Long Term Ecological Observatories

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LTEO INDIA

Contents

Introduction

The Need for Climate-Change Related Research

Human activities since the mid-18th century have led to an unprecedented increase in the concentration of heat-trapping gases such as carbon dioxide and methane in the atmosphere. The resulting increase in global average temperatures and concomitant long-term and large-scale changes in weather patterns are referred to as *climate change*.

According to the Inter-governmental Panel on Climate Change (IPCC), climate change can have severe impacts on a range of global-scale phenomena including ecosystem functioning, food and freshwater availability, and increased disease burden associated with extreme weather events. Recent examples where climate change is implicated as a major driver of biodiversity and ecosystem change include desertification of tropical semiarid rangelands, conversion of Arctic Tundra to shrub land, bleaching of coral reefs, and sudden collapses of fisheries. Multiple lines of evidence suggest that there are certain critical ecological thresholds where small changes in one or more external conditions result in large and persistent changes in an ecosystem. There is, thus, an urgent need for research on climate change and its impacts. This need was recognized in 1992 with the adoption of United Nations Framework Convention on Climate Change (UNFCCC), whose ultimate objective was to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent adverse effects on natural ecosystems and humankind.

In the light of the urgency of bringing biodiversity to the forefront of discussions regarding land- and ocean-based climate mitigation and adaptation strategies, IPCC and International Science-policy Platform on Biodiversity and Ecosystem Services (IPBES) came together to conduct a workshop virtually in December, 2020 (due to pandemic) to address climate change and its effects on the biodiversity. It was a first ever initiative where the two governmental bodies came together to form a collaboration which focused on exploring various complex connections between biodiversity and climate change. It also addressed the synergies and trade-offs between climate change mitigation and adaptation, and biodiversity protection. This included exploring the impact of climate change on biodiversity, the capacity and limits of species to adapt to climate change, the resilience of ecosystems under climate change considering thresholds to irreversible change. It also addressed the contribution of ecosystems to climate feedbacks and mitigation, against the background of an ongoing loss in the biomass of biota and associated risks to key species and biodiversity as well as ecosystem services.

Countries such as India, whose economies are closely tied to climate-dependent sectors such as agriculture and forestry, have been identified as being particularly vulnerable to the effects of climate change. India faces the dual challenge of a large, vulnerable population and the lack of fine-scaled information on which to base mitigation and adaptation measures. Information is particularly needed on how climate change is likely to alter the distribution and quality of natural ecosystems and resources, and the impacts this will have on the livelihoods of people.

India's Response to Climate Change

India is party to all major forums, conventions, treaties and action plans to mitigate the effects of the climate change. These include the UNFCCC and treaties within it such as the Kyoto Protocol and the Paris Agreement, and several other global climate-change initiatives. In addition, India announced its Intended Nationally Determined Contributions (INDC) ahead of the UN Conference of Parties, 2015, in which India committed, amongst other things, to enhancing its carbon sink by reforestation, increasing cleaner economic development, investing in adaptation programs to fight climate change, and investing in knowledge management and capacity building.

Information regarding the long-term effects of climate change on natural and human-modified ecosystems in India is lacking particularly due to a dearth of long-term ecological studies. Although a few isolated long-term research programmes on forests and select animal species exist, the Ministry of Environment, Forest and Climate Change recognized the need for a coordinated, national-level programme specifically targeting ecological challenges arising from climate change.

Long-Term Ecological Monitoring Programmes Across The World

Across the world, various monitoring programmes have been established to integrate social and natural science research in the context of climate change. Some of the leading networks include:

a. Long Term Ecological Research network set up by the National Science Foundation, USA (US-LTER), which considers natural and social systems as a single, integrated ecological system.

b. Nutrient Network (NutNet), which aims to understand general patterns in how ecosystems respond to different aspects of global change in 40 countries.

c. National Ecological Observatory Network (NEON) for North America, which attempts to understand processes operating at continental scales.

d. Long Term Socio-economic and Ecological Research (LTSER), which covers 21 European countries was also formed in accordance with the successful US-LTER programme.

e. The Forest Global Earth Observatory (ForestGEO) is a global network of scientists and forest research sites dedicated to advancing the long-term study of the world's forests to understand and predict the forest dynamics in an era of rapidly changing landscapes and the climate.

LTEO: India's Long-Term Ecological Monitoring Programme

Recognizing the need for long-term ecological research, the Ministry of Environment, Forest and Climate Change launched the Long-Term Ecological Observatories (LTEO) programme in 2015. LTEO was envisioned as a multi-disciplinary and multi-institutional in which government and non-government entities come together to address the larger global crisis and carry out activities across six major biogeographic zones in India. Ecological and social perspectives were incorporated while developing the LTEO Science Plan, which was released at the Paris Climate Summit by the Minister for Environment, Forest & Climate Change in 2015. Each LTEO site will have a research focus that will maximize understanding of the specific ecological system ecosystem change and the diversity of challenges that surround the research site. The LTEO programme aims to monitor ecosystems over time in order to understand the drivers of ecosystem change (changes in plant and animal populations and soils) across different spatial scales.

LTEO Focuses on The Following Goals Across Different Themes and Biogeographic Zones:

a. To understand the biophysical and anthropogenic drivers of ecosystem change and their effects on ecological responses.

b. To understand the ecology of major biomes at multiple spatial and temporal scales, through long-term and interdisciplinary research.

c. To inform scientists, policy makers, and the public about the implications of environmental change to the ecological systems.

d. To promote training and learning about environmental change through long-term ecological research and monitoring within India.

The LTEO programme covers a range of representative landscapes in the country. Doing so facilitates an understanding of the similarities and differences in the links between climate change and ecological processes across different landscapes.

In its first phase, the LTEO programme will monitor a range of themes, and taxa that were selected by a committee set up by the MOEFCC. The themes include soils, forests, grasslands, arthropods, freshwater fishes, herpetofauna, birds, animal movement, and coastal and marine ecosystems. Long-term ecological observatories will be initially established in the following six regions:

1. Western Himalaya
2. Eastern Himalaya
3. North-Western Arid Zone
4. Western Ghats
5. Central India
6. Andaman and Nicobar Islands

In the second phase of the programme, the LTEO programme will focus on expanding the research in different landscapes and include more themes or taxa. It will also aim to establish new LTEO research stations that increase representation of understudied systems across the country.

Western Himalaya

The Western Himalaya represents a vast landscape covering a large elevational gradient with its distinctive vegetation structure. The sub-montane regions at the Himalayan foothills and Shiwaliks with elevation of 500m -1000m are dominated by sal forest and other mixed deciduous forests. The mid-elevations from 1000 m -2000m have mixed broad-leaf oak forests and conifer forests. Beyond 3000m, the vegetation is dominated by alpine meadows. Above 4000 m, the Western Himalayas are characterized by arid shrub-steppes found in Ladakh and Spiti. To cover this vast landscape, study sites will be established along an elevational gradient in the state of Uttarakhand, from the Terrain Corbett Tiger Reserve to alpine ecosystems in Kedarnath Wildlife Sanctuary. In the future, this may be extended northwards into the arid shrub-steppes of Spiti in Himachal Pradesh in order to cover the entire range of Western Himalayan habitats.

Host Institution:

Wildlife Institute of India (WII), Dehradun

Field Stations:

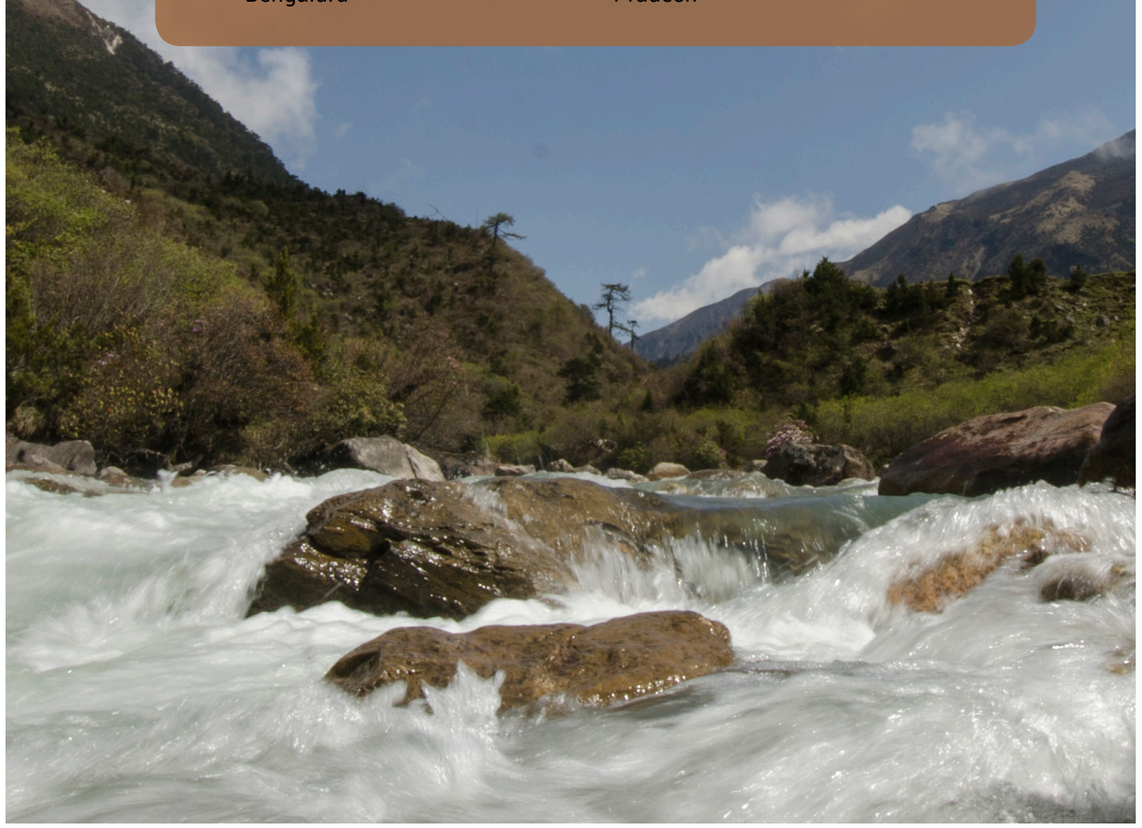
Ramnagar and Mandal in Uttarakhand

Eastern Himalaya

The Eastern Himalayan region is large and complex in topography and diversity and spans the Himalaya and the Indo-Burma Biodiversity Hotspots. The range of habitat types is similar to the Western Himalayas in some respects, although the bio-geographical and evolutionary origins of the flora and fauna are distinct. Species richness across taxonomic groups is amongst the highest globally, and several taxa show high endemism, and extreme range restriction. In recent years, a considerable number of species new to science have been discovered from this region, including a large number of amphibians and reptiles, and even mammals and birds. This highlights that much of the Eastern Himalaya's biodiversity still remains unknown to science. Several sites will ideally have to be established here to capture this diversity but, in Phase 1, an elevational transect covering different vegetation types from Pakke Tiger Reserve in the foothills through Eagle Nest Wildlife Sanctuary and up to Sela pass in Arunachal Pradesh will be established.

Host Institution:
Centre for Ecological Sciences (CES), Indian Institute of Science, Bengaluru

Field Stations:
Seijusa, Bomphu and Ramalingam in Arunachal Pradesh



North Western Arid Zone

Vast tracts of northwestern India fall in the arid and semi-arid zones. On average, the regions covered by the Aravalli-Vindhya ranges receive less than 1000 mm of precipitation annually, and include the deserts of Rajasthan. These arid and semi-arid tracts are thought to be highly vulnerable to ongoing and projected changes in the region's climate. Sites will be established along a transect encompassing a temperature-seasonality gradient in Gujarat, from Gir National Park in the south to Jessore Sloth Bear Sanctuary in the north. An additional transect encompassing an aridity gradient in Rajasthan, from Mount Abu in the east to Desert National Park in the west, may be established in the future. These transects will capture a range of vegetation types including tropical dry deciduous forest, tropical savanna, grassland, and desert.

Host Institution:
Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar

Field Stations:
Sasan Gir, Hingolgarh, Bajana, and Jessore in Gujarat

Western Ghats

Far older than the Himalayas, the Western Ghats is an escarpment which runs parallel to the West coast of India over a distance of 1600 km. The Western Ghats supports high species diversity and endemism, and is recognized as a global biodiversity hotspot. The forests of the region include some of the best representatives of tropical evergreen and montane forests in the country. Large populations of elephants and tigers occupy this landscape, and it also contains numerous endemic genera and species of fish, amphibians and reptiles, of which > 40%, > 80% and > 65% are endemic, respectively. It is also one of the most densely populated biodiversity hotspots in the world. Increasing fragmentation of forests is a major threat to the landscape, with consequences for both wildlife and humans, with many forms of conflict.

The Nilgiri Biosphere Reserve, located centrally in the Western Ghats, includes a rainfall gradient, an elevational gradient, and a matrix of land use types and forest types (including tropical dry thorn forest, dry deciduous forest, moist deciduous forest, semi-evergreen and evergreen forest, montane grassland, and stunted montane evergreen forest). This landscape has been the location of at least 30 years of previous long-term research on numerous taxa including plants, which are being monitored in permanent vegetation plots. Alongside the existing long-term sites in the Mudumalai forests, adjacent sites will be incorporated to cover additional representative forest types of the Nilgiri eco-region. The study will be conducted considering the rainfall gradient.

Host Institution:

Centre for Ecological Sciences (CES), Indian Institute of Science, Bengaluru and Kerala Forest Research Institute, Peechi

Field Stations:

Masinagudi in Tamil Nadu, and Nilambur in Kerala

Central India

The Central Indian highlands consist of a continuous landscape of deciduous forest across the states of Madhya Pradesh, Maharashtra, Chhattisgarh and Andhra Pradesh which include Deccan Plateau, Chota Nagpur Plateau and Satpura range. Increasing industrial, agriculture and urban pressure has resulted in the fragmentation of large tracts of intact forest. Nevertheless, this landscape offers an opportunity to study the interactions between vegetation, herbivores and predators in the absence of the human disturbance as many remnant forests fall under protected area network. The teak-sal transition zone in the region will be the primary focus of research in this landscape. A transect spanning the teak-sal gradient centered in and around Satpura Tiger Reserve will be established during the first phase.

Host Institution:

Indian Institute of Forest Management (IIFM), Bhopal

Field Stations:

To be finalised

Andaman and Nicobar Islands

The Andaman and Nicobar group of islands in the Bay of Bengal comprise over 500 islands, islets and rocks, which harbor vast stretches of tropical evergreen forests, rocky and sandy shores and diverse nearshore marine ecosystems. These tropical islands are unique in how these various ecosystems lie in close proximity to each other, often interacting with and influencing each other strongly. Coupled with the islands' unique bio-geographic history, and high degree of endemism, they serve as excellent natural laboratories to study the long-term responses of ecosystems and taxa to the effects of climate change. In addition, the islands also provide a habitat for many charismatic and threatened species of birds, mammals, herpetofauna and marine animals. In the past few decades, a dramatic increase in natural and anthropogenic disturbance, including climate change, has severely undermined the health of these unique ecosystems, both in the marine and terrestrial realm.

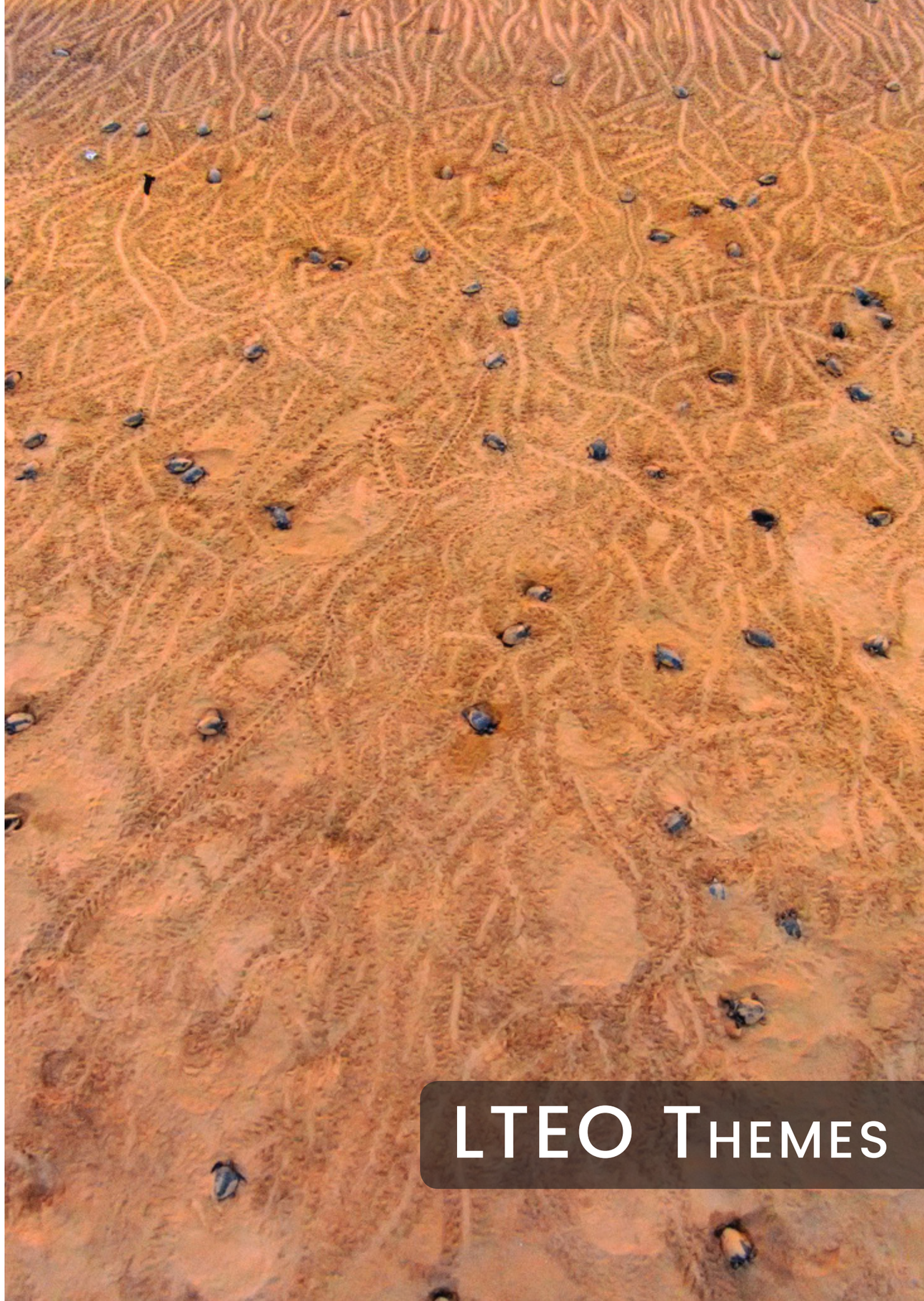
The inland and coastal habitats of South, Middle and North Andaman have been selected for their accessibility as well as representativeness of tropical evergreen forest and coastal/marine habitats. The forests in the South Andaman Island are sites for ongoing ecological research, as are the coral reefs and seagrass meadows in and around the Mahatma Gandhi Marine National Park and Rani Jhansi Marine National Park. Similarly, marine turtles are being monitored in Little Andaman and in the Nicobar Islands. The monitoring of terrestrial and marine habitats will be conducted at these sites.

Host Institution:

Andaman Nicobar Environment Team (ANET) / Dakshin Foundation, Bengaluru

Field Stations:

ANET, North Wandoor, South Andaman Island



LTEO Themes

The first phase of the LTEO research programme will focus on establishing baselines in each theme in order to understand processes and patterns of change in the medium- to long-term. In this phase, the programme will collect data on a set of climatic and ecological parameters that will serve as indices of change over the monitoring period.

The LTEO research themes are:

1. Soil
2. Forests
3. Grasslands
4. Arthropods
5. Freshwater Fishes
6. Herpetofauna
7. Birds
8. Animal Movement
9. Coastal and Marine Ecosystems

Soil

Material and energy flow through ecosystems are broadly controlled by biological and geological properties of soil, and these are fundamental to the functioning of all terrestrial ecosystems. Soils processes are a major source of greenhouse gases such as carbon dioxide, methane and nitrous oxide.

To cover a wide range of the environment conditions such as soil type, regional climate, and land-use across different habitats, a portable gas analyzer will be used in each site to assess the rate of emissions of CO_2, CH_4 and N_2O from soils. This will be a crucial step in interpreting how vegetation responses alter soils and associated feedbacks with ecosystem structure and functions. Soil moisture probes will be installed to record changes in soil water content over time, and soil cores will be collected for laboratory analysis of physical (e.g., soil texture) and chemical (e.g., carbon-to-nitrogen ratio) properties.

Plant carbon and nutrient pools will be estimated based on chemical analyses of plant tissue, and their fluxes determined by combining these with plant production estimated using allometric equations from tree growth data. Soil carbon fluxes will be determined by quantifying soil respiration rates, while soil nutrient fluxes will be evaluated based on estimating monthly mineralization rates using open-top mineralization tubes.

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Forests

Long-term forest monitoring studies around the world suggest that climatic fluctuations and fires can cause tree species compositions to change over time. These compositional changes depend not only on the traits of the constituent species (favoring deciduous over evergreen species in response to prolonged drought, for instance) but also on the type of forest. Changes to vegetation can affect ecosystem functioning, alter carbon balance and hydrology, and have a feedback effect on regional and global climate.

The importance of long-term forest studies is highlighted by the 50 ha Mudumalai Forest Dynamics Plot that, in over 30 years of monitoring by the Centre for Ecological Sciences, Indian Institute of Science, has yielded key insights into the role of factors such as fire and drought in regulating the dynamics of tropical dry-deciduous forests. However, it remains unclear whether the patterns observed in Mudumalai hold true for other forest types or even other dry-deciduous forests in the country.

The objective of the LTEO Forests theme is to set up the baselines for understanding the responses of the diverse forest communities across India's major forest biomes to environmental change. The study aims to characterize how forest structure, species diversity, and biomass change across broad environmental gradients, and to determine their dynamics in relation to local climate, soil characteristics, and fire.

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Grasslands

Tropical grassy biomes occupy 20% of the Earth's terrestrial surface. They are ancient ecosystems that support unique biodiversity including many endemic species. In India, they are a major source of ecosystem services for dependent human communities, and support large populations of both livestock and wildlife. Unfortunately, despite their high ecological and societal relevance, grasslands have been historically neglected, frequently designated as wastelands, and have often been subjected to inconsistent policy decisions resulting in their conversion to other land uses.

Monitoring of grassland ecosystem structure and function will involve establishing permanent plots that cover the spectrum of grassland types across the country, current land-use and fire regimes. Data on species composition, biomass, soil nutrient status and plant functional traits will be collected annually from these permanent plots using standardized protocols. Paired experimental burning and herbivore exclusion plots will also be established to gain a better idea of the impacts of these top-down forces on grassland dynamics wherever applicable.

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Arthropods

Arthropods are the most informative and sensitive indicators of environment and ecological change and possibly affected most by the climate change. Arthropods are inarguably the most diverse phylum on earth. The role of arthropods in ecosystem functioning is quite significant and many human activities depend upon the survival of arthropod groups such as bees. Like many other organisms, the changes in climatic conditions, anthropogenic disturbances, and habitat loss have led to the catastrophic decline of arthropod populations and diversity worldwide.

This theme will study the effect of climatic changes on the diversity and distribution of ecologically important arthropods in terrestrial and freshwater ecosystems. The groups chosen will be broadly interconnected in ecological communities and ecosystems, relatively conspicuous and easy to sample, taxonomically and ecologically well-studied with standard sampling methods, and ecologically diverse with variety of life history strategies. The study will document the diversity, distribution, and ecological traits of selected arthropods such as scorpions, centipedes, wasps, bees, butterflies, crabs, mayflies, dragonflies, stoneflies, and termites. The theme expects to identify indicator taxa and develop monitoring protocols in different ecosystems across LTEO landscapes to assess and monitor the impact of climate change.

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Freshwater Fishes

Freshwater fishes are the best-known group of aquatic vertebrates, and they exist at or near the top of aquatic food chain. They are highly sensitive to environmental changes in their habitats. However, in recent decades, freshwater habitats have been extensively altered due to development and other human activates. The cumulative impacts of aquatic habitat alterations such as flow obstructions, entry of untreated effluents from cities, industries and agricultural fields and introduction of invasive species are main threats to freshwater fish and their habitats. Climate change coupled with local impacts can cause severe declines or loss of fish species entirely. Given the importance of maintaining healthy freshwater habitats, it is necessary to monitor these ecosystems using suitable indicator fish species.

Fishes inhabiting streams/ rivers are highly specialized in their morphology and exhibit a high degree of endemism to a particular watershed. The presence and abundance of these unique fishes can be measured as an index of the quality of freshwater habitats over a period. Fish will be monitored by conducting periodic fish sampling using standard fishing gears. Parameters such as the presence/absence of indicator species, the abundance of select species, and body size can be used to monitor trends in fish populations. In addition, the long-term collection of fish population status and environmental variables can provide baselines for testing the effects of natural and anthropogenic disturbances on fish populations over time

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Herpetofauna

Amphibians and reptiles, collectively called herpetofauna, are dependent on external temperature regulation for maintaining physiological functions. This makes them particularly sensitive to changes in the environment. Amphibians can serve as early warning systems for environmental changes caused by global and local drivers such as climate change, pollution and infectious disease. These threats have decimated amphibian and reptile populations in many parts of the world. India has more than a thousand species of herpetofauna, most of which are endemic to small regions, with many discovered in the last couple of decades. We know little about the biology and population status of a majority of these species.

One of the predicted impacts of global climate change is alteration of geographical ranges of species. For example, dry adapted herpetofaunal species of northwest India or central India could show changes in distribution and abundance in response to changes in rainfall patterns. Montane herpetofauna are particularly vulnerable to changes in temperature, especially the cold adapted montane endemics that may find themselves unable to shift to more favorable habitats. Therefore, one of the objectives of this project is to study the response of herpetofauna to changes in precipitation and temperature associated with global climate change. In addition, the project will examine the population dynamics, breeding phenology and thermal biology of select species to determine the impact of climate change on these biological traits.

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Birds

Long term information on bird communities, populations, demography, movements and long-distance migration has been used in many parts of the world to gain detailed information on the effects of climate and habitat change. Birds are ubiquitous, easily identifiable, and high in the food chain; this makes them excellent indicators of environmental change. To monitor bird populations and communities across all landscapes, we will take a coarse- to fine-scale approach.

At the largest scale we will set up grids for rapid surveys and assessments of bird populations based on semi structured data collection methods like timed checklists. At a finer scale, permanent line transects or fixed-point counts will be established for getting densities and abundances of birds. At the finest scale, demographic processes will be monitored to understand the influence of survival and reproduction on population outcomes. This will be done through establishing permanent plots at each LTEO site, within which mist netting and ringing will be carried out during defined periods. By analyzing this data using robust spatially explicit capture-recapture techniques, it is possible to estimate population densities, survival rates and reproductive rates. Measuring the latter two vital rates is crucial if one is to understand the causes of population change over time.

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Animal Movement

Climate change is projected to alter species distributions, demography, and diversity, but these population and community-wide changes are likely to be detected over multiple years. By contrast, behavioral processes, such as the spatial and temporal patterns of animal use of their landscape, are highly sensitive to environmental change and are likely to be the first detectable shifts in animal responses to climate-related changes in environments. The LTEO programme will employ advances in the field of movement ecology, including high-end GPS and satellite telemetry and recent innovations in analytical techniques, to understand how animals are utilizing the environment. An understanding of how willing animals are to traverse the fragmented and changing human-dominated matrix that comprises their environments is critical to understanding coexistence and survival strategies. By tracking the movement ecology of key sentinel species, this programme will provide the fastest insight into the effects of local and global anthropogenic disturbances.

The overall objective is to understand the multi-scale movement strategies of animals in response to changing environments. The project will aim to determine fine-scale, daily, seasonal and annual movement patterns of key sentinel species. We aim to track the Indian peafowl (*Pavo cristatus*), golden jackal (*Canis aureus*), and sambar (*Rusa unicolor*) at all LTEO sites. These species play key functional roles in the ecosystem and their movement strategies will provide us with critical information about the generalities across sites, as well as site-specific drivers. Such data provides us with unique insight into the requirements and challenges for animal movement in real time.

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Coastal and Marine Ecosystems

Marine ecosystems such as coral reefs, salt marshes, mangrove forests and sea grass beds are known for their high biological productivity, ecosystem services and their ability to provide habitat for a wide range of aquatic plants and animals. In addition, healthy oceans play a vital role in regulating global climate and act as a major carbon sink and source of atmospheric oxygen. In the past century, human activities such as overfishing, shipping, coastal development and discharge of untreated effluents have caused considerable damage and pose a severe threat to coastal and marine biodiversity. Coupled with global warming induced climate change, these threats can severely impact marine ecosystems and consequently the coastal communities that directly depend on these systems for coastal protection, income and nutrition.

Monitoring will be carried out in the Andaman Islands to understand the impact of local and global stressors on marine ecosystems and taxa. This will include monitoring key biological, ecological, physical and chemical aspects of marine ecosystems across a gradient of disturbance. The project will include monitoring of coral reefs and reef fish, sea grass habitats and physico-chemical parameters at select sites. In addition, the project will also include monitoring of marine turtles.

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- Guru Gobind Singh Indraprastha University, New Delhi
- Indian Institute of Forest Management (IIFM), Bhopal
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- Wildlife Institute of India (WII), Dehradun
- World Wildlife Fund (WWF), Bengaluru
- Zoological Survey of India (ZSI), Kolkata