knowledge for improving quality of life and society. Few would disagree that the environmental problems of the future are going to overwhelm all other challenges. Indian universities can hardly ignore their responsibility of conducting research to resolve these problems and of imparting education to equip the society to face them effectively.

My target in this article is the non-vocational higher-education system in the universities. It is the higher-education system that is expected to yield the analytical and theoretical precepts leading to the evolution of 'anticipate and prevent' strategies, as opposed to 'react and cure' strategies which should arise from the technological institutions. I am also not concerned here with the exoteric incorporation of environment-related courses in other disciplines (e.g. environmental biology, environmental geology), which is useful, though, for generating environmental awareness and gives a new perspective to the disciplines concerned. Further, I consider the current proliferation of newspaper-veneered and ready-with-advice-on-any-problem environmental scientists encouraging but not reassuring

Resolution of the problems listed above is not possible without a thorough understanding of ecological principles, and therefore appropriately trained ecologists (both generalists and specialists) will be required increasingly. The new generation of ecologists will require the capability to *predict*, *plan* and *manage* the environment and resources[22]. Training for such ecologists cannot be accomplished in traditional university departments designed for compartmentalized teaching of plant or animal science. The ecology and environmental science courses will have to be interdisciplinary and, often, transdisciplinary in nature. Universities will therefore have to create linkages between departments in order to bring together a combination of necessary disciplines, in the form of centres for ecology and environmental science.

These centres should, however, have a critical mass of full-time teaching faculty of their own in addition to the borrowed expertise from the other, pre-established departments, and should be entrusted with the task of teaching all ecology courses, and at all levels, in the university. They should have long-range integrated research programmes dealing with perceived local problems, and in this way can participate in regional development. For example, a centre can adopt a degraded ecosystem of the region and can concentrate its efforts on restoring it.

New departments of ecology and environmental science can be established in selected universities. It is encouraging that some schools/departments of environmental science have already come up. However, they still remain largely multidisciplinary, maintaining discipline-oriented style and content of teaching and solving problems within disciplines. Sectoral research activity results in a diffusion of effort and monetary resources, and in redundancy of results. Disciplinarians tend to look at an environmental problem with the bias of their own discipline. Ecology, on the other hand, has grown by internalizing the different disciplines of natural and, more recently, social sciences[23]. I feel that environmental science has to be strongly biocentric; the holocoenotic environment (i.e. the life-support system) is the object and ecology is the science that deals with it. Ecology therefore must be at the core of any environmental-science programme.

I summarize below the areas that should be focused on in training and research in this preparatory stage.

Ecosystems analysis and modelling, i.e. analysis of ecological processes at the ecosystem level, to understand the functioning of ecological systems in relation to perturbations, so that mechanistic ecosystem modelling can be pursued.

Conservation and evolutionary ecology, for the protection of biological diversity and the translation of theoretical advances into concrete recommendations for management so as to ensure symbiotic man–nature interactions, and to understand the biological equipment of species which enables them to survive stresses.

Restoration ecology, for the restoration of degraded ecosystems and of biological productivity, diversity and stability or resilience of impacted ecosystems.

Ecology of global change, specially to assess the magnitude and likely impact of climatic and associated changes on species and ecosystems, and to develop the capability to take advantage of positive effects and mitigate negative effects through management.

Ecological biotechnology, for producing transgenic organisms and devising biological systems—including micropropagation of stress-tolerant, fast-growing plants—that can be useful in environmental restoration, waste recycling, detoxification, biological control, etc., and to assess the ecological risk of planned introduction of genetically engineered organisms into the environment.

Ecological economics, for integrating the study and management of nature and economics, so that the cost of damage done to the air, water, soil and biota and that of restoring this damage can be articulated in redifining progress and development goals and in recalculating GNP.

An institute of ecology

The advanced curriculum should not be just an entombment of knowledge, but rather a structure wherein knowledge is *communicated* and *used*[24]. There is a need to integrate advanced teaching programmes of ecology and environmental science with ongoing long-range, site-specific and/or problem-specific research programmes: advanced teaching and research should snugly fit into each other[22]. *Predictive capability* must be developed. Sustained experiments at various scales are called for. Expertise is required to extrapolate from processes studied at small scales and to observe the various phenomena of interest directly at large scales. Integrative form of scientific analysis is required and this in turn requires a thorough knowledge of the fundamentals (ecological processes) as well as the tools (computer modelling, remote sensing, etc.). Modelling studies require an efficient, interactive data bank. A coordinated network of sites is needed for observing short- and long-term trends in ecological processes and for conducting comparative experiments and total-system studies.

This approach to teaching and futuristic research goals calls for an institute of ecology. It is here that India has a particular responsibility because of a relatively well-developed scientific infrastructure and because many environmental problems transcend national boundaries, generally for the whole of South Asia and particularly for the Indian subcontinent[22]. World ecologists, in 1960, founded the International Society for Tropical Ecology (ISTE) and sited its headquarters at the Banaras Hindu University (BHU) in India with the assumption—rearticulated by the ecologists at the 1987 ISTE symposium—that a regional institute of ecology would emerge[25]. Earlier, in 1975, UNESCO's Programme on Man and Biosphere (MAB) regional meeting had also recommended setting up of a national institute of tropical ecology at BHU[26], which has the longest tradition of teaching and research in ecology in the region.

Such an institute, with long-range research programmes on permanent study sites, can be linked with various ecology centres in universities and research institutions for multidirectional information flow. India is endowed with a great diversity of climate and life zones, which represent all possible ecological conditions in South Asia.

Biosphere reserves to cover distinct ecoclimatic zones have been and are being established. Some of these reserves, coupled with certain areas that experience rapid changes owing to intense anthropogenic forcing, could serve as permanent research sites for the institute. Operating within the university system, the institute can have more latitude and establish effective links with other centres of importance within and outside the South-Asian region for collaborative training and research with international funding from UNESCO, the South Asian Association for Regional Cooperation (SAARC), World Bank, the Food and Agriculture Organization (FAO), the United Nations Environment Programme (UNEP), etc. The six disciplines outlined earlier should be the focus of research at the institute, which can also have a flexible programme of degree, diploma and certificate courses on selected topics of environmental concern to the South-Asian region. The Ministry of Environment and Forests, together with the University Grants Commission, could be the nodal agency for the institute, with active support from the Department of Science and Technology (DST), Department of Space (DoS), Department of Biotechnology (DBT) and the Council of Scientific and Industrial Research (CSIR).

The proposal of reorganizing non-vocational higher education to create centres of ecology and environmental studies, and to establish an institute of ecology, will probably encounter resistance owing to (i) the inertia of the system, (ii) the faith of the academia in existing disciplines and system, (iii) uncertainty of employment generation, (iv) interdisciplinary and interinstitutional rivalries, and (v) lack of funds. I shall leave this article open-ended and let the readership, including policy makers and those concerned with funding of science, react to the possible factors of resistance. Much will depend, however, on the way we set national priorities in dealing with the burgeoning environmental concerns.

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While this article was in press, the Ecological Society of America, recognizing that many of the environmental problems that challenge human society are fundamentally ecological in nature, came out with a multiauthor report on sustainable biosphere initiative (*Ecology*, 1991, **72**, 371), which focuses on the necessary role of ecological science in the wise management of Earth's resources and the maintenance of Earth's life-support systems. This document proposes three research priorities for the nineties: (i) global change, (ii) biological diversity, and (iii) sustainable ecological systems. The report presents a detailed ecological research agenda, and should be read by all those interested in ecology and environmental science.

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