Phenology and climate change

The subject of climate change continues to be a topic of hot debate at global conventions, world summits and international conferences and symposia. Global climate change is a reality, a continuous process that needs to be taken seriously, even though there are large uncertainties in its spatial and temporal distribution. Many evidences have been gathered to depict that climate change is taking place. Over the past 100 years, the global average temperature has increased by approximately 0.6°C and is projected to rise at a rapid rate[1]. The third assessment report from the Intergovernmental Panel on Climate Change (IPCC) projects that the earth's average surface temperature will increase by 1.4 to 5.8°C between 1990 and 2100, if no major efforts are undertaken to reduce the emissions of greenhouse gases. This is significantly higher than what the panel predicted in 1995 (1.8–3.5°C). Although several species have responded to climatic changes throughout their evolutionary history, there is concern as to how different ecosystems and populations will respond to this rapid rate of change. India is a land with a wide range of variation in climate, altitude and physiography. The wide variety in physical features and climate situations has resulted in a diversity of habitats such as deserts, deciduous, evergreen and moist forests, mangroves and alpine grasslands. There is considerable divergence of opinion about the magnitude of climate change predicted for the Indian region and its effect on plants. Both climate models and observational studies give conflicting and hazy pictures of the effect of climate change on vegetation. The assessment of impacts of projected climate changes on natural ecosystems is not based on accurate scientific modelling or field studies at regional level, but on current vulnerability and global level projections of impacts from the literature[2]. Climatic conditions determine where individual species of plants can reproduce. The species in some ecosystems are so strongly adapted to the long-prevailing climatic pattern that these are vulnerable even to modest changes. The alpine forests at high elevations in Himalayas exist where they do, because the plants that comprise these are adapted to the cold conditions that would be too harsh for other species. The desert vegetation is adapted to high summer temperature and aridity of the region. Forests in the Western Ghats are adapted to moderate temperature and high rainfall. Erratic rainfall in these regions can create problems for species regeneration. If drought conditions persist in high rainfall areas, grasses and shrubs would start competing with tree seedlings, leading to formation of completely different ecosystems[3]. Rapid sea-level rise can surpass the ability of plants to disperse, making it impossible for coastal wetland ecosystems to sustain themselves[4].

Phenology refers to the study of seasonal appearances and timing of life-cycle events. It involves study of the response of living organisms to seasonal and climatic changes of the environment in which they live. Seasonal changes include variations in the duration of sunlight, precipitation, temperature and other life-controlling factors. Plants are adapted to the annual seasonal cycle and all the life-cycle stages are regulated by seasonal atmospheric changes. It is important to keep track of cyclical events such as appearance of buds, leaves, first bloom, pollination and fertilization and dispersal of seeds from year to year, and determine how they relate to the weather patterns. For plants, the seasonal timing of such events can be critical to survival and reproduction[5]. Phenological patterns are most diverse and least understood. Phenology offers evidence of climate change happening now and helps in assessment of the significant effect on plants in future. Erratic weather patterns will have long-term effects on life-cycle stages and phenological patterns of almost all plant species.

Change in plant phenology may be one of the earliest observed responses to rapid global climate change and could potentially have serious consequences both for plants and animals that depend on periodically available resources. The species in some ecosystems are so strongly adapted to the long-prevailing climatic pattern that these are vulnerable even to modest changes. Phenological changes can be observed visually and no specialized techniques or sophisticated equipments are required to monitor how plants respond to climatic variation. Parameters such as appearance of leaf primordia, leaf fall, timing of opening of flowers, anthesis and period of maximum bloom can be recorded right at the field site. These parameters generate authentic data to study the effect of climate change on phenology. Little is known about the reproductive cycle and ecological factors necessary for flowering and reproduction in individual species. Increase in level of carbon dioxide in the atmosphere and consequent global warming may have a profound effect on the flowering time of plants[6].

Phenological changes have been studied by many plant scientists in Europe. It has been observed that in certain plant species leaf unfolding in spring has advanced by up to six days, whereas the autumn leaf colouring is delayed by 4–8 days. Similar changes have also been observed in flowering pattern of many other tree species[7]. Abu-Asab *et al.*[8] have studied changes in first-flowering times of over 100 plant species, representing 44 families of angiosperms for 29 years (1970–99) in Washington DC. They observed that most of the trees now flower 3–5 days earlier than they did some years ago.

Although the onset of flowering in most plants is clued by photoperiodism, break in dormancy in many plants is triggered by temperature. For some plants growing in temperate regions, a period of winter dormancy is essential for flowering to take place. Biennial plants such as chrysanthemums, celery and sugar beet need low-temperature treatment for flowering. The shoot meristem is sensitive to temperature changes and severe fluctuation will bring a halt in flowering response. Thus, global warming will affect flowering of many plant species. The dependence of current phenological patterns on high interannual and spatial variability suggests that plant species may suffer maximum due to phenological deviations caused by climate change. In fragmented vegetational areas the consequences of climate change on flowering, fruit development and seed dispersal will be more serious. Detailed life-history studies, including phenology, breeding system, pollination, fruit and seed set, dispersal mechanisms and seed germination, could provide valuable clues about the effect of projected climate changes. Rare and endangered species are important to be considered in the context of sensitivity analysis of global climate change, particularly because many of such species are already facing reproductive stress.

Studies carried out in India are either fragmentary or inconclusive. In alpine Himalayas, while some plant species such as rhododendrons complete their flowering and seed formation in the short spring, others such as conifers spread the life cycle to the favourable summers of 2–5 successive years. How such species will respond to longer and warmer spring needs to be investigated? Some deciduous trees may leaf earlier and produce flowers in advance than before. This may also result in the appearance of predators who feed on leaves of these trees and pollinators of the flowers earlier than expected. The different responses may disrupt the complex linkages between different trophic levels in nature and disturb the ecological balance. An understanding of how vegetation responded to past climate is needed for predictions of response of plants to future climate change. We urgently need to develop a scientific database on chronology of major phenological events for Indian flora. This can be done with the help of the large number of botanists in the university departments and colleges, who will generate data at the regional level through a close networking. The Ministry of Environment and Forests is currently running some projects in this area. It is also important for funding agencies to invest grants in this thrust area, so that the effect of predicted climate change on ecosystems and species is studied at regional and local levels, and steps for possible mitigation are planned in advance.

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Need for reassessment in the post-tsunami scenario

The large tsunami (26 December 2004) triggered by the Sumatra earthquake has warned the earth sciences community to relook into the morphology, structure and tectonics of Andamans and continental margin of Tamil Nadu. Earlier geophysical studies related to northern offshore Cauvery basin, Tamil Nadu between Vedaranyam and Pondicherry, indicated existence of two major fault lineaments; one off Pondicherry (12°N) and the other off Nagapattinam (10°45′N) trending E–W[1]. Magnetic analysis indicates that the E–W trending lineament inferred over continental margin off Nagapattinam can be spatially correlated to lineament associated with down-faulted basement from earlier aeromagnetic studies. Two fault zones have been demarcated from gravity studies[2]. One of them coincides with the epicentre of Pondicherry earthquake of September 2001. Tamil Nadu, in particular Nagapattinam, has experienced major wrath of the tsunami. Various organizations have carried out studies in the aftermath of the tsunami in Andamans and in Tamil Nadu. However, in view of the proximity of southern Tamil Nadu, being almost perpendicular to the line of rupture of the seismically active Andamans, it is of paramount importance to carry out geophysical studies over coastal and shelf regions to analyse the tectonic changes leading to demarcation of new lineament patterns of Tamil Nadu margin and contiguous land part in the post-tsunami scenario. This can be carried out in two stages. (i) Bathymetry, magnetic, single and multichannel seismic reflection studies between 10°N and 12°30′S, and 80° and 82°E, in order to compare the earlier results (pre-tsunami) to note deviations in lineament pattern. (ii) Geophysical studies over coastal regions of Tamil Nadu for correlating with offshore results for better understanding of the land–ocean tectonics.

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