SANH – The Initiative.

Supported by GCRF UKRI

INMS

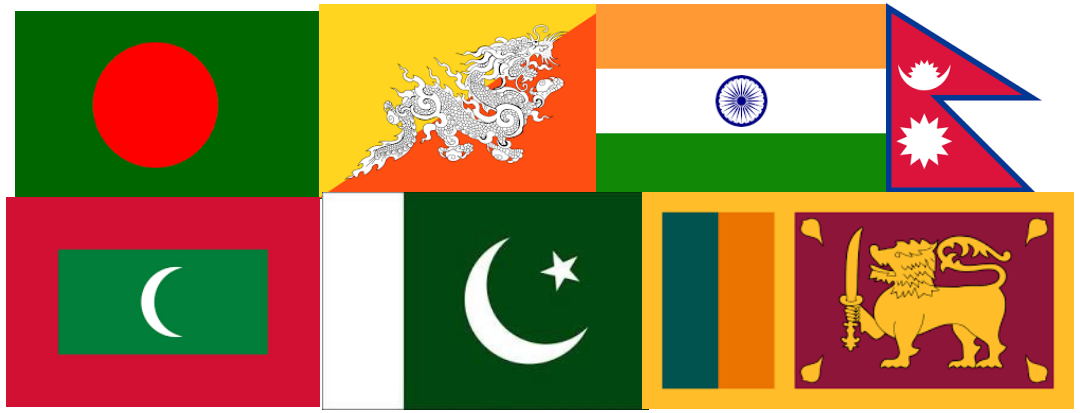
SACEP
South Asia Co-operative Environment Programme

UNEP Resolution by India.
Colombo Declaration

Reduce Nitrogen Waste by half by 2030.

SDG Goals

- **Life on Land**
- **Life on water**
- **International Cooperation**



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SACEP
South Asia Co-operative Environment Programme

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RESEARCH PACKAGES

1. POLICY

2. NITROGEN USE EFFICIENCY

3. IMPACTS ON ECOSYSTEM SERVICES
   - 3.1 a Lichens in Himalaya
   - 3.1 b Enrichment Expt
   - 3.2 b Corals and sea grass
   - 3.3 MOOC on lichens.

4. MODELLING N POLLUTION

Nitrogen impacts on forests: lichens as an indicator in Himalayas, South Asia

Mark Sutton[1], Sudipto Chatterjee[2], Christopher Ellis[3], Matt Jones[1], Massimo Vieno[1], Subodh Sharma[4], Dendrup Tshering[5], Pat Wolseley[6], Gothamie Weerakoon[6], Himanshu Rai[7], Sahaj Kaur[2], Charu Bhanot[2], Sidharth Negi[8]

[1] Centre For Ecology & Hydrology, [2]TERI School Of Advanced Studies, [3]Royal Botanic Garden Edinburgh, [4]Kathmandu University, [5]Royal University of Bhutan, [6]Natural History Museum, [7]Banaras Hindu University, [8]Uttaranchal Youth and Rural Development Centre

1. BACKGROUND

The SANH project (South Asia Nitrogen Hub) will address the little-studied impact of nitrogen air pollution in Himalayan forests.

The Indo-Gangetic Plain (IGP) is reported to have the highest atmospheric NH_3 concentration in the world, and major impacts are expected, with parallel concerns about wet N deposition to the east of the region (Fig. 1).

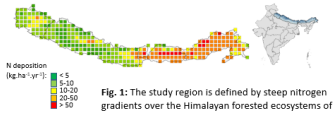


Fig. 1: The study region is defined by steep nitrogen gradients over the Himalayan forested ecosystems of Bhutan, India and Nepal.

2. LICHENS

Lichens are intimately linked to their surrounding environment (Fig. 2); they access water and nutrients from the air, and are exposed to pollution.

Different lichen species show different degrees of tolerance at low to medium nitrogen pollution; the assemblage of lichens can therefore be used to indicate invisible excess nitrogen.

At high levels of nitrogen, all lichens are killed off.

Fig. 2: The lichen genus *Everniastrum* (A.) is a focal group that can indicate the effects of nitrogen in forested landscapes (B.).

Map source: Centre For Ecology & Hydrology
Picture source: TERI School Of Advanced Studies

3. ECOSYSTEM SERVICES

Not only are lichens indicators for the harmful effect of nitrogen pollution, they are used by people (Fig. 3); as a marketable resource, such as in the perfume industry, as a food source, for ritual ceremony and for their aesthetic qualities.

Lichens are part of a global trade in medicinal and aromatic plants worth $60 billion; the threat to lichens from nitrogen pollution is a threat to economic sustainability as well as cultural identity.

Fig. 3: Lichens collected and traded in bulk, are processed and converted to a high value end-product

4. OUR AIMS

We will quantify the response of lichen diversity to nitrogen pollution, as well as the threshold tolerances for economically and culturally valuable species.

We will project the future response of lichens to alternative nitrogen management scenarios, as an example of impacts on the natural world.

We will understand how human-nature relationships can be affected by nitrogen pollution to inform our response to this challenge.

Our results will help policy makers to set sustainable nitrogen levels, and sustainable harvest rates to protect biodiversity under different nitrogen regimes.

PHILOSOPHICAL TRANSACTIONS A

royalsocietypublishing.org/journal/rsta

Alkaline air: changing perspectives on nitrogen and air pollution in an ammonia-rich world

Mark A. Sutton[1], Netty van Dijk[1], Peter E. Levy[1], Matthew R. Jones[1], Ian D. Leith[1], Lucy J. Sheppard[1], Sarah Leeson[1], Y. Sim Tang[1], Amy Stephens[1], Christine F. Braban[1], Ulrike Dragosits[1], Clare M. Howard[1], Massimo Vieno[1], David Fowler[1], Paul Corbett[2], Mohd Irfan Naikoo[3], Silvana Munzi[4,5], Christopher J. Ellis[6], Sudipto Chatterjee[7], Claudia E. Steadman[1,8], Andrea Móring[1,8] and Patricia A. Wolseley[9]

Research

Cite this article: Sutton MA *et al*. 2020 Alkaline air: changing perspectives on nitrogen and air pollution in an ammonia-rich world. *Phil. Trans. R. Soc. A* **378**: 20190315. http://dx.doi.org/10.1098/rsta.2019.0315

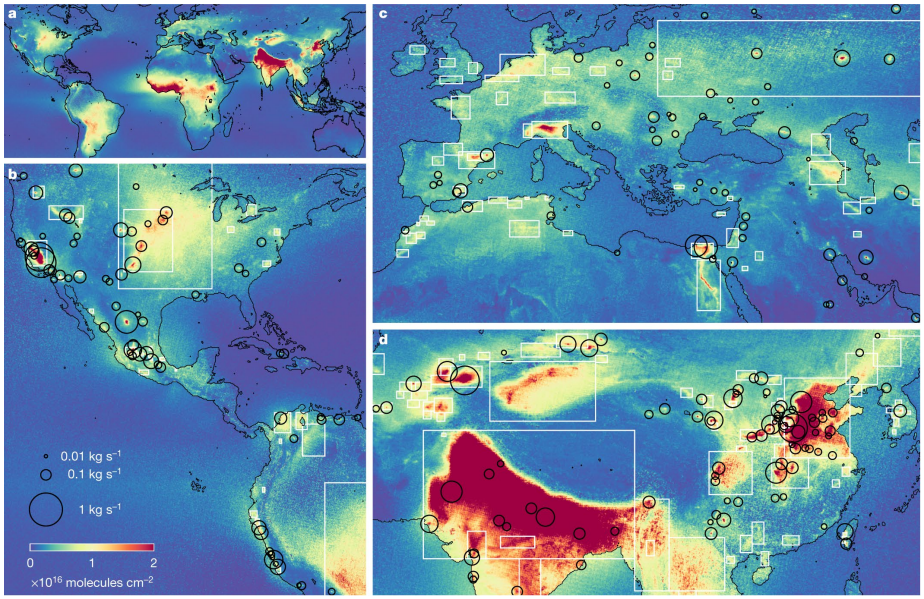
Accepted: 7 August 2020

One contribution of 17 to a discussion meeting issue 'Air quality, past present and future'.

Industrial and agricultural ammonia point sources exposed

Martin Van Damme, Lieven Clarisse, Simon Whitburn, Juliette Hadji-Lazaro, Daniel Hurtmans, Cathy Clerbaux & Pierre-François Coheur

Nature **564**, 99–103 (2018) | Cite this article



NH_3

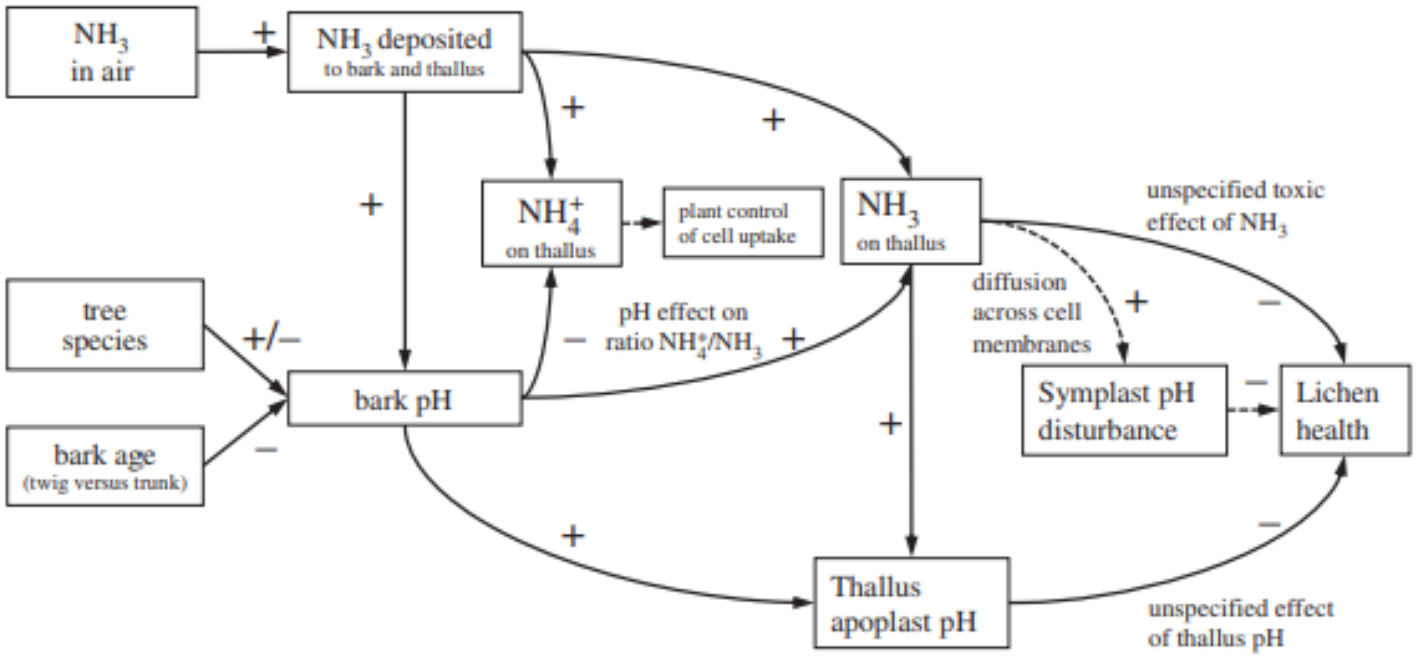
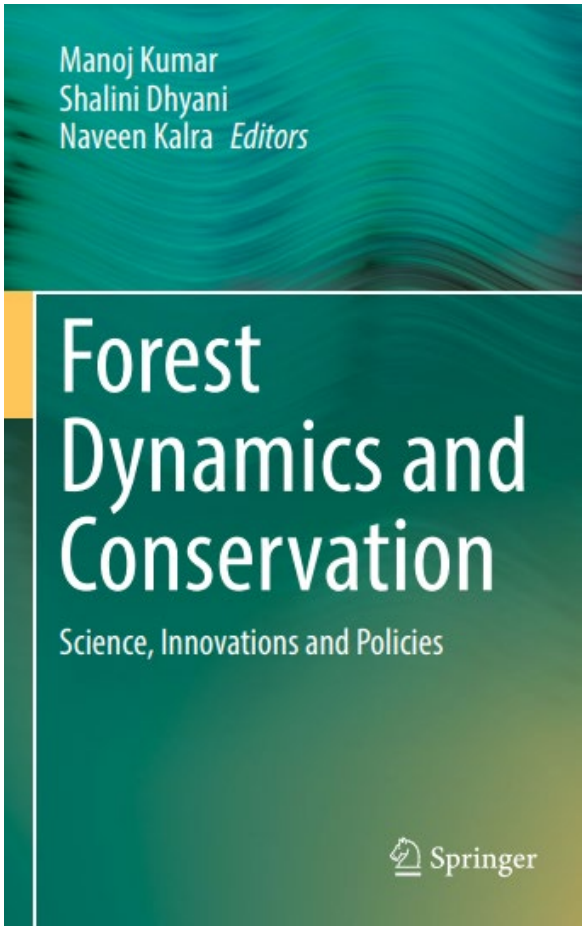


Figure 10. Possible mechanisms by which atmospheric NH_3 pollution affects epiphytic lichens, including both positive (+) and negative (—) effects. Solid lines indicate observed relationships or those directly implied by physico-chemistry. Dashed lined indicate hypothesized relationships. The toxic and pH effects apply especially to acidophyte lichens, but may also apply to nitrophyte lichens at high levels of NH_3 exposure (figure 4).



Gangetic Plains of India: High on the Water and Air Pollution Map

4

Sudipto Chatterjee, Manab Das, Himanshu Rai, Dharmesh Singh, K. Preeti, and Vasundhara Pandey

Abstract

As per global studies on atmospheric air quality at the Center for Ecology and Hydrology, UK and NASA, USA, the Indo-Gangetic Plain has emerged as a global ammonia (NH3) hotspot, due to which Himalayan foothills are experiencing "Alkaline air". Apart from existing threats of rapid land use change and overharvesting of forest products, preliminary investigations have reported forest dieback, invasion by invasive species including pests and pathogens, and low regeneration of forest trees in this region. Local communities in this largely agricultural landscape traditionally depend on these forests for their livelihood, including for firewood and nontimber forest products. Unless these impacts are studied in finer detail, with baselines developed and mapped, the health of the forest ecosystem will not receive conservation priority. Therefore, under the aegis of the South Asia Nitrogen Hub (SANH), this chapter attempts to undertake a preliminary study of the present status of pollution in the air, and for surface and groundwater and soil in the Indo-Gangetic plain, focusing on four states in India viz. Uttarakhand, Uttar Pradesh, Bihar, and West Bengal through which the Ganges flows. We also look specifically at lichens, which are known indicators of pollution. Our study reveals that while the region has shown enhanced levels of pollution of soil and water, the forest cover of the four states remains largely the same over time, though there has been a decline in both the NDVI (Normalized

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M. Das · H. Rai
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M. Kumar et al. (eds.), *Forest Dynamics and Conservation*,
https://doi.org/10.1007/978-981-19-0071-6_4

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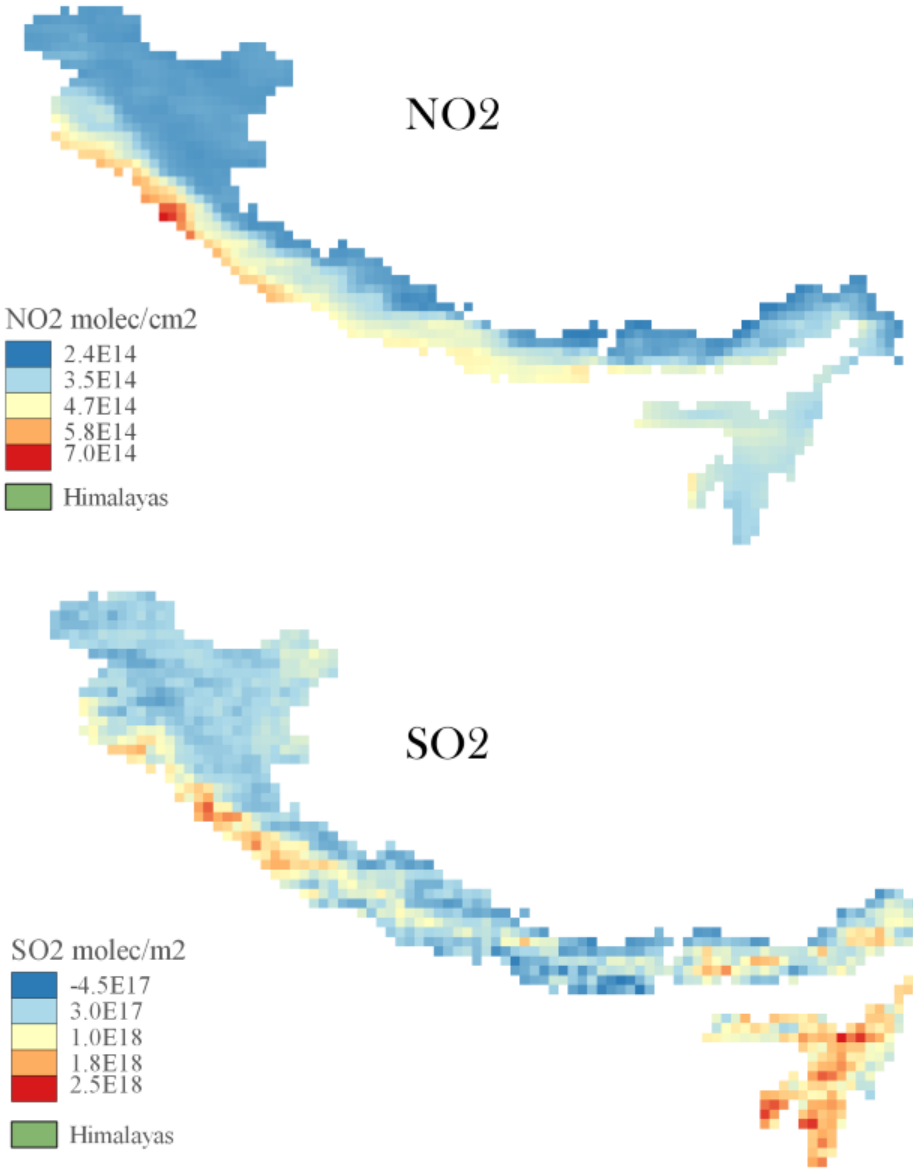
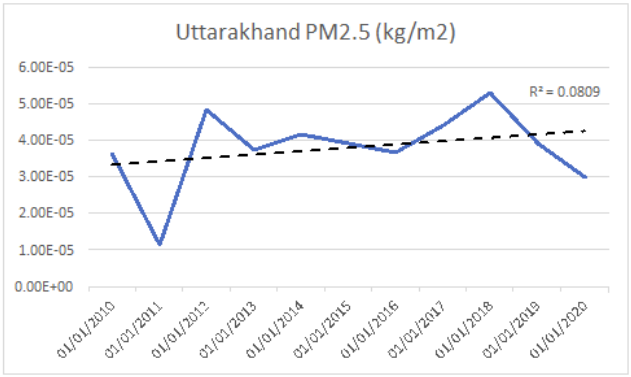
Pollution maps for the Himalayan belt of India, Nepal and Bhutan from 2010-2020

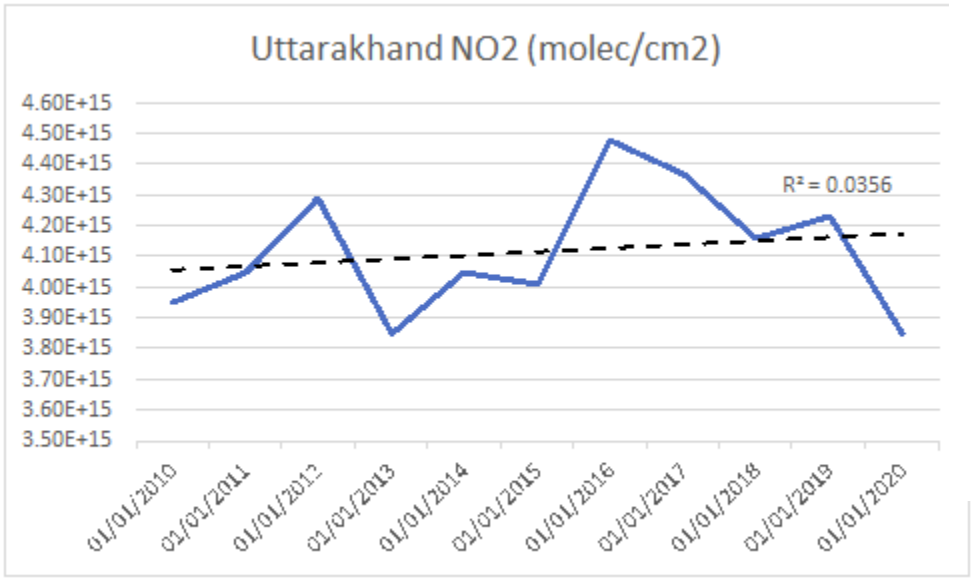


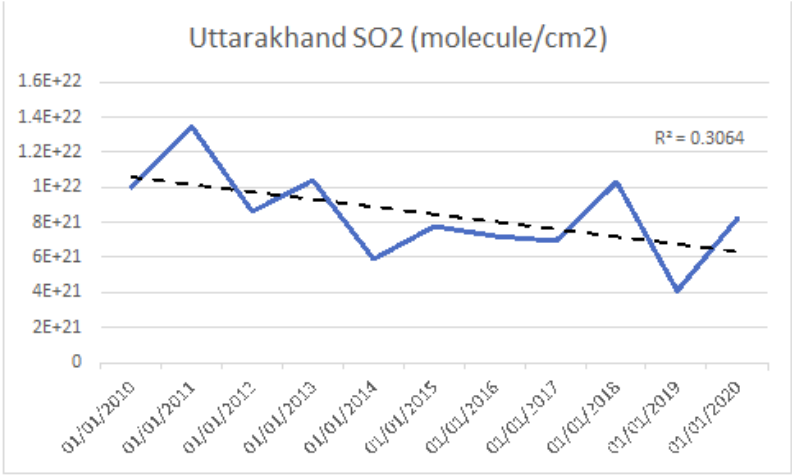
Mann Kendall Test for Trend - results

For the period 2010-2020 yearly average for the state of Uttarakhand.

Pollutants	Mktau	2 sided p-value	comments
NO2	0.13	0.63839	upward slope but not statistically significant
PM2.5	0.127	0.64043	upward slope but not statistically significant
SO2	-0.382	0.11947	downward slope but not statistically significant







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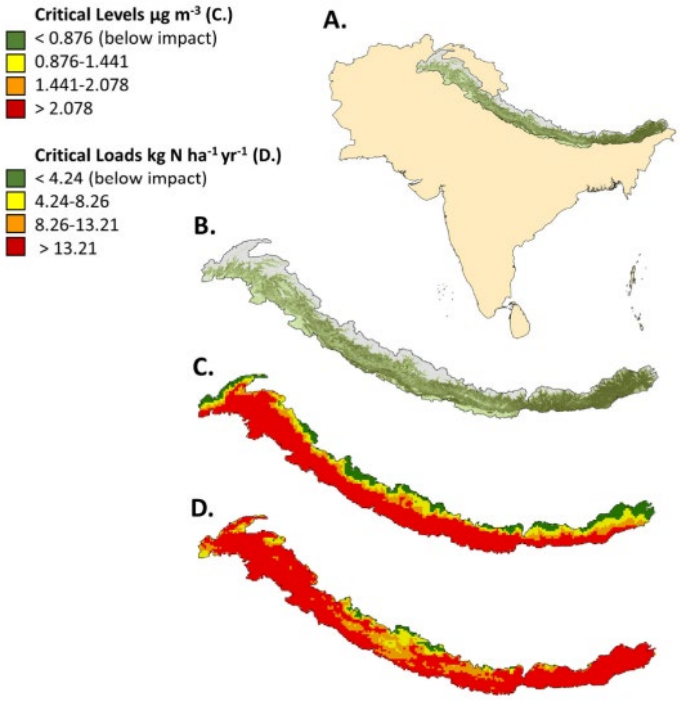
Estimating nitrogen risk to Himalayan forests using thresholds for lichen bioindicators

Christopher J. Ellis [a,*], Claudia E. Steadman [b], Massimo Vieno [c], Sudipto Chatterjee [d], Matthew R. Jones [c], Sidharth Negi [e], Bishnu Prasad Pandey [f], Himanshu Rai [g], Dendup Tshering [h], Gothamie Weerakoon [i], Pat Wolseley [i], David Reay [b], Subodh Sharma [j], Mark Sutton [c]

[a] Royal Botanic Garden Edinburgh, Edinburgh, UK

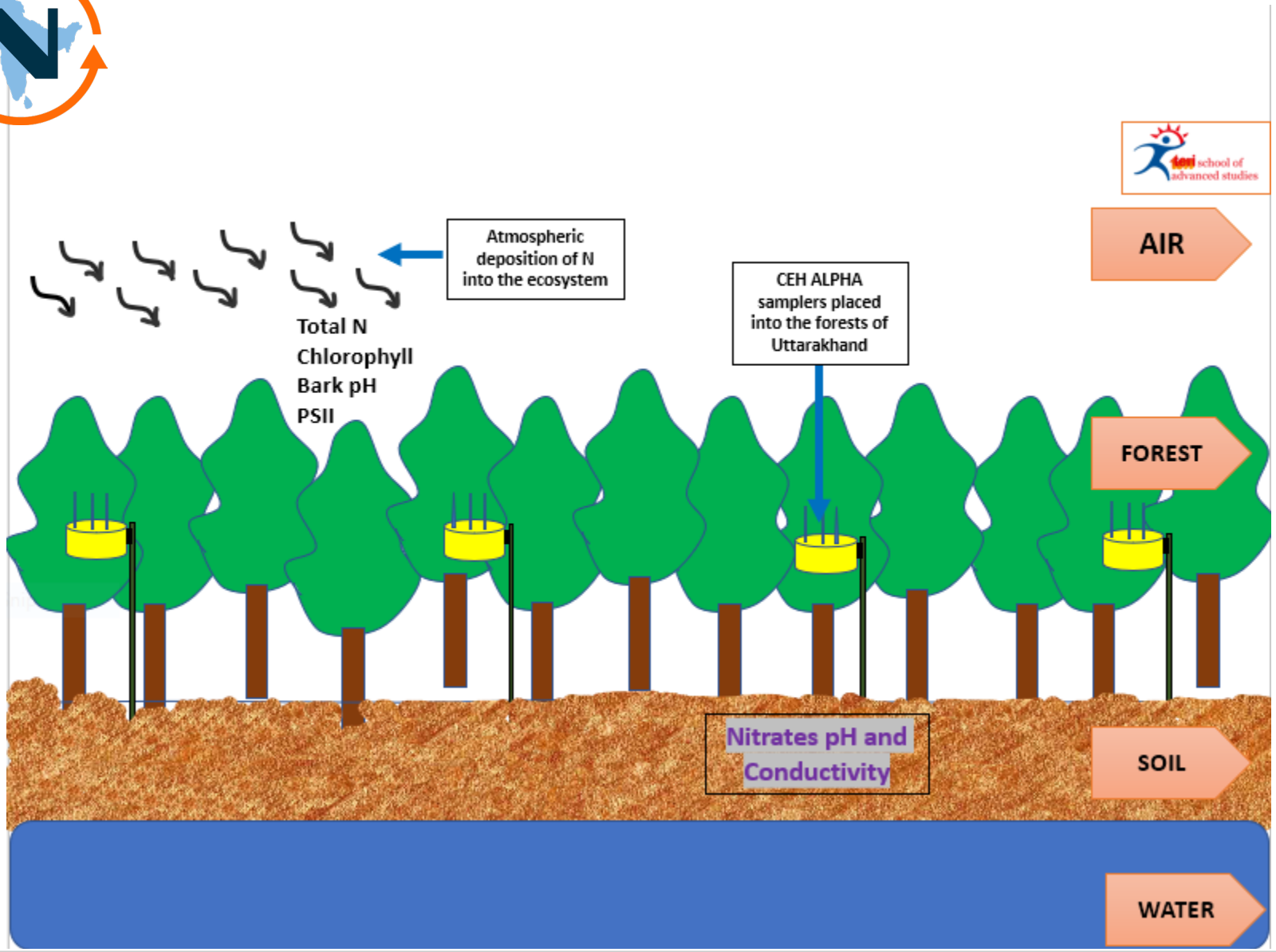


A. Forest Cover

B. Density of Forest Cover

C. Zones with critical levels of NH3

D. Critical levels of total N
(*EMEP WRF Model Projections. 2010 emissions, 2020 meteorology and 0.11 X 0.11 projections.*


Atmospheric deposition of N into the ecosystem
Total N
Chlorophyll
Bark pH
PSII
CEH ALPHA samplers placed into the forests of Uttarakhand
AIR
FOREST
Nitrates pH and Conductivity
SOIL
WATER

Sample Collectors

SANH personnel

Community

Student Community

Data Base

Data Analysis

Modelled Data Enrichment Expts.

Forest Degradation Indicators

Instrumentation Facility

Impacts of N pollution to Forests and Ecosystem services

Policy makers and Outreach

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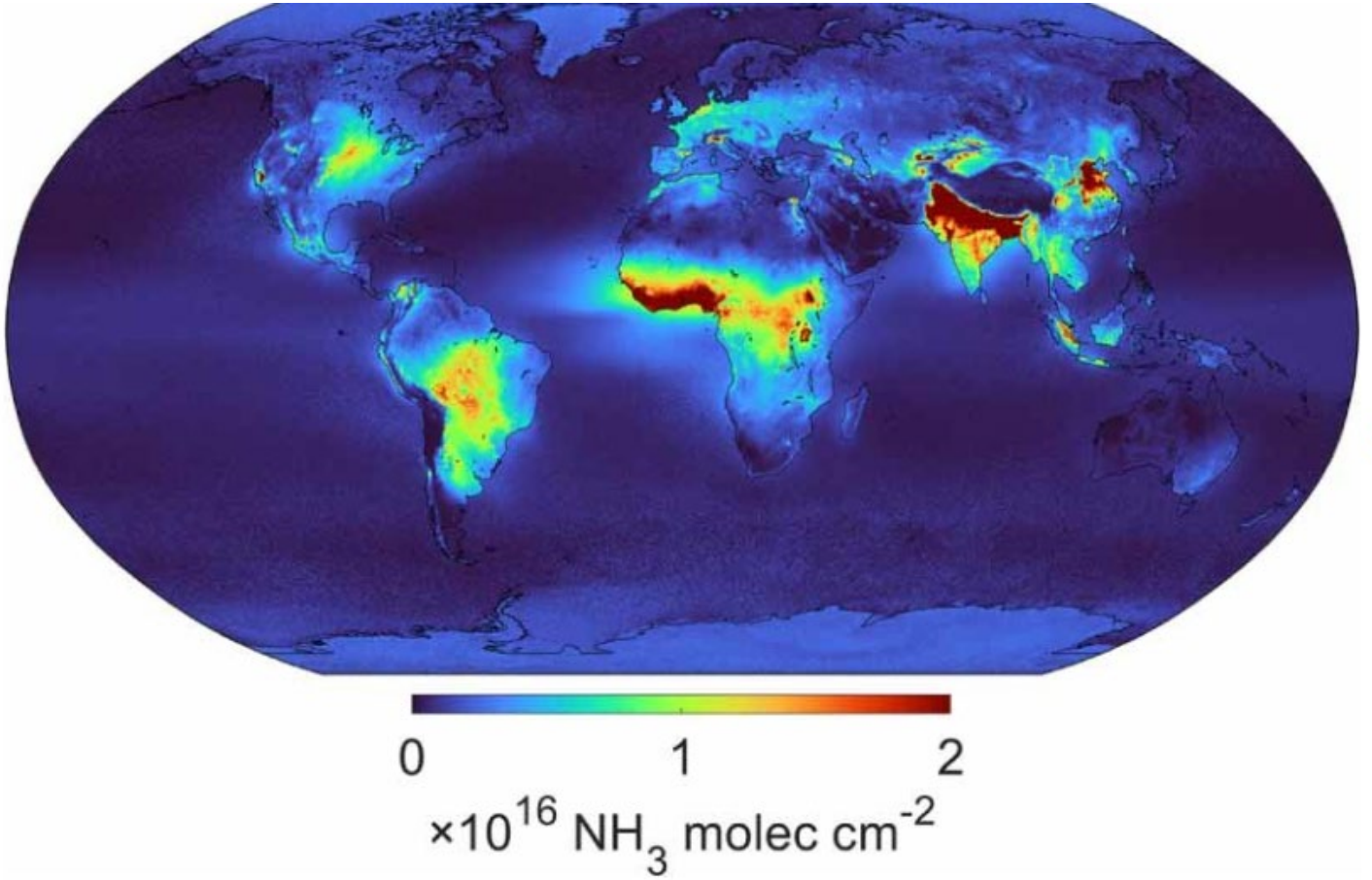
- **The Approach**

1. Identification of High-Low pollution areas through RS &GIS.
2. N deposition on dominant forest trees.
3. Soil Chemistry.
4. Bark pH and its effect on associated diversity.
5. Floristic diversity.

By 5 post graduate students from each country.

Objectives	India – convenient sampling	
High-Low pollution	Remote sensing – Uttarakhand	
N deposition	Total N and δ15N test on lichen, ground level NH3	
Soil Chemistry	Nitrate, EC and pH, mycorhiza	
Bark pH and diversity	pH of Oak trees bark	
Lichen	Community structure, Secondary metabolites, crystal formation, PSII activity	

TROPOMI METOP B



IASI-NH3 total columns distribution (molec cm^{-2}) averaged from 11 years of IASI/Metop-A measurements (1 January 2008 to 31 December 2018, morning overpasses, ANNI-NH3-v3R-ERA5 dataset) on a 0.5°× 0.5° grid.

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Alpha Samplers

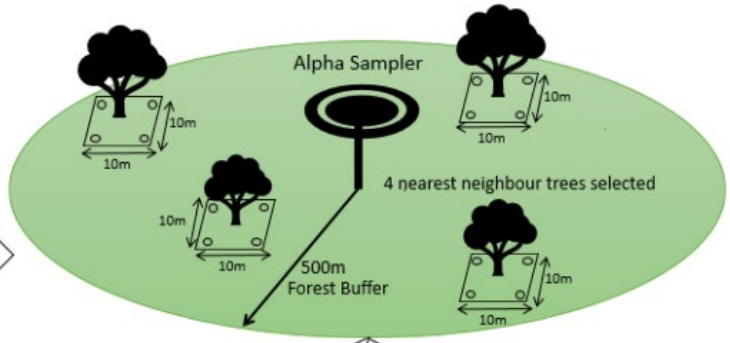
Community support in managing the Alpha samplers

Impact on Lichens and Vegetation is a function of land use, forest type, elevation, host species

Sampling strategy for the 3 broad indicators namely; Soil, Bark and N deposition for pollution in temperate forest of Himalayas.

CHAMOLI LANDSCAPE
(Placement of Alpha Samplers)

At every site



N deposition using Lichen
4 nearest neighbour trees having lichen wrt ALPHA Samplers will be selected and thalli will be collected

Soil Nitrate
From the base of the trees, a 10x10m quadrat will be constructed and soil samples form 4 corners will be collected as a composite sample.

Bark pH
Bark samples from the 4 trees with lichen closest to Alpha sampler will be selected and analysed.

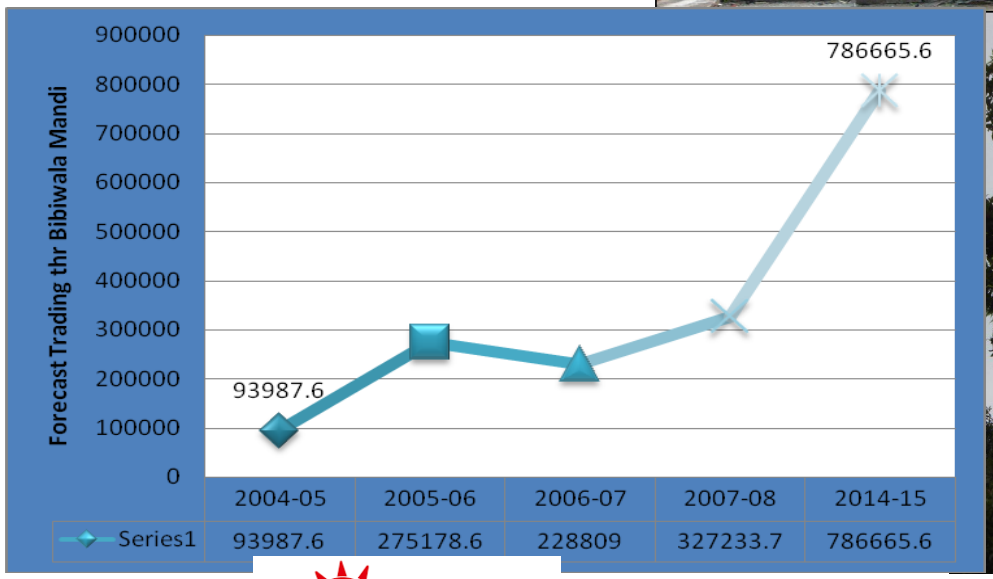
Everniastrum ciliatum.

Why Lichens

Identified as one of the best indicators of Pollution. Indicates Ecosystem Health. Nitrophobhic lichens get replaced by the nitophobic

Lichens do not have roots, they draw all nutrients from the atmosphere.

A projection in increase in Jhula trade (based on data available at Bibiwala depot)



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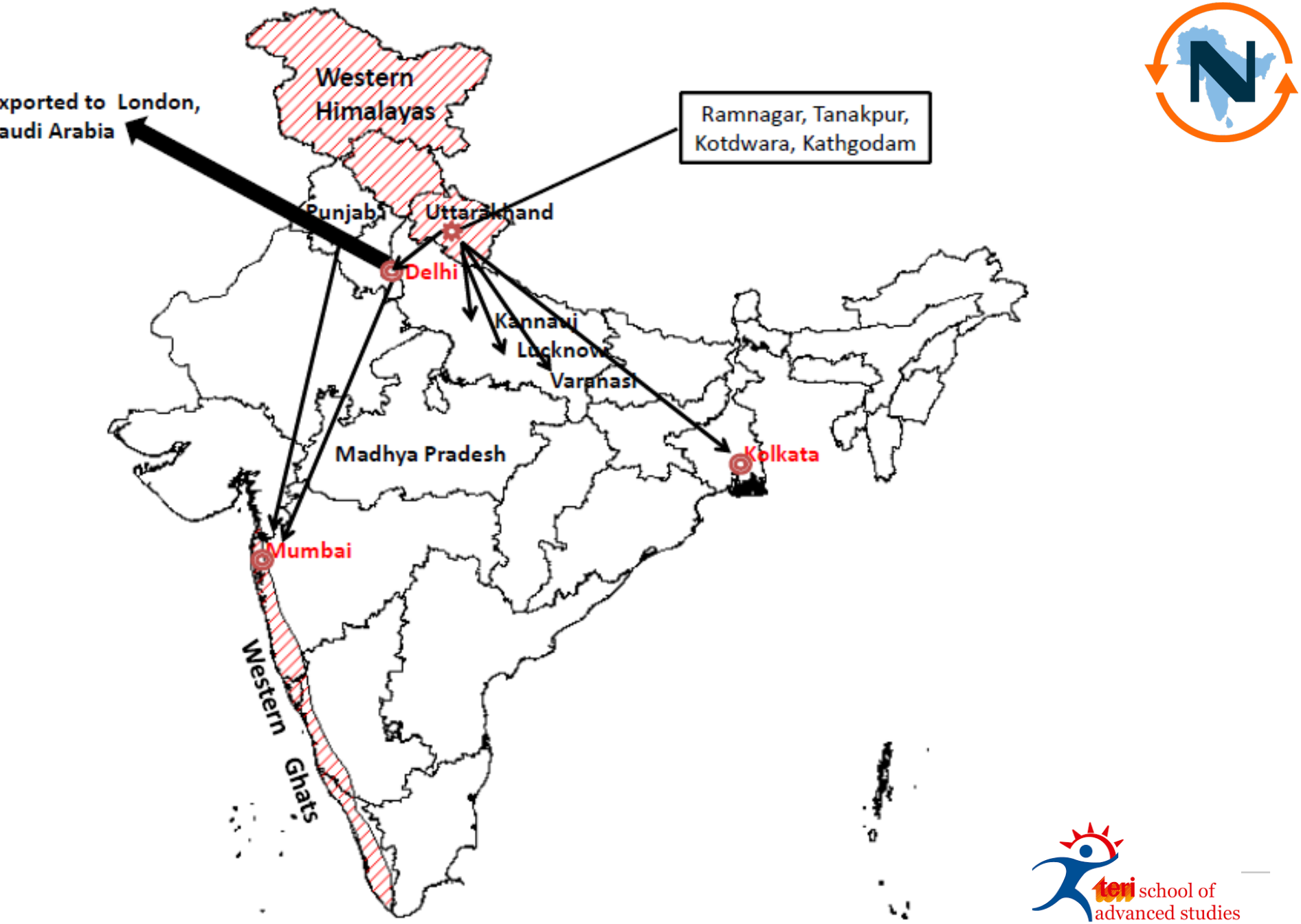

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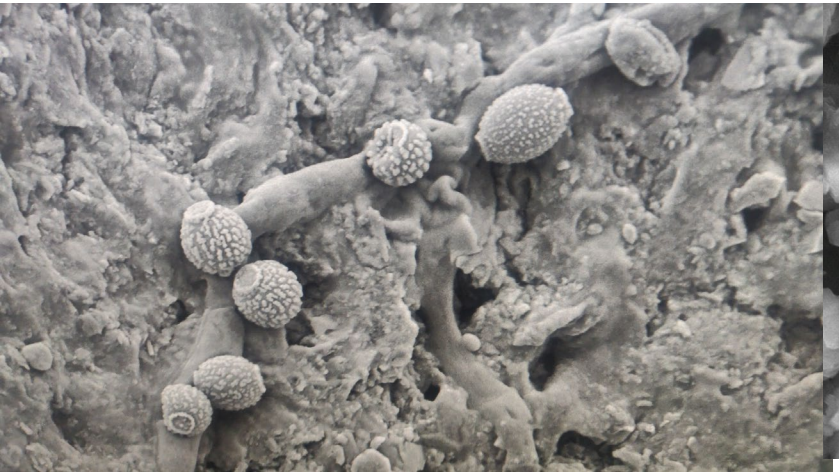
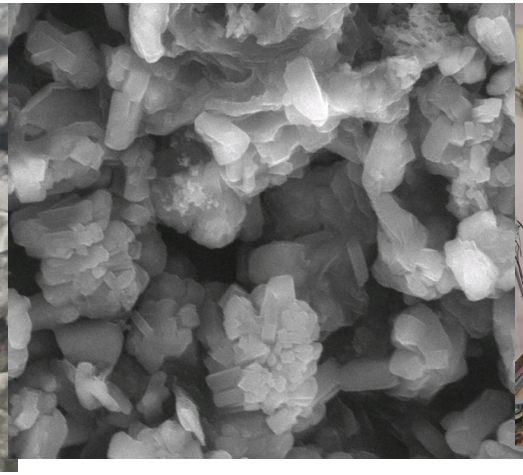
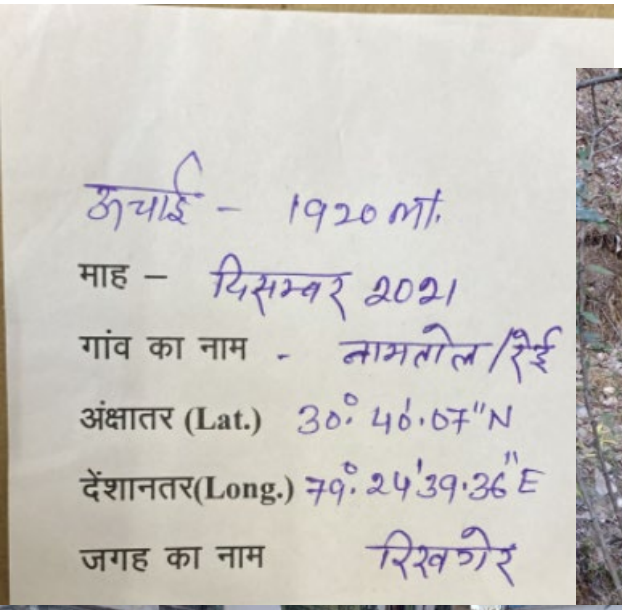
HINA


ATTAR HIN
ASSAM
Hina
Md. Yaqub


Lichen Conservation Area with villagers for Long Term Ecological Monitoring (LTEM)



Questionnaire for community perception

1. Have you observed any changes in climate over the past 10 years?

   In terms of rainfall, temperature, yield of crops, microclimate, etc.

2. Does your livelihood depend on lichen population?
3. *What is the average income from lichen trading?
4. Have you observed any decrease in lichen population?
5. What are the factors that affect lichen availability?
6. Are there any changes in availability due to seasonal variability?
7. Why do you think there has been a decrease?
8. Do you think there is a role of overharvesting in decrease of lichen population?
9. What are the challenges in lichen trade?
10. Would you be agreeable to setting up a lichen conservation area?
11. What do you think can be done to prevent the rapid decrease in population?
12. Do you think land use, deforestation and other human activities play a role on lichen population?

Community Structure of Lichens along Altitudinal Gradient

Landscape – 2 Jhinjhoni

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Enrichment site in Sri Lanka.

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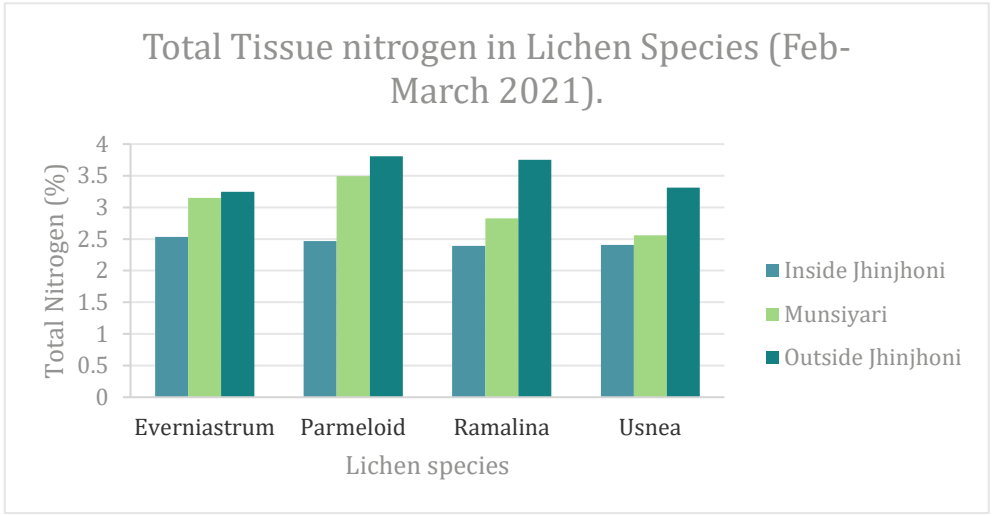
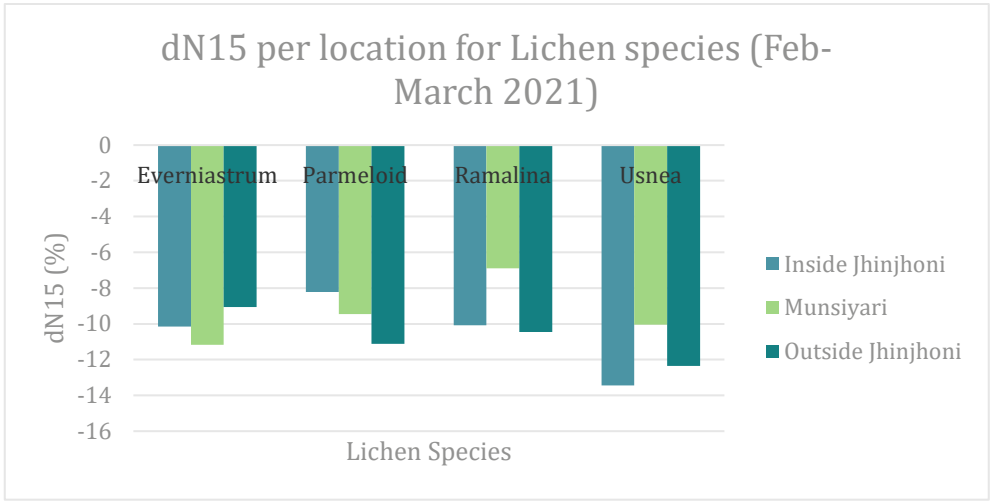
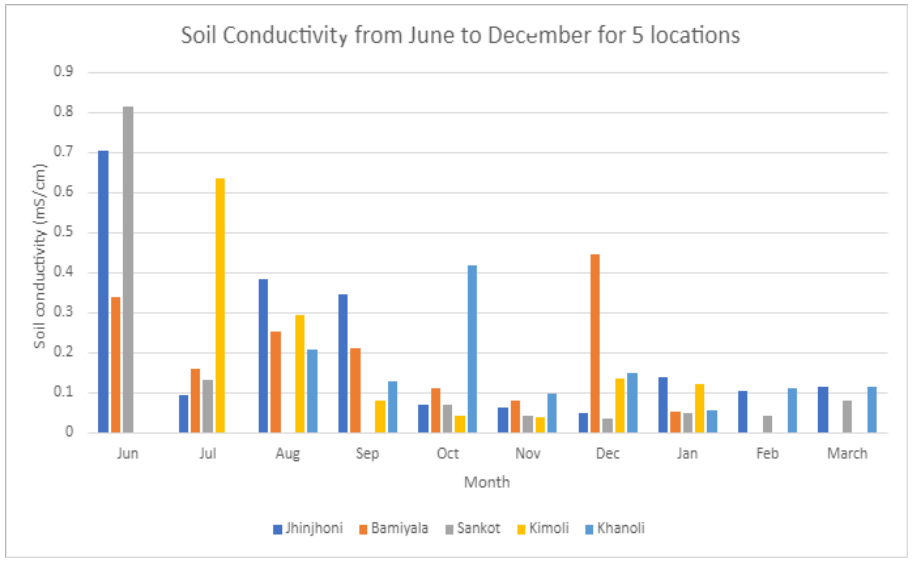
Objective Results - India

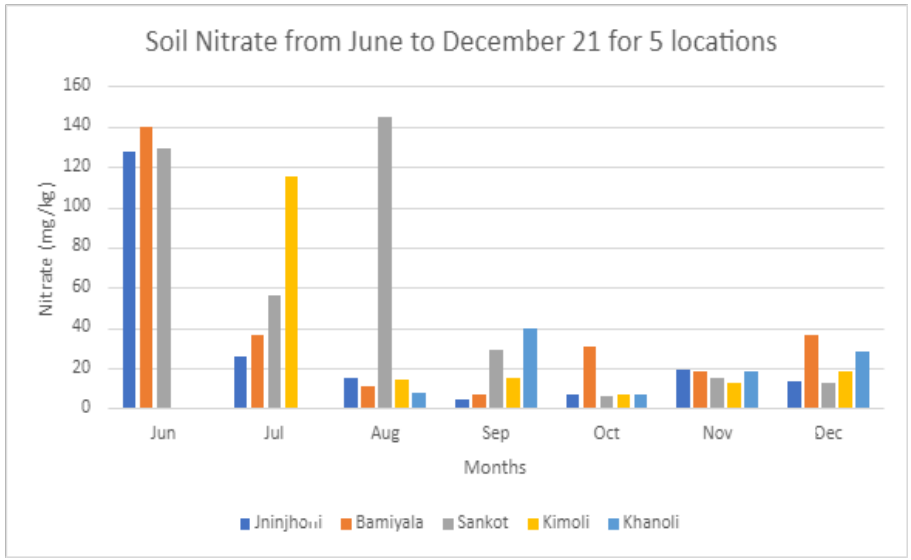


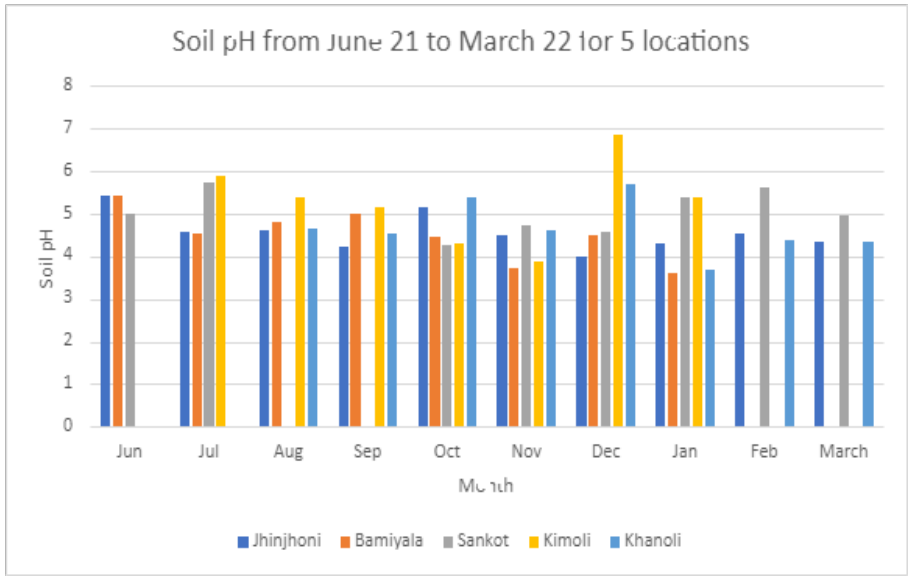


- Inside forest shows least tissue nitrogen, outside forest is highest across all lichens.
- d15N though irregular, very negative indicating organic N pollution. (Edison Armando Diaz-Alvarez, Roberto Lindig Cisneros and De, 2018)

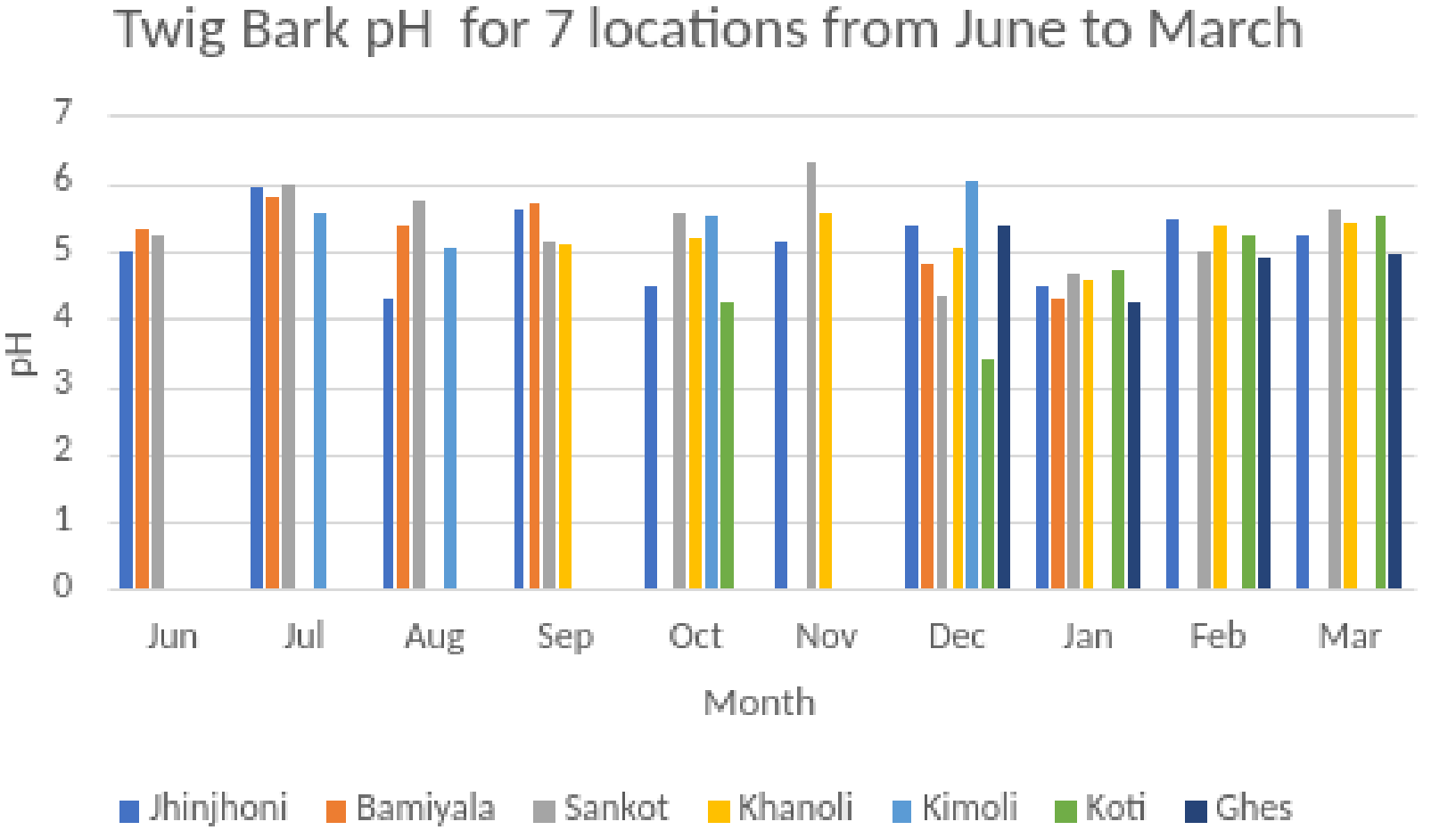
Results - India



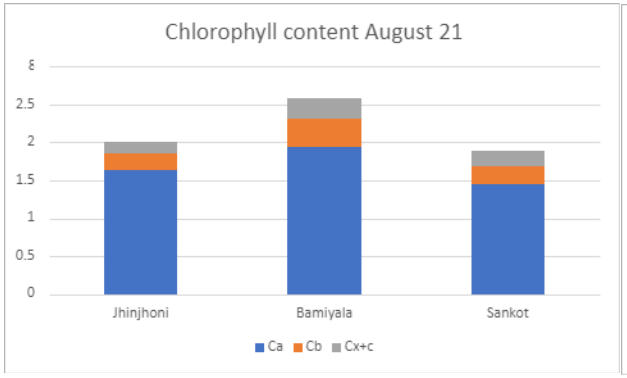


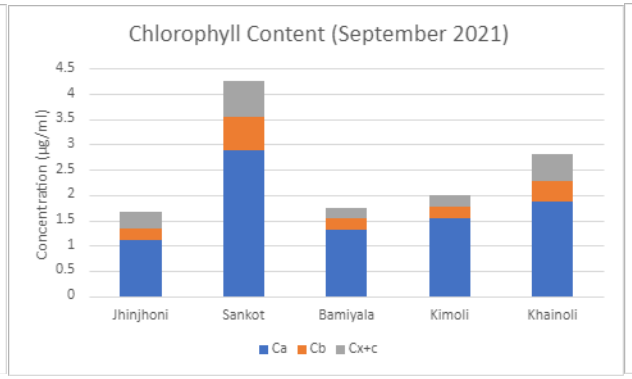


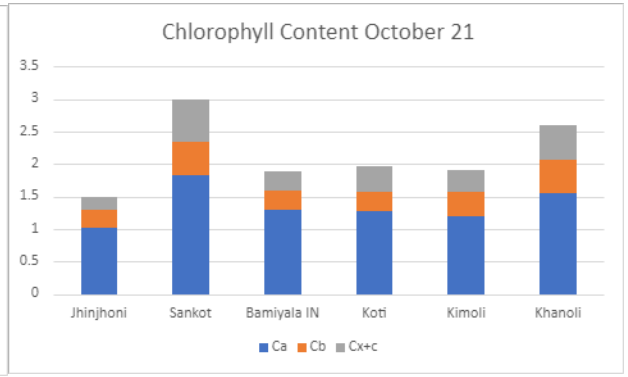
4th Objective Results - India

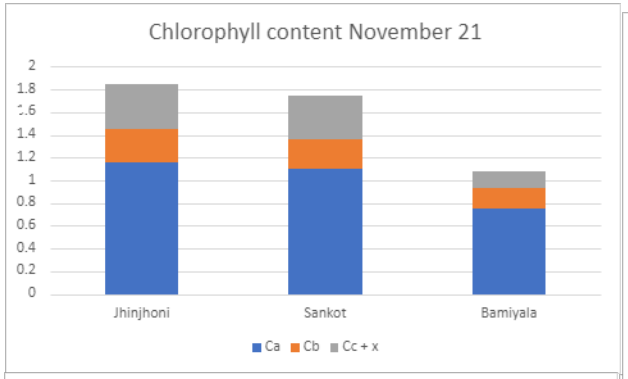


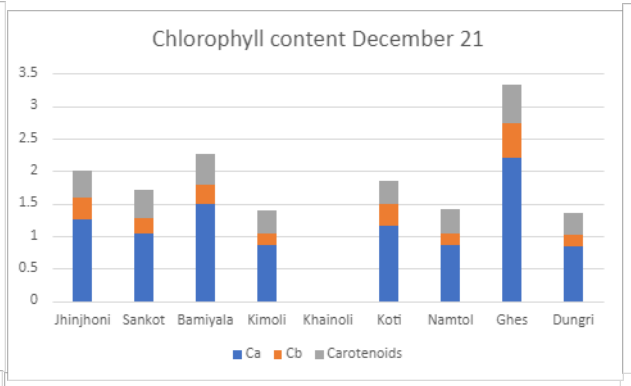
Results - India

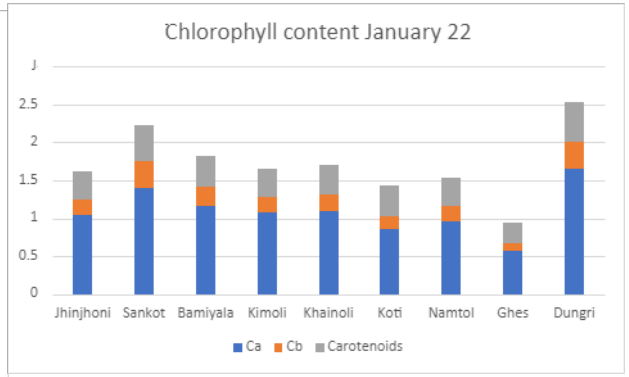


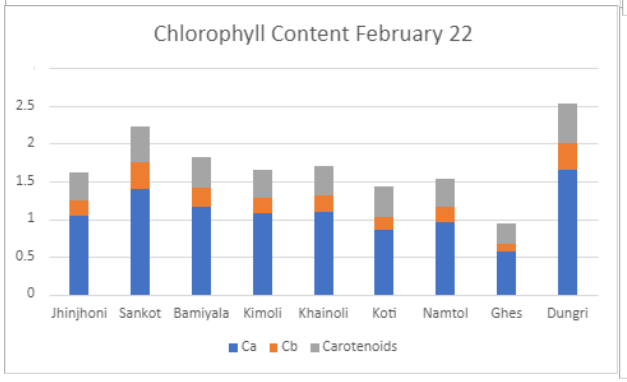


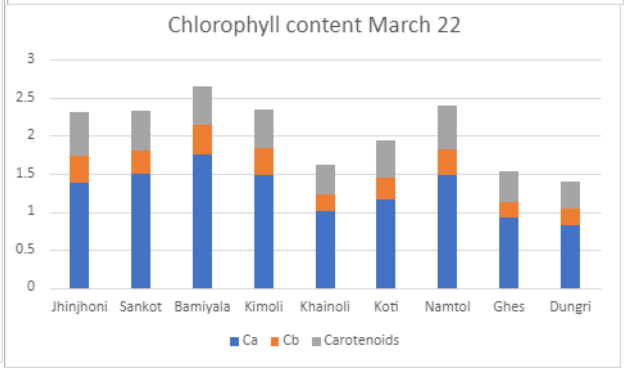












Engaging Policy makers.
Impact on the Ocean Ecosystem

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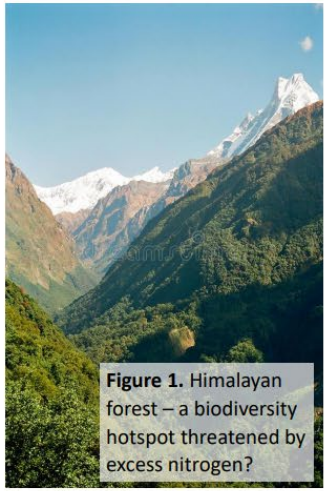

Figure 1. Himalayan forest – a biodiversity hotspot threatened by excess nitrogen?

Functional traits of lichens in Himalayan forests as indicators of nitrogen deposition

Pat Wolseley[1*]; Sudipto Chatterjee[2]; Matthew Jones[3]; Sarath Nissanka[4]; Bishnu Pandey[5]; Himanshu Rai[6], Mark Sutton[3]; Dendup Tshering[7]; Buddhika Weerakoon[4]; Gothamie Weerakoon[1]; Christopher Ellis[8*]

[1] The Natural History Museum, UK; [2] TERI, India; [3]Centre for Ecology and Hydrology, UK; [4]University of Peradeniya, Sri Lanka; [5]Kathmandhu University, Nepal; [6]Centre of Advanced Study in Botany, India [7]Royal University of Bhutan, Bhutan; [8]Royal Botanic Garden, Edinburgh, UK.

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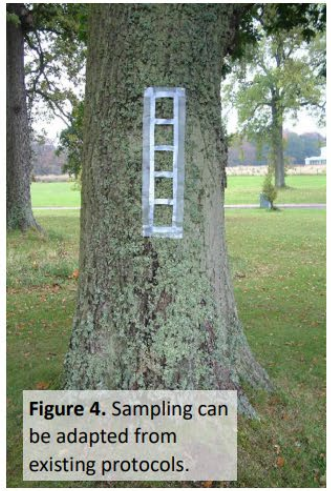


Figure 4. Sampling can be adapted from existing protocols.

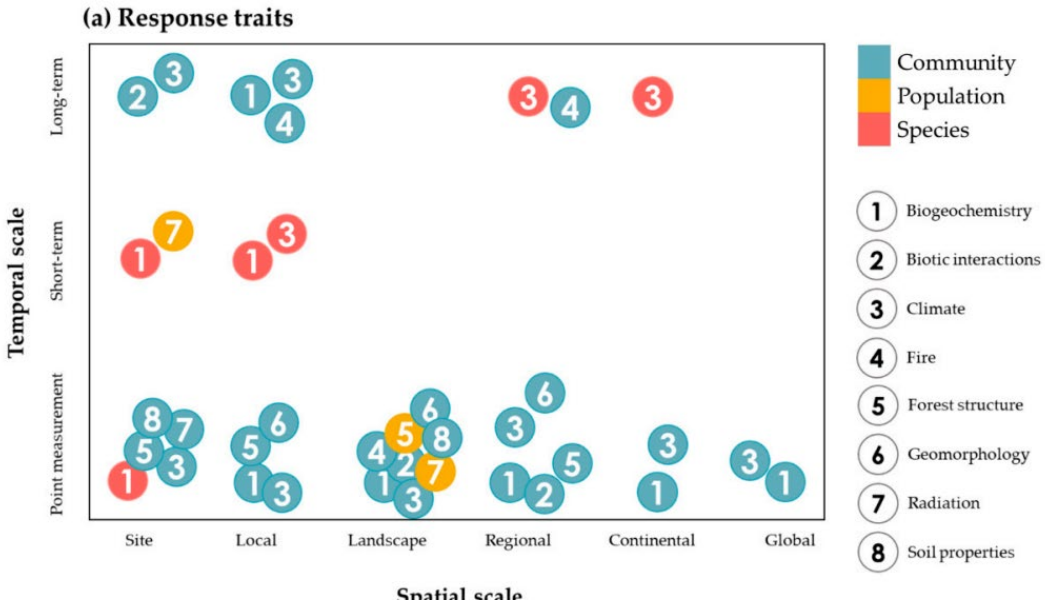
microorganisms

MDPI

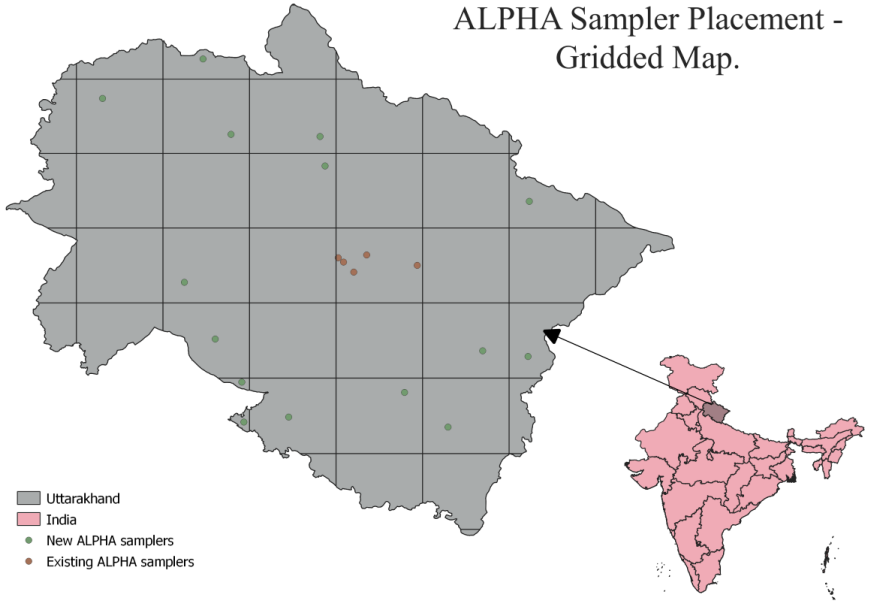
Review

Functional Traits in Lichen Ecology: A Review of Challenge and Opportunity

Christopher J. Ellis [1,*], Johan Asplund [2], Renato Benesperi [3], Cristina Branquinho [4], Luca Di Nuzzo [3], Pilar Hurtado [5,6], Isabel Martínez [5], Paula Matos [7], Juri Nascimbene [8], Pedro Pinho [4], María Prieto [5], Bernardo Rocha [4], Clara Rodríguez-Arribas [5], Holger Thüs [9] and Paolo Giordani [10]



Scaling up from 5 to 20 sites in Western Himalaya



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Dendup Sherring – RGB Bhutan

Laboratories

Biodiversity and Conservation, TERI SAS. India
National Centre for Sustainable Coastal Management, Chennai . India
Fare Labs, Gurgaon India
Natural History Museum , London

UK Centre for Ecology & Hydrology

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