The Indian critical zone – a case for priority studies

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The dawn of the 21st century saw the emergence of a new domain in earth science when the US National Research Council (NRC) recommended the integrated study of the 'critical zone' (CZ) as one of the most compelling research areas in earth sciences. NRC defined[1] CZ as 'a heterogeneous, near surface environment in which complex interactions involving rock, soil water, air and living organisms regulate the natural habitat and determine availability of life sustaining resources.' It was realized that the growing population is putting stress on the ecosystems and services provided by them. Thus, in order to make life sustainable on the Earth it is important for earth scientists to understand the processes impacting ecosystem. Realizing the need of the hour, several critical zone observatories (CZOs) were established to monitor the processes in CZ.

There are several examples where soil erosion has been shown to be a contributing factor behind the demise of past civilizations[2,3]. Erosion and loss of fertility of soil pushes the civilization to a threshold beyond which major natural calamities and/or war results in the downfall of the civilizations[3]. Soil erosion due to continuous agriculture, and in some cases wrong agricultural practices, leads to the loss of soil fertility (Figure 1); this results in a demand and supply gap causing the collapse of the society. This has happened in the past and recent studies have shown that soils in large part of the world have degraded in the past several decades[4]. Modern civilization is on similar course as the past civilizations, but due to scientific advancements we have been able to keep the threats to society at some distance. However, this global threat is getting closer, and more so for India as it is predicted that the Indian population will increase from 1.2 to 1.5 billion by 2030.

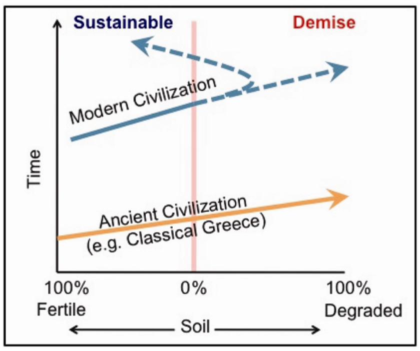

Figure 1. A diagram showing trajectory of the past and modern civilizations and its link to soil fertility. The modern civilization has been able to sustain and increase the productivity by means of technological and scientific advances but still it is moving towards degraded soil and it is up to us to either continue on the same trajectory or reverse it towards fertile soil by changing agricultural practices.

This growing population will lead to increase in the demands on ecosystem services, thus putting stress on the ecosystem. Therefore, it is essential to study the CZ processes that control the ecosystem. Due to the fact that the demand of ecosystem services is going to increase and also, humans are making rapid and profound changes in the Earth's surface, there is a need to critically analyse the Earth's surface and ask some high priority science questions[5]. We need to ask the questions like – What is the rate of soil production in different terrains of the country? What is the rate at which we are loosing our soil? Can we distinguish and quantify the soil loss due to natural processes and anthropogenic activities? Can we further quantify and segregate between anthropogenic activities causing the soil loss? What is the relationship between the rainfall and soil erosion? What is the rate at which our groundwater is extracted and at what rate are they getting recharged? How much of the subsurface water is taken up by different species of plants and how much flows into the surface water bodies? Have anthropogenic activities influenced the rate of extraction and recharge of the groundwater? How are anthropogenic activities and various physical processes affecting microbes? How is water moving over and under the surface? How does subsurface water receive nutrients from the soil and rock, and interact with the ecosystem? What are the proxies to determine soil health? What responds first to the declining health of the soil? Are there any markers to determine it? How can we restore health of our degraded soils? Are these practices similar for different types of terrains? Finally, can we predict the health trajectory of our soil? To achieve this goal CZOs are being established around the world. There are around 24 CZOs present globally funded by the National Science Foundation (NSF) of United States and the Soil Transformations in European Catchments (SoilTrEC) of European Commission. In contrast, in spite of having vast land area with diverse geologic and climatic conditions (Figure 2), there is only one CZO – located in the Kabini River basin (in Karnataka) – in India. Just one basin cannot be representative of the processes occurring elsewhere in India; in order to understand the CZ processes, there is a need to establish a network of observatories. India has tectonically active mountain belts (i.e. Himalaya) interacting with a well-established monsoon system. Thus, setting up of an observatory would also contribute to the world science by providing datasets from a different geologic setting.

India is unique in terms of its lithological and climatic variability. Climate varies from Thar Desert in Rajasthan receiving less than 250 mm/yr to Mawsynram in Meghalaya recording 11,872 mm/yr rainfall (Figure 2); lithology varies from vast Indo-Ganga alluvial plains in north to Archean complexes in the south (Figure 2). In terms of topography we have the world's highest mountains to one of the world's largest deltaic system, i.e. Ganga–Brahmaputra. In terms of tectonics, we have tectonically active Himalaya in the north and stable Archean craton in the south. This variability requires a huge effort to understand the CZ processes in these terrains. CZ studies in a few locations may not be sufficient to understand the earth surface processes in all the locations. On the basis of topography, lithology and climate at least ten CZOs with several satellite sites are required to develop the first order understanding. The potential sites are: Ladakh, Southern slope of NW Himalaya, NE Himalaya, Western Indo-Gangetic Plains, Central Indo-Gangetic Plains, Eastern Indo-Gangetic Plains, Area around Thar Desert, Western Ghats Area, Southern Indian Plataeu, Coastal Area.

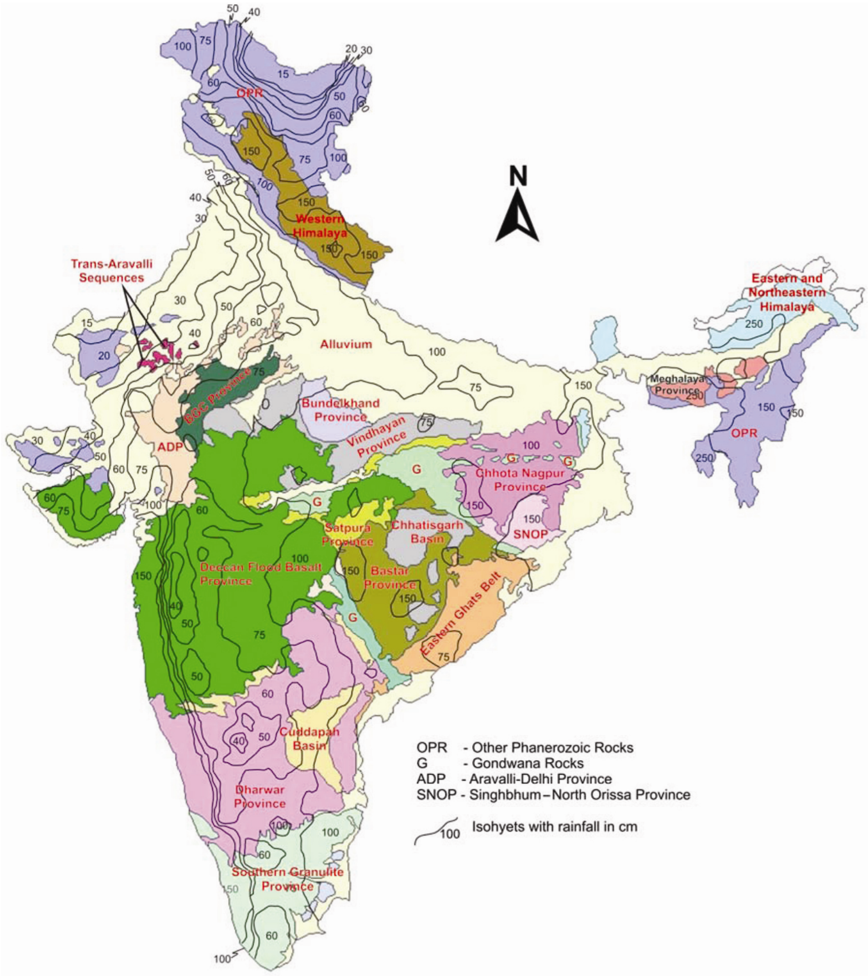

Figure 2. Map showing rainfall and geological provinces in India (Source: Rainfall map: India Meteorological Department; Geological Provinces; ref. 6).

As soil lies at the heart of CZ research, it is important that pedologists, geomorphologists, geochemists, hydrologists, environmental scientists, computational scientists and biologists come together to resolve these important issues and obtain answers which can lead us to model the future scenario of the soil condition in the country. This will help in the evolution of management strategies that optimize soil health and agricultural output.

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