National Institute of Disaster Management

Ministry of Home Affairs, Government of India

One Week Faculty Development Programme

on

Understanding the Critical Zone and Natural Hazards

Date: 19th – 23rd January 2026

Collaborator:
Department of Geology,
University of Delhi

Concept Note

1. Introduction

The term Critical Zone in the current context is defined as "*...the 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.*" (NRC, 2001). In simpler words, Critical Zone is broadly defined as the thin outer skin of the planet extending from the top of the vegetation canopy to the bottom of the circulating groundwater. This is that zone of the planet where all the spheres of the planet, namely, lithosphere, hydrosphere, atmosphere, and biosphere interact with each other in a complex web of feedback mechanism (fig 1). The interaction of the spheres is delicately balanced with each other. Since the system works on a feedback mechanism, a change in any of the parameters in any of the spheres is reflected in varying magnitude in the other spheres. Such stochastic events tend to give rise to extreme events which can be termed as 'hazards' from an anthropocentric perspective.

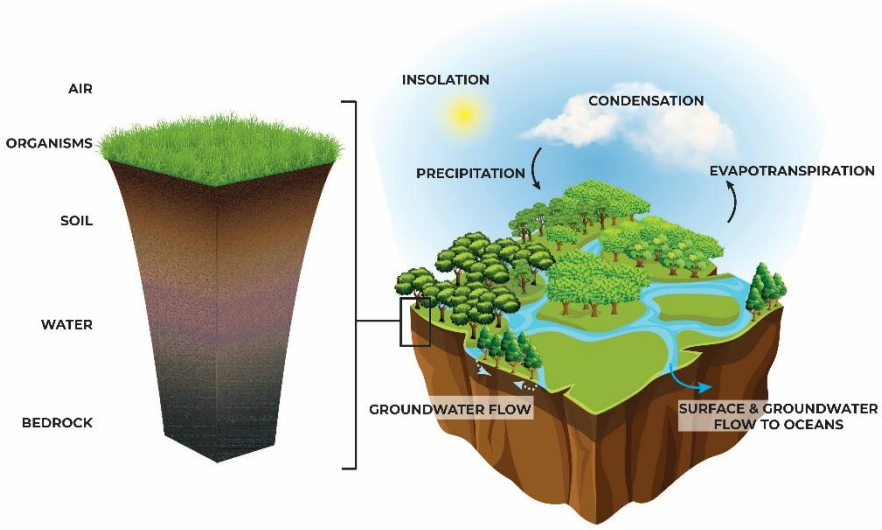

Figure 1: Vertical profile of the Critical Zone and its relationship with surface geomorphic units (after NRC, 2001).

These hazards have the potential to adversely affect the biosphere, including humankind. Under certain circumstances, the hazards can convert into disasters. The Great Acceleration (Steffen et al., 2015) shows an abrupt change in

anthropogenic activities that is destabilizing the functioning of the Critical Zone. In order to restore the natural balance, there has been a rise in the frequency of extreme events since the Great Acceleration period.

It is imperative to decouple the processes of the Critical Zone and understand its functioning so as to understand the dynamics of the hazards better. A better understanding of the hazards would strengthen the pre-disaster phase of the disaster management cycle. This would not only assist in reducing the risk of pulsating catastrophic disasters such as flash floods, landslides, cloudbursts etc., but also monitor the indicators of gradualistic disasters such as water and air contamination, hillslope creep, heatwave/coldwave, water scarcity etc. Understanding the nature of interactions, controls, and dependencies of each of the components of the Critical Zone would further be helpful in forecasting the direct and indirect effects of the hazards, so that adequate mitigative and preparedness measures can be taken up with a significant lead time.

1.1.Critical Zone Observatories

The Critical Zone processes operate as coupled physical, chemical, and biological processes. The response of the systems is recorded in air (very short term), river/ocean (intermediate to long term), and soil/sediment (very long term). A collaboration of experts from geology, pedology, zoology, botany, microbiology, geochemistry, hydrology, geomorphology, geophysics, environmental science, and atmospheric science is required to retrieve and interpret these records. This led to the development of Critical Zone Observatories (CZOs) and the Global Critical Zone Network.

Critical Zone Observatories are scientific monitoring and experimentation setups in relatively pristine areas of the planet with diverse geological and climatic settings. The modus operandi of the CZOs is laid down as seven major objectives (Banwart et al., 2011, 2013):

- Hypothesis testing
- Process understanding across temporal and spatial scales
- Development of mathematical models and geomorphic transport laws
- Utilization of multiple sensor and sampling methods
- Installation and utilization of high-density instrument arrays
- Undertaking time series/real-time measurements of coupled process dynamics
- Combination of large datasets with numerical simulations

The concept of CZO was initiated by the National Science Foundation, United Stated of America, in 2006 in three sites but was soon expanded to a dense network across USA. The Global network formed when European nations and China established their network of CZOs. At the time, there was only one operational CZO in India under Indian Institute of Science (IISc) Bangalore. With the support of Ministry of Earth Sciences, Government of India, there are 12 operational CZOs across the country established by the premium institutes of India such as NCESS Trivandrum, NEERI Nagpur, University of Delhi, IIT Gandhinagar, NIH Roorkee, and others (fig 2).

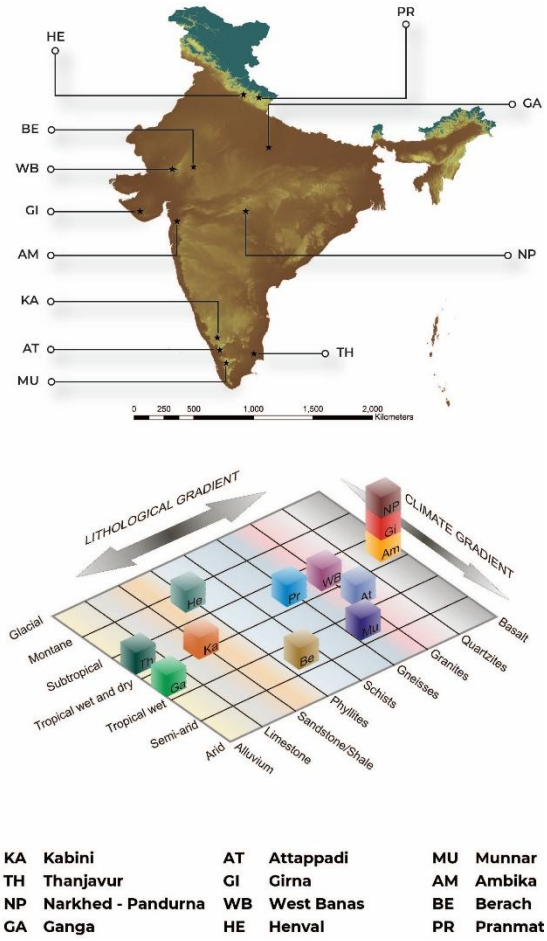

Figure 2: Indian Critical Zone Observatories and their geological and climatic profiles (after Pujari et al., 2020)

India is on the path of establishing its own network of indigenous CZOs to understand the Indian Critical Zone systems and manage the risks of the natural hazards such as floods, landslides, water scarcity, air pollution, water pollution, land degradation, etc. Simultaneously, better understanding of the system would also help in developing the country in a sustainable manner. However, owing to the diversity of the country in terms of physiography, geology, climate, and culture, the country needs more CZOs to be established, especially in the islands, East coast, deltaic region, Northeastern region and the cold deserts of Karakoram.

As stated by NRC (2001), the critical zone regulates the natural habitat and is essential to sustain life on Earth. The health and the optimum functioning of the Critical Zone is essential for the Biosphere to thrive.

2. Objective of the Training Programme

This training programme aims to introduce the concept of critical zone studies and research to the Indian scientific community of faculties and scientists.

This novel area of research is in its nascent stage in India and owing to the diversity of physiography of India, the

3. Key topics of Discussion

- **Critical Zone and its basic concepts**
- **Anthropocene** – Concept and Implications
- **Soil and Land** – Mass movement hazards, soil health and control of microbial communities, root zone interactions, and effects of degradation
- **Water** – Meteorological processes and hydrological pathways, water chemistry imbalances, effects of hydrological processes on aquatic biodiversity
- **Field Visit** – Yamuna Biodiversity Park

- **Tools and techniques** for monitoring and modelling processes within the critical zone – mass movements, hydrology, water and air quality, aquatic biodiversity, soil microbial biodiversity, soil and water biogeochemistry.
- **Hands-on exercises** of topographic analysis, river styling and classification, hydrochemical facies identification and water quality assessment, and flood assessment and hydrograph study.

4. Expected Outcomes

- Participants will have a basic understanding of the Critical Zone system.
- Participants will have a holistic idea about the functioning of the natural systems and the linkages between various spheres.
- Participants will have an idea of imparting a comprehensive knowledge of the functioning of the natural system in undergraduate and postgraduate classroom teaching, at the same time emphasizing on their area of interest and expertise.
- Participants will get an idea of the research methodology followed in critical zone studies and, therefore, will motivate experts of various disciplines to work on practical problems.

5. Nature of Participants

- Scientists from physical science and natural science fields.
- Faculties of physical science and natural science departments of colleges and universities.
- Early career researchers from physical science and natural science fields.

5.1.Number of Participants: 40

Course Schedule

Day-1 (Monday) Inaugural Session		
0930-1000	Registration	**Dr. Arkaprabha Sarkar** Assistant Professor NIDM **Dr. Prerna Joshi** Assistant Professor NIDM Course team
1000-1030	**Inaugural Session**	**Opening Remarks - Dr. Arkaprabha Sarkar** *Course Coordinator* **Welcome Address - Shri Madhup Vyas, IAS** *Executive Director, NIDM* **Inaugural Address – Prof. Pankaj Srivastava** *HoD, Department of Geology, University of Delhi* **Keynote Address – Prof. Vimal Singh,** *Department of Geology, University of Delhi* **Vote of Thanks - Col Manoram Yadav SM** *Joint Director, NIDM*
1030 - 1145	**Plenary Talk: The Anthropocene**	**Prof. S.K. Tandon**, *Professor Emiritus, University of Delhi*
1145-1200	**Group Photo and High Tea**	

Time	Sessions	Faculty/ Institution	Andragogy
Day-1 (Monday) 19.01.2026			
1200-1300	**Session 1: Participants' Introduction, Pre-course Assessment & Expectation of the course** ***Session Objective:*** *To facilitate participant introductions, capture expectations, and conduct a pre-course assessment to establish baseline understanding and align the programme with participants' academic and professional needs.*	Dr. Arkaprabha Sarkar Assistant Professor NIDM Prof. Vimal Singh Professor DU Young Professional NIDM	Discussion and PPT

1300-1400	**Lunch**		
1400-1530	**Session 2: Introduction to Critical Zone** ***Session Objective:*** *To provide an understanding of the basic concepts of Critical Zone, Critical Zone Observatories (CZOs) and familiarize participants with India's CZO programme.*	Prof. Vimal Singh Professor DU Young Professional NIDM	Interactive Lecture, PPT and Group Discussion
1530-1545	**Tea**		
1545-1700	**Session 3: Soil – The Nucleus of the Critical Zone** ***Session Objective:*** *To orient participants on soil formation, dynamics and movement within the landscape system, and identification hazardous zones in the landscape systems.*	Dr. Arkaprabha Sarkar Assistant Professor NIDM Young Professional NIDM	
1830 - 2000	**Movie Screening**		
Day-2 (Tuesday) 20.01.2026			
1000-1015	Recap & Key Takeaways from Day 1	Volunteer Participant	Creative Activity/ Role Play/ PPT
1015-1115	**Session 4: Life in soil – Understanding Soil Health at a microbial level** ***Session Objective:*** *To explore the role of microbes and microbial activity in the soil and root zone region, and understand the role of soil dynamics.*	Dr. Vijay Shridhar Assistant Professor Doon University Young Professional NIDM	Interactive Discussion
1115-1130	**Tea**		
1130-1300	**Session 5: Water – The thread of Critical Zone** ***Session Objective:*** *To understand the role of water in uniting the planetary spheres, the hydrological cycle and potential hazards*	Prof. Vimal Singh Professor DU Young Professional NIDM	PPT and Group work
1300-1400	**Lunch**		

1400-1445	**Session 6: Landscape-scale hydrological events** ***Session Objective:*** *To understand the changing geomorphic thresholds during extreme hydrological events.*	Dr. Arkaprabha Sarkar Assistant Professor NIDM Young Professional NIDM	PPT and group work
1445-1530	**Session 7: Wetlands – the marriage of Hydrosphere and Lithosphere** ***Session Objective:*** *To understand the wetland system and ecology with emphasis on wetlands of delhi.*	Dr. Prerna Joshi Assistant Professor NIDM Young Professional NIDM	PPT and group work
1530-1545	**TEA**		
1545-1630	**Session 8: Assessment of Hydrochemical facies and water quality assessment** ***Session Objective:*** *To understand the different hydrochemical facies and identify them on a Hill-Piper plot*	Dr. Prerna Joshi Assistant Professor NIDM Young Professional NIDM	PPT and group work
1630-1730	**Session 9: Aquatic biodiversity and interaction with the critical zone** ***Session Objective:*** *To understand the aquatic macroinvertebrates and vertebrate biodiversities*	Prof. Neeta Sehgal Professor DU Young Professional NIDM	Interactive Discussion
1830-2000	**Movie Screening**		
Day-3 (Wednesday) 21.01.2026			
0945-1000	Recap & Key Takeaways from Day 2	Volunteer Participant	Creative Activity/ Role Play/ PPT
1000-1100	**Session 10: Living with Floods** ***Session Objective:*** *To critically examine the causes, patterns, and impacts of floods in India and to explore research-based approaches and adaptive strategies for sustainable flood risk management.*	Prof. Vikrant Jain Department of Earth Sciences IIT Gandhinagar Young Professional NIDM	Interactive Lecture and Discussion
1100-1115	**Tea**		

1115-1200	**Session 11: Concepts of Ecohydrology** ***Session Objective:*** *To explore synergistic interactions of the hydrological functions and ecosystem, and its role is maintaining resilience of ecosystems*	Prof. Sumit Sen Young Professional NIDM	Interactive Lecture and Discussion
1200-1300	**Session 12: Characteristic and Role of Groundwater in the Critical Zone** ***Session Objective:*** *To explore the mechanism of groundwater circulation in the landscape and its role in Critical Zone processes.*	Dr. Paras Pujari, NEERI Nagpur	Interactive Lecture and Discussion
1300-1400	**Lunch**		
1400-1500	**Session 13: Topographic analysis with steepness index and chi analysis** ***Session Objective:*** *To understand the basic concept of steepness index and data interpretation*	Dr. Rahul Devrani Assistant Professor OP Jindal Global University Young Professional NIDM	Interactive Lecture, Discussion, and hands-on exercise
1500-1600	**Session 14: Mass movement processes and risk in the CZ** ***Session Objective:*** *To explore the process of mass movements and its potential impacts and risks on the Critical Zone.*	Prof. Ashish Saha, Department of Geography, University of Delhi	Interactive Lecture and Discussion
1600-1615	**Tea**		
1615-1700	**Session 15: Understanding the Urban Critical Zone system** ***Session Objective:*** *To understand superimposed anthropogenic processes on the natural critical zone and functioning of the urban critical zone.*	Dr. Arkaprabha Sarkar, NIDM Prof. Vimal Singh, Department of Geology, University of Delhi	Interactive Lecture and Discussion
1830 - 2000	**Movie Screening**		
Day-4 (Thursday) 22.01.2026			
1015-1115	**Session 16: Understanding Thin skin tectonics and Himalayan Earthquakes**	Prof. Malay Mukul	Interactive Lecture, Activity and Discussion

	Session Objective: *To build understanding of thin skin tectonics and its role in Himalayan earthquakes.*	Department of Earth Sciences IIT Bombay Young Professional NIDM	
1115-1130	**Tea**		
1130-1215	**Session 17: Nature Based Solutions and the Critical Zone** ***Session Objective:*** *To enhance understanding of nature based solutions for hazards and their interactions with critical zone.*	Dr. Prerna Joshi Assistant Professor NIDM Young Professional NIDM	PPT and Group discussion
1215-1300	**Lunch**		
1300-1730	**Visit to Yamuna Biodiversity Park** ***Session Objective:*** *To demonstrate tools, techniques, methodologies and field examples of:* • *Restoration of degraded ecosystems* • *Development of Green Patches within metro cities* • *Nature-based solutions of flood control and management*		
Day-5 (Friday) 23.01.2026			
0945-1000	Recap & Key takeaways from Day 4	Volunteer Participant	Creative Activity/ Role Play/ PPT
1000-1045	**Session 18: Environmental eDNA – Sampling and assessment** ***Session Objective:*** *To understand the concept of environmental DNA, sampling of eDNA from water bodies, and potential applications.*	Dr. Rishikesh Krishan Laxmi Faculty University of Delhi Young Professional NIDM	
1045-1130	**Session 19: Real Time Kinematics and GNSS** ***Session Objective:*** *To understand the fundamental concept of Global Navigation Satellite System and applications of real time kinetics.*	Prof. Malay Mukul Department of Earth Sciences IIT Bombay Young Professional NIDM	
1130-1145	**Tea**		

1145-1230	**Session 20: Hydrological modelling** ***Session Objective:*** *To introduce participants to hydrological modelling and open source softwares available for*	Dr. Gagandeep Singh Assistant Professor NIDM Young Professional NIDM	PPT and Group discussion
1230-1315	**Session 21: Impact of Glacial Geomorphology on CZ processes** ***Session Objective:*** *To understand glacial processes and their roles in controlling high altitude critical zones.*	Dr. Naresh Rana, Department of Geology, University of Delhi	Lecture cum interaction
1315-1400	**Lunch**		
1400- 1500	**Session 22: River styles** ***Session Objective:*** *To assess the river styles of various fluvial systems through group activities.*	Dr. Parv Kasana Project Scientist (PBHCZO) Young Professional NIDM	Group Work
1500-1600	**Session 23: Cosmogenic Radionuclides and Optically Stimulated Luminescence** ***Session Objective:*** *To introduce the principles cosmogenic radionuclides and luminescence and their applications in erosion rate calculations.*	Dr. Arkaprabha Sarkar Assistant Professor NIDM Young Professional NIDM	PPT and Group discussion
1600-1615	**Tea**		

1615-1710	**Valedictory Session**	
1615-1630	Course Summing up	**Dr. Prerna Joshi** *Course Coordinator*
1630-1640	Outcomes achieved	**Prof. Vimal Singh** *Professor, University of Delhi*
1640-1645	Way Forward	**Shri Randeep K Rana** *Senior Advisor, NIDM*
1645-1705	Certificate Distribution & Valedictory Address	**Shri Madhup Vyas, IAS** *Executive Director NIDM*
1705-1710	Vote of Thanks	**Col Manoram Yadav SM** *Joint Director NIDM*

No Objection Certificate

TO WHOMEVER IT MAY CONCERN

This is to certify that Prof./Dr./Mr./Ms. _____(name) is working as _____(designation) in_____(department) at _____ (university/institute/organisation). He/she is permitted to attend the five-day Faculty Development Programme on "Understanding the Functioning of the Critical Zone during Natural Hazards" that is being jointly organized by National Institute of Disaster Management and Department of Geology, University of Delhi from 19th to 23rd January 2026 at NIDM Rohini campus.

This letter recommends that when selected, the above named personnel will be relieved in time to participate in the above course.

Place:

Date:

Signature

(Head of the department/institute/organization or supervisor)