South Asian Smallholder Forests and Trees Outside of Forests:

Synthesizing LCLUC to assess evidence-based Nature-based Solutions for climate change

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A Target on Synthesis (Not New Research per se)

- The team: 6 university teams with 12 regional counterparts and collaborators. Current PIs in SARI who are focused on tree-based land cover systems and TOF
- Target Objective:
  - synthesize existing research to assess the current state and trends of land-use change in the SARI region,
  - identify important emerging trends and themes relevant to global change science *and* climate change policy.
  - Advance our understanding of the processes, drivers and impacts on carbon emissions and removals, with the ultimate goal of developing new understanding of the landscape-level drivers of biotic emissions and removals.

Trees Outside of Forest

nature communications

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More than one quarter of Africa's tree cover is found outside areas previously classified as forest

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…nt monitoring of trees both inside and outside of forests is key to …nd management. Current monitoring systems either ignore trees …ts or are too expensive to be applied consistently across coun… …eated basis. Here we use the PlanetScope nanosatellite con… …ich delivers global very high-resolution daily imagery, to map …nd non-forest tree cover for continental Africa using images from … Our prototype map of 2019 (RMSE = 9.57%, bias = −6.9%). …s that a precise assessment of all tree-based ecosystems is pos… …nental scale, and reveals that 29% of tree cover is found outside …usly classified as tree cover in state-of-the-art maps, such as in …d grassland. Such accurate mapping of tree cover down to the

NEWS AND VIEWS | 01 March 2023

Carbon stocks of billions of individual African dryland trees estimated

An inventory of nearly 10 billion individual trees has been compiled for the African drylands, estimating biomass and carbon stocks. The data will aid dryland restoration projects and assessments of the land carbon budget.

Jules Bayala & Meine van Noordwijk

Article | Open Access | Published: 01 March 2023

Sub-continental-scale carbon stocks of individual trees in African drylands

Compton Tucker, Martin Brandt, Pierre Hiernaux, Ankit Kariryaa, Kjeld Rasmussen, Jennifer Small, Christian Igel, Florian Reiner, Katherine Melocik, Jesse Meyer, Scott Sinno, Eric Romero, Erin Glennie, Yasmin Fitts, August Morin, Jorge Pinzon, Devin McClain, Paul Morin, Claire Porter, Shane Loeffler, Laurent Kergoat, Bil-Assanou Issoufou, Patrice Savadogo, Jean-Pierre Wigneron, … Rasmus Fensholt

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Abstract

The distribution of dryland trees and their density, cover, size, mass and carbon content are not well known at sub-continental to continental scales[1,2,3,4,5,6,7,8,9,10,11,12,13,14]. This information is important for ecological protection, carbon accounting, climate mitigation

NATURE CLIMATE CHANGE | VOL 11 | DECEMBER 2021 | 1006–1016 | www.nature.com/natureclimatechange

Trees outside of forests as natural climate solutions

Trees outside of forests are numerous and can be important carbon sinks, while also providing ecosystem services and benefits to livelihoods. New monitoring tools highlight the crucial contribution they can make to strategies for both mitigation and adaptation.

David L. Skole, Cheikh Mbow, Maurice Mugabowindekwe, Martin S. Brandt and Jay H. Samek

High-biomass natural forests are an important focal point for climate change mitigation action and thus are targets of large public and private investments, particularly in developing countries in the tropics. The most prominent international forest initiative for climate change mitigation is the framework for reducing emissions from deforestation and forest degradation in developing countries, or REDD+, which emphasizes closed canopy tropical forests. However, with emerging new capabilities for measuring and mapping trees outside forests (TOF), especially using new Earth-observation methods, there will be a missed opportunity if the mitigation dialogue does not include a range of non-forest tree-based systems, which could provide broad additional benefits, including landscape restoration, conservation of biodiversity and enhancing the livelihoods of more than a billion people, many of whom live in extreme poverty[1].

economic value as compared to annual crops (Fig. 1).

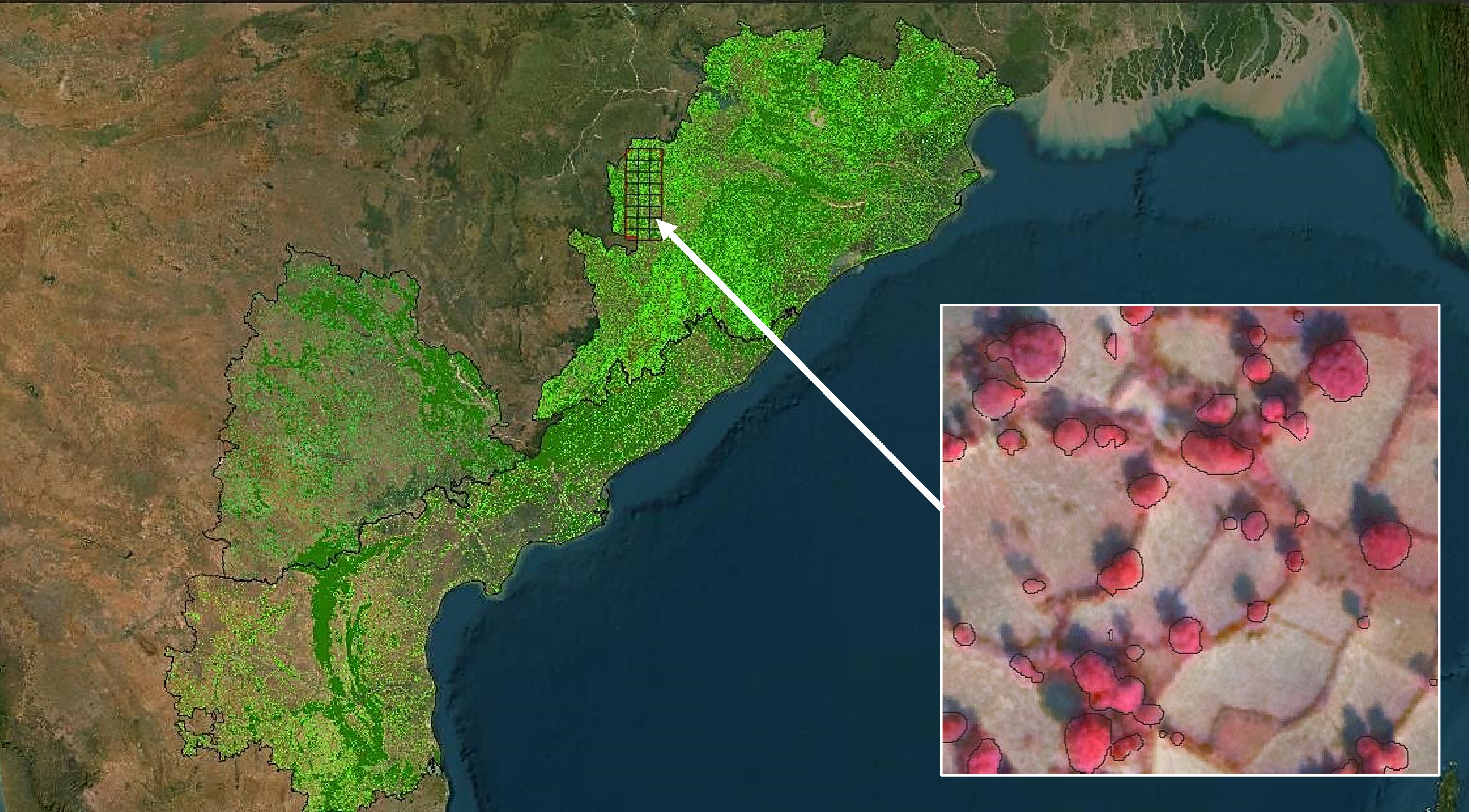
Worldwide, there are many non-forest landscapes with considerable tree cover and increasing biomass, which are important sinks for carbon[2,3]. An interesting recent analysis[4] mapped more than 1.8 billion isolated trees outside of forests across 1.3 million ha in West Africa, which is a relatively high and unexpected density of trees in areas previously thought to be desert or highly degraded savannah. These trees are both widely spaced natural trees and tree-based production systems actively managed by local farmers. We estimate that the carbon stocks here could be up to 22 MgC ha^{-1}, which is higher than what was estimated in global biomass mapping[5] and is thus essentially hidden from the international dialogue on natural climate solutions.

Some studies have suggested that extensive areas of TOF, and the trend that this area is increasing, are attributed to actions promoted and mediated by farmers as a deliberate way to capture market

Fig. 1 | Trees outside of forests in central Malawi. Naturally occurring trees and farmer-managed tree-based systems provide a range of ecosystem services and livelihood benefits, are often intentionally promoted across agricultural landscapes and provide opportunities for carbon sequestration. Credit: D. L. Skole.

from 1.8 Mg ha^{-1} yr^{-1} to 10 Mg ha^{-1} yr^{-1} as compared with 0.6 Mg ha^{-1} yr^{-1} for conservation agriculture[9]. Agroforestry is

TOF is Ubiquitous in South Asia



NASA LCLUC South Asia (ToF)

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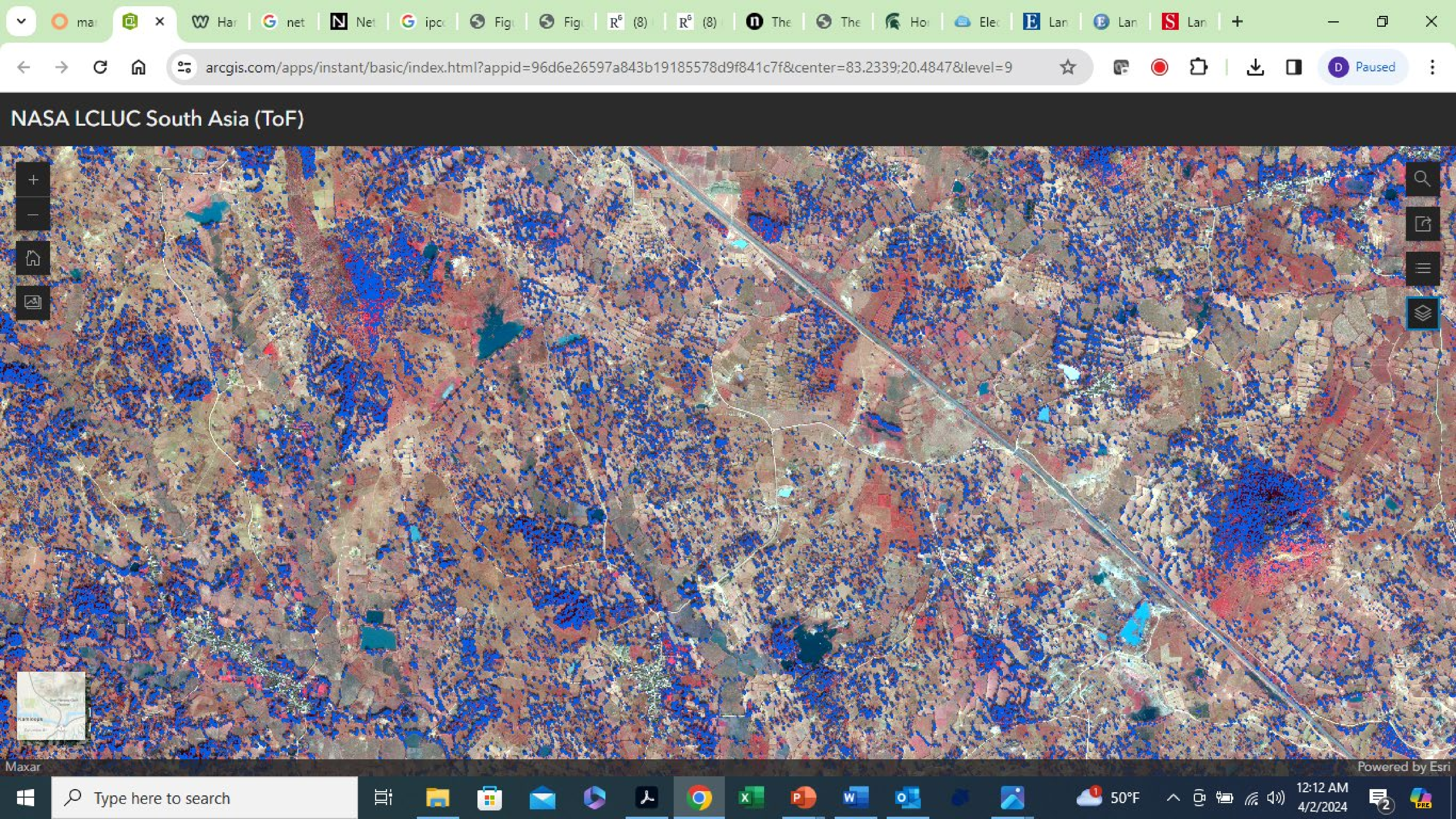
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TOF, Forest Landscape Restoration, Climate Change Policy

npj | biodiversity

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COMMENT OPEN

Check for updates

Combining socioeconomic and biophysical data to identify people-centric restoration opportunities

Pooja Choksi[1] ✉, Arun Agrawal[2], Ivan Bialy[3], Rohini Chaturvedi[4], Kyle Frankel Davis[5,6], Shalini Dhyani[7], Forrest Fleischman[8],
Jonas Lechner[9], Harini Nagendra[10], Veena Srinivasan[11] and Ruth DeFries[1]

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POLICY FORUM

CLIMATE CHANGE

Land management can contribute to net zero

The voluntary carbon market needs to embrace changes for the land sector

By Ruth DeFries[1,2], Richie Ahuja[3], Julio Friedman[4,5], Doria R. Gordon[3,6], Steven P. Hamburg[3], Suzi Kerr[3], James Mwangi[2,8], Carlijn Nouwen[7], Nitin Pandit[9]

Demand for credits on the voluntary carbon market is poised to surge as corporations implement net-zero commitments. Approximately half of all credits issued from 2000 to 2021 on the voluntary carbon market re-lated to land use, mostly from forest proj-

uncertain and potential land conflicts raise serious concerns. Estimates indicate that up to 60% of emissions from agriculture relative to 2030 business-as-usual projections and 110% of emissions from the forestry sector are technologically and economically feasible to reduce (3).

Multiple approaches can economically incentivize reduced emissions and carbon sequestration from land management, including fines for violating regulations, sub-sidies and tax credits, capped emission in-

addressed), leakage (whether r
in one place are displaced by em
another place), and quantification
reductions are accurately quantifi
to an appropriate baseline and
Another factor contributing to l
dence is the potential for displace
inequitable benefit sharing with
ized and Indigenous peoples in p
conflicts between customary and
land tenure, asymmetric power re
poor governance. Such negative

nature climate change

PERSPECTIVE

https://doi.org/10.1038/s41558-021-01245-w

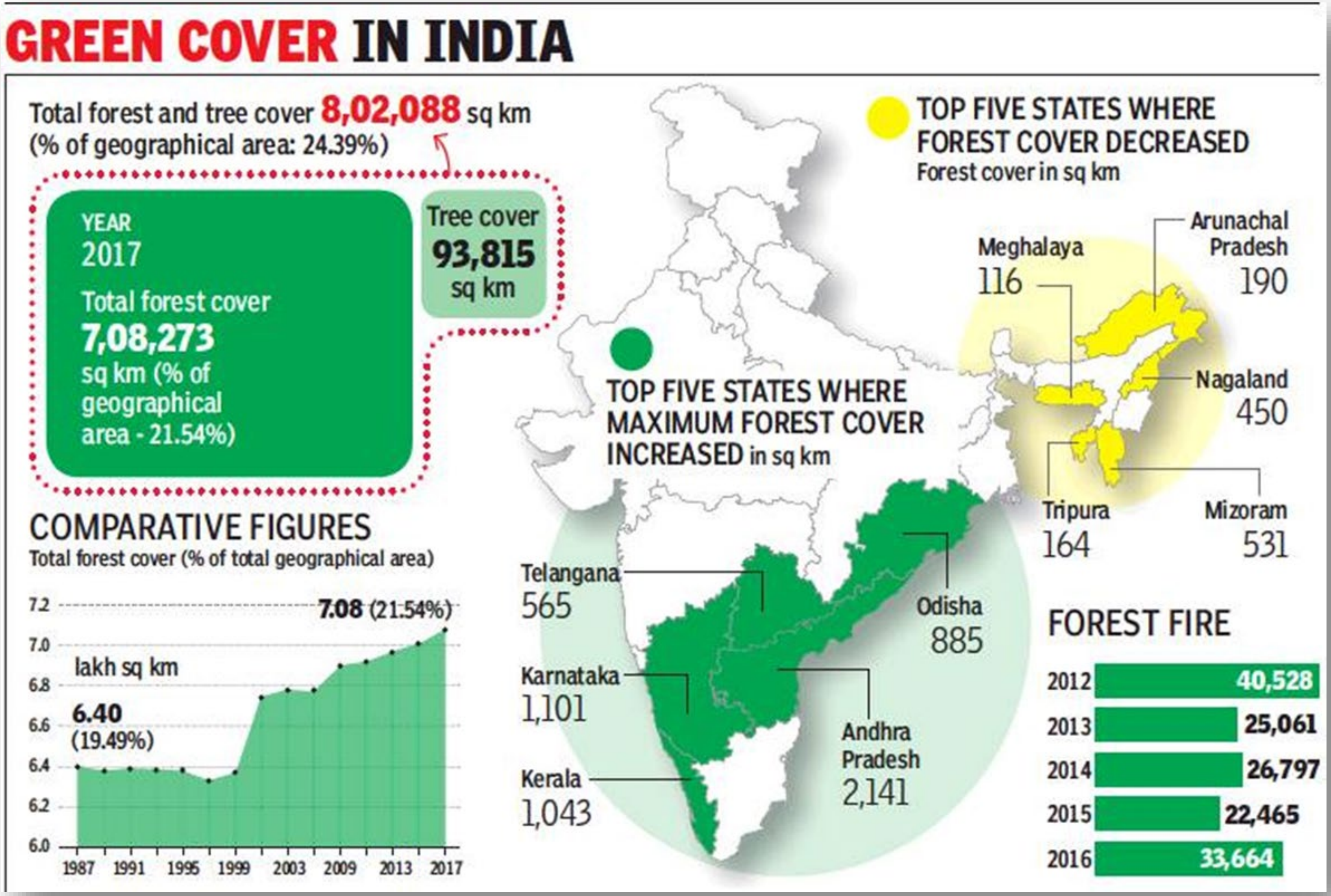
Check for updates

The meaning of net zero and how to get it right

Sam Fankhauser[1,2] ✉, Stephen M. Smith[1], Myles Allen[2], Kaya Axelsson[1], Thomas Hale[3], Cameron Hepburn[1], J. Michael Kendall[4], Radhika Khosla[1], Javier Lezaun[5], Eli Mitchell-Larson[2], Michael Obersteiner[6], Lavanya Rajamani[7], Rosalind Rickaby[4], Nathalie Seddon[8] and Thom Wetzer[1,7]

The concept of net-zero carbon emissions has emerged from physical climate science. However, it is operationalized through social, political and economic systems. We identify seven attributes of net zero, which are important to make it a successful framework for climate action. The seven attributes highlight the urgency of emission reductions, which need to be front-loaded, and of coverage of all emission sources, including currently difficult ones. The attributes emphasize the need for social and

India: Increasing Tree Cover Outside of Forests

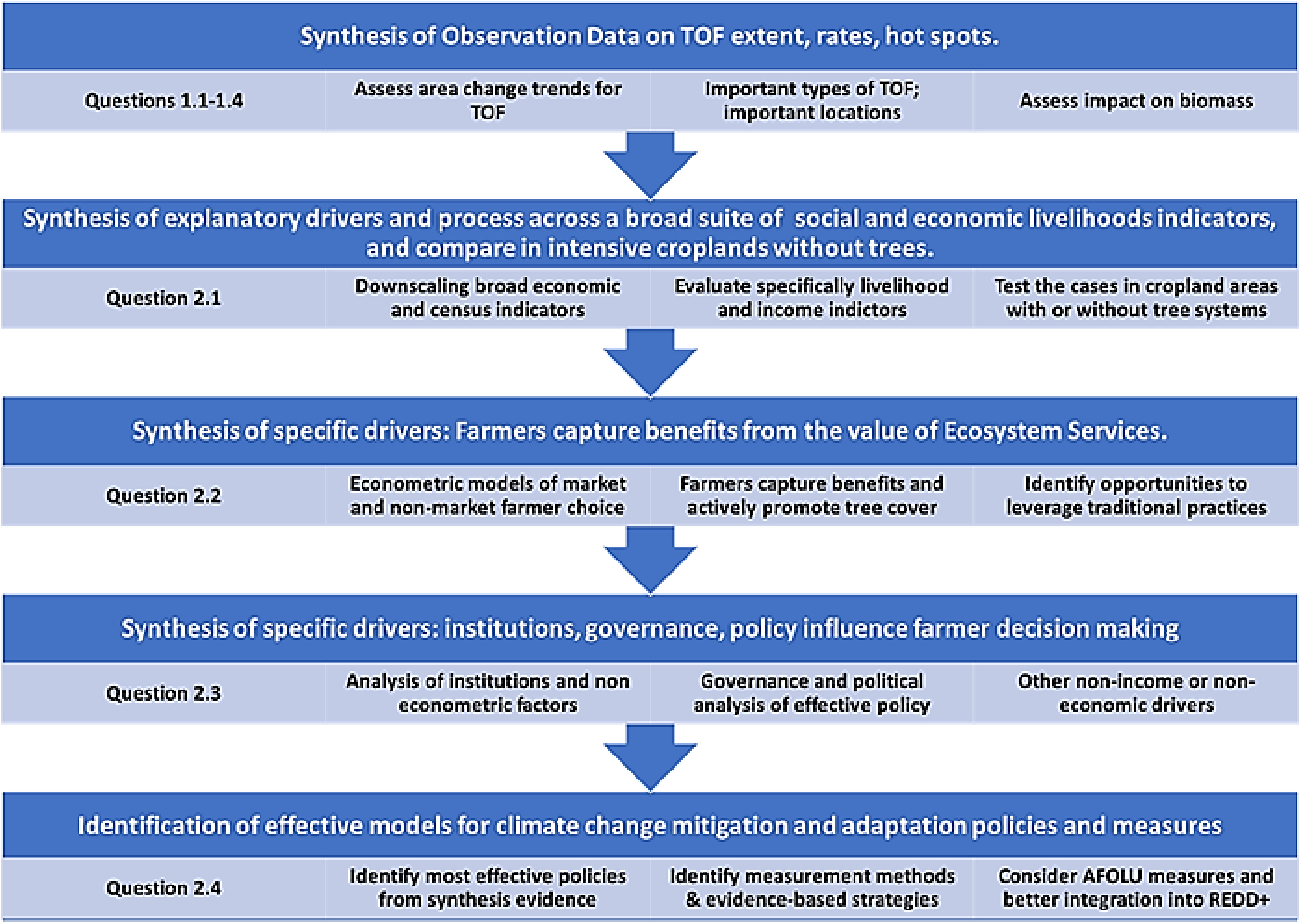


Synthesis Rationale

- Understanding LCLUC patterns and processes related to agricultural landscapes of smallholder tree-based systems and their potential as natural climate solutions.
- Observation-based:
  - How are these landscapes are increasing cover and biomass, and then evaluate what conditions lead to increases in tree and forest cover in South Asia, and
- Process-based:
  - under what conditions do improvements in tree and forest cover contribute to improving rural livelihoods?
- Objectives:
  1. Synthesize current and recent NASA research on LCLUC to contribute to a fundamental understanding of their patterns and drivers and
  2. translate fundamental science into evidence-based contributions to important climate mitigation and adaptation policy for the region.

Synthesis Framework

- *Objective:* Fundamental science for evidence-based applications.
- *Model:* Sustainable Landscapes.
  - an emerging framework that combines evidence from empirical and process-based scientific research with policy and oriented models that integrates biophysical and socio-economic analysis.
  - Actionable Science: framework is adept at translational work that links evidence from empirical analysis to successful policy interventions
- *Thematic, cover types country focal points*: primarily India, but extended to the region by testing
- *Knowledge characterization and limitations:* Systematic Quantitative Literature Review (SQLR) framework (Pickering et al. 2021)
- *Scientific and technical context:* Beyond the forest fringe, beyond the land sector type, integrated landscapes, TOF
- *Policy context:* Expanding the REDD+ Framework (AFoLU), FLR, Net-Zero, NbS


Synthesis of Observation Data on TOF extent, rates, hot spots.
Questions 1.1-1.4
Assess area change trends for TOF
Important types of TOF; important locations
Assess impact on biomass
Synthesis of explanatory drivers and process across a broad suite of social and economic livelihoods indicators, and compare in intensive croplands without trees.
Question 2.1
Downscaling broad economic and census indicators
Evaluate specifically livelihood and income indictors
Test the cases in cropland areas with or without tree systems
Synthesis of specific drivers: Farmers capture benefits from the value of Ecosystem Services.
Question 2.2
Econometric models of market and non-market farmer choice
Farmers capture benefits and actively promote tree cover
Identify opportunities to leverage traditional practices
Synthesis of specific drivers: institutions, governance, policy influence farmer decision making
Question 2.3
Analysis of institutions and non econometric factors
Governance and political analysis of effective policy
Other non-income or non-economic drivers
Identification of effective models for climate change mitigation and adaptation policies and measures
Question 2.4
Identify most effective policies from synthesis evidence
Identify measurement methods & evidence-based strategies
Consider AFOLU measures and better integration into REDD+

Process and Structure

- Meta analysis of the LCLUC-led research, this project Co-Is plus other LCLUC PIs, additional external research – the SQLR method
- Structured Questions
- From White Papers to Major Papers (WP in review)
- Synthesis Workshops in the region – PIs plus regional scholars
- First Workshop (April 9-11, Sonipat, India): *Synthesis Meeting on Scientific Foundations of Natural Climate Solutions in Tree Based Systems of LCLUC in South Asia*

Workshop Objectives

- Clarify the current state of scientific evidence of LCLUC in agricultural and tree-based landscapes including trees outside of forests (TOF) and climate change…
- …that can better inform climate change mitigation and adaptation. Thus, the important outcomes of these discussions are expected to be:
  1. synthesis of current and recent NASA research on LCLUC to contribute to a fundamental understanding of their patterns and drivers and
  2. the translation of fundamental science into evidence-based contributions to important climate mitigation and adaptation policy for the region.

Workshop Structure

Thematic Sessions Presented in Plenary

1. Recent results from coupled social and biophysical research, and what we are learning from integrated analysis,
2. An empirical review from the perspective of observations, across earth observations (EO), ground-based measurements, and statistical data,
3. Ideas on how these processes and patterns reveal and underpin an understanding of Nature-based Solutions, and
4. An integration of evidence to support land-based climate change policy with NbS that leads to net-zero emissions pathways.

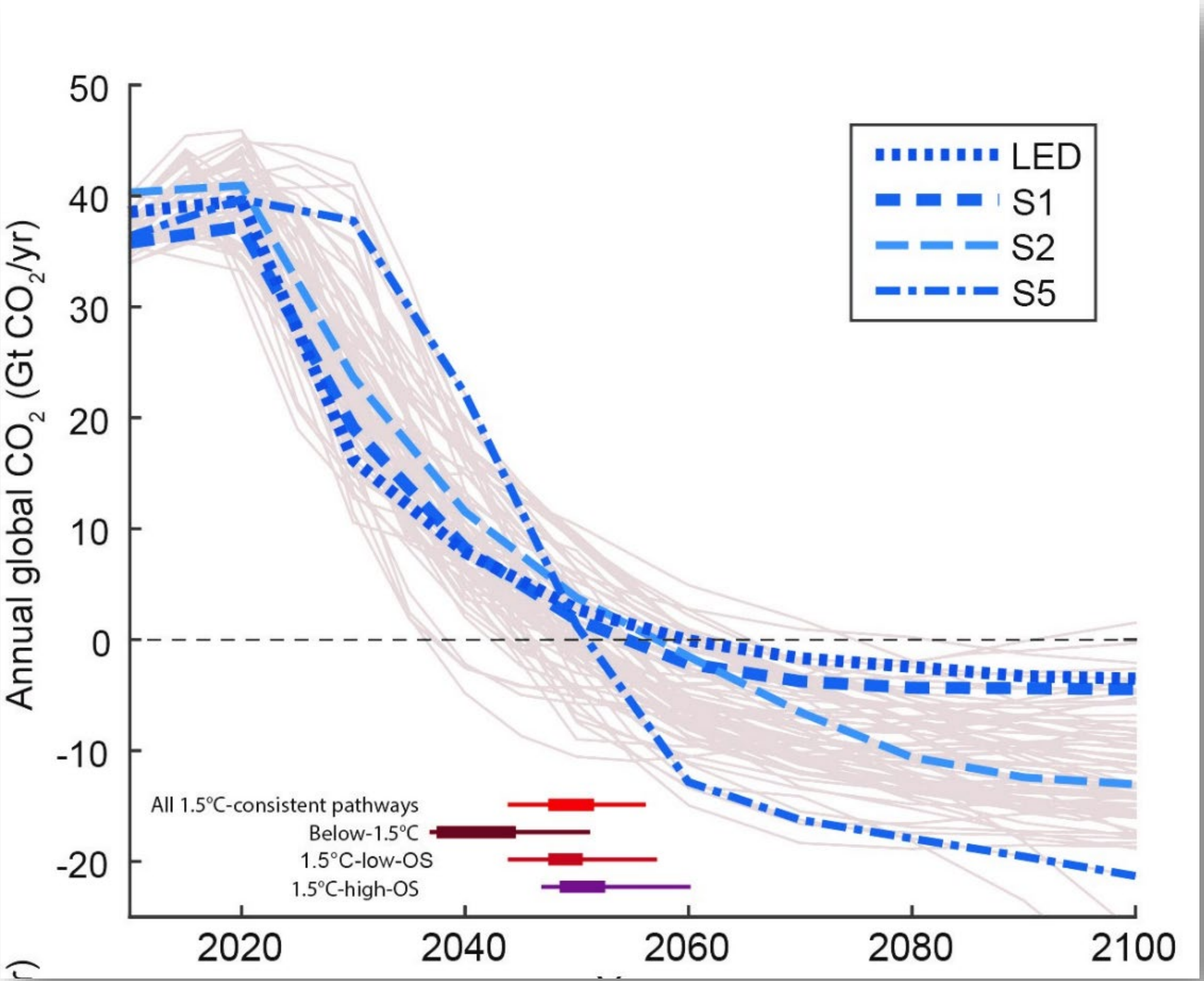
Workshop Structure

Extended Deliberative Discussions in Small Groups

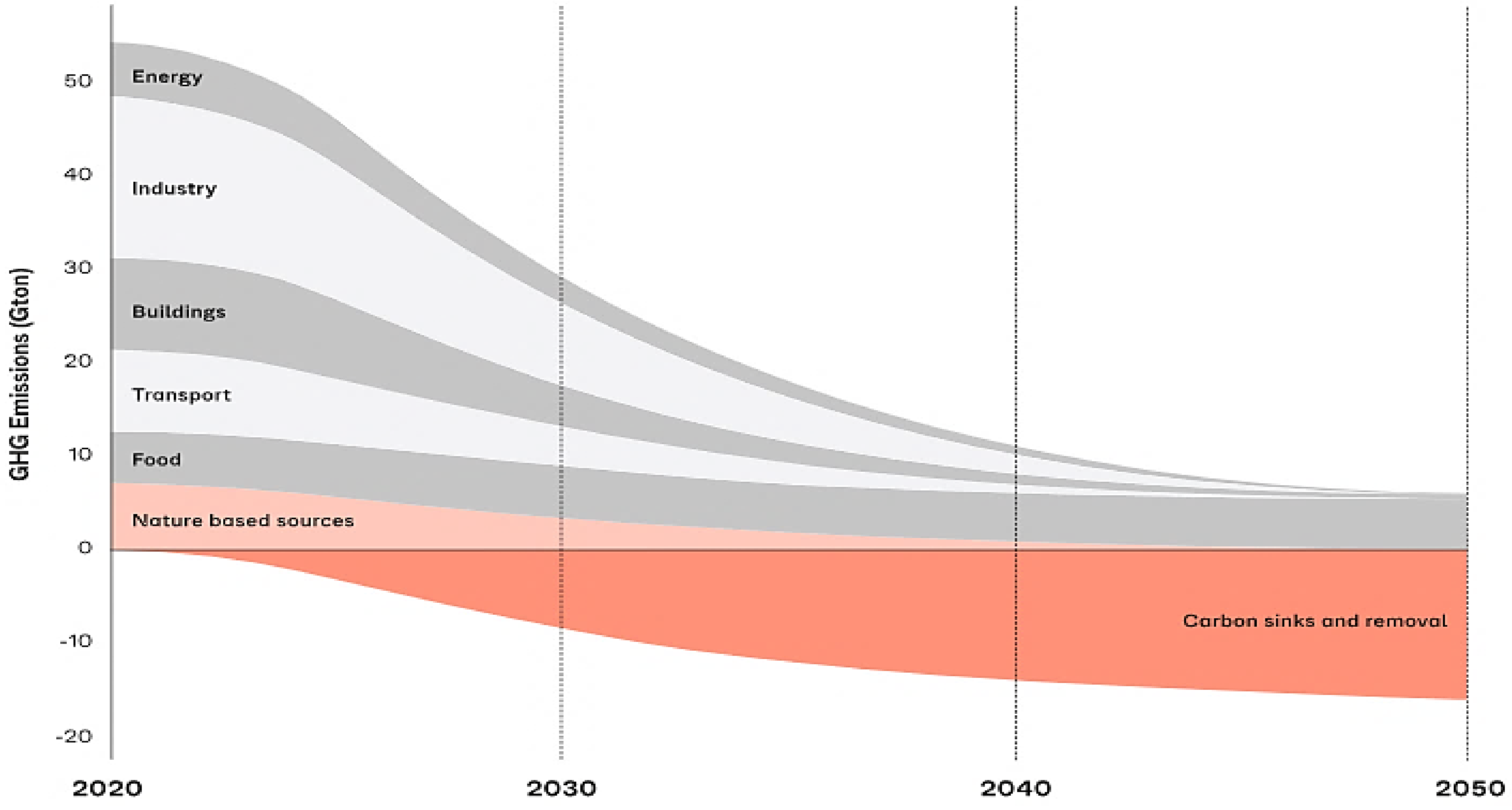
- Consider the value of integrating biophysical and socioeconomic patterns and processes, and how is the approach is leading to better scientific evidence to support NbS?
- What is the state of the science in Earth Observations, what has been revealed and where are the uncertainties and errors? How can technical observations improve policy outcomes specifically?
- What do we know about drivers of TOF; e.g. are they promoted by farmers out of awareness of ecosystem values, or does policy and governance play a more substantial role in increasing TOF NbS and carbon removals?
- How has NASA LCLUC science increased the evidence basis for NbS and climate change mitigation and what are the next big questions to address?

NbS, land systems, and and Net Zero

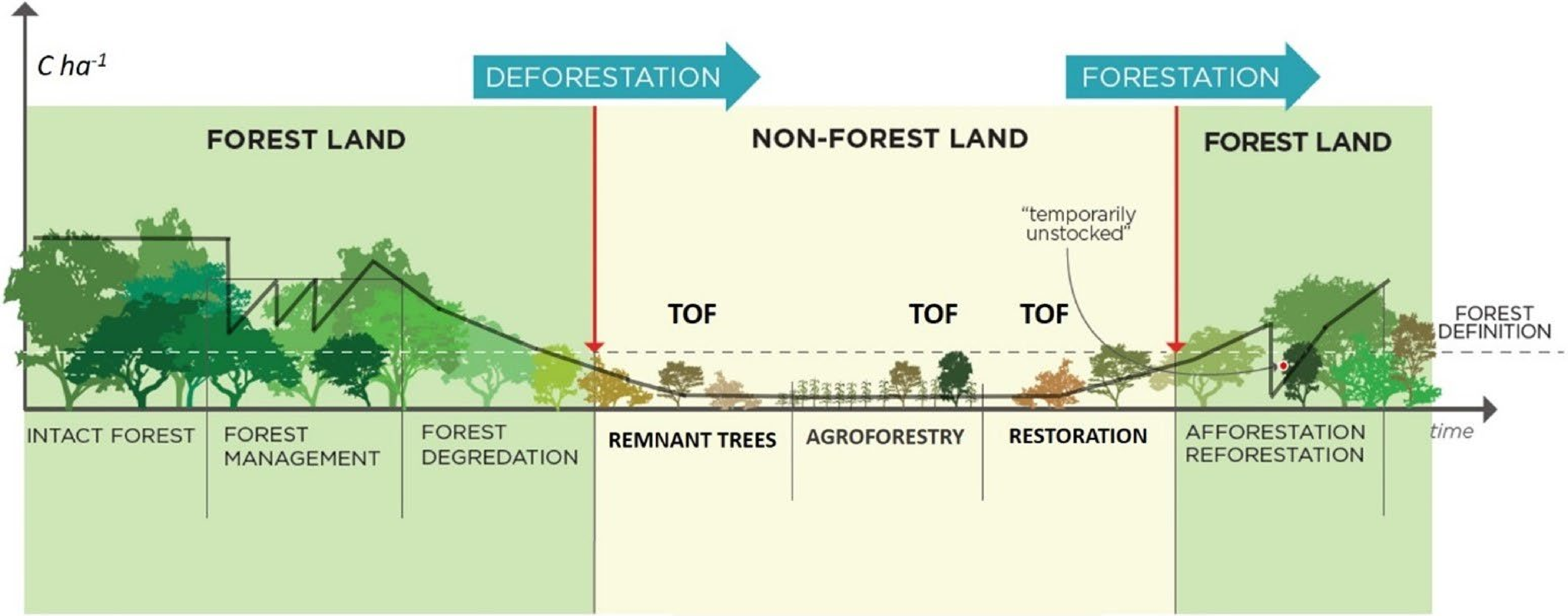
- IPCC Emission pathways to avert a 1.5 degree C impact.
- Aggressive in time
- Intensive in magnitude
- Avoid Overshoot (OS)



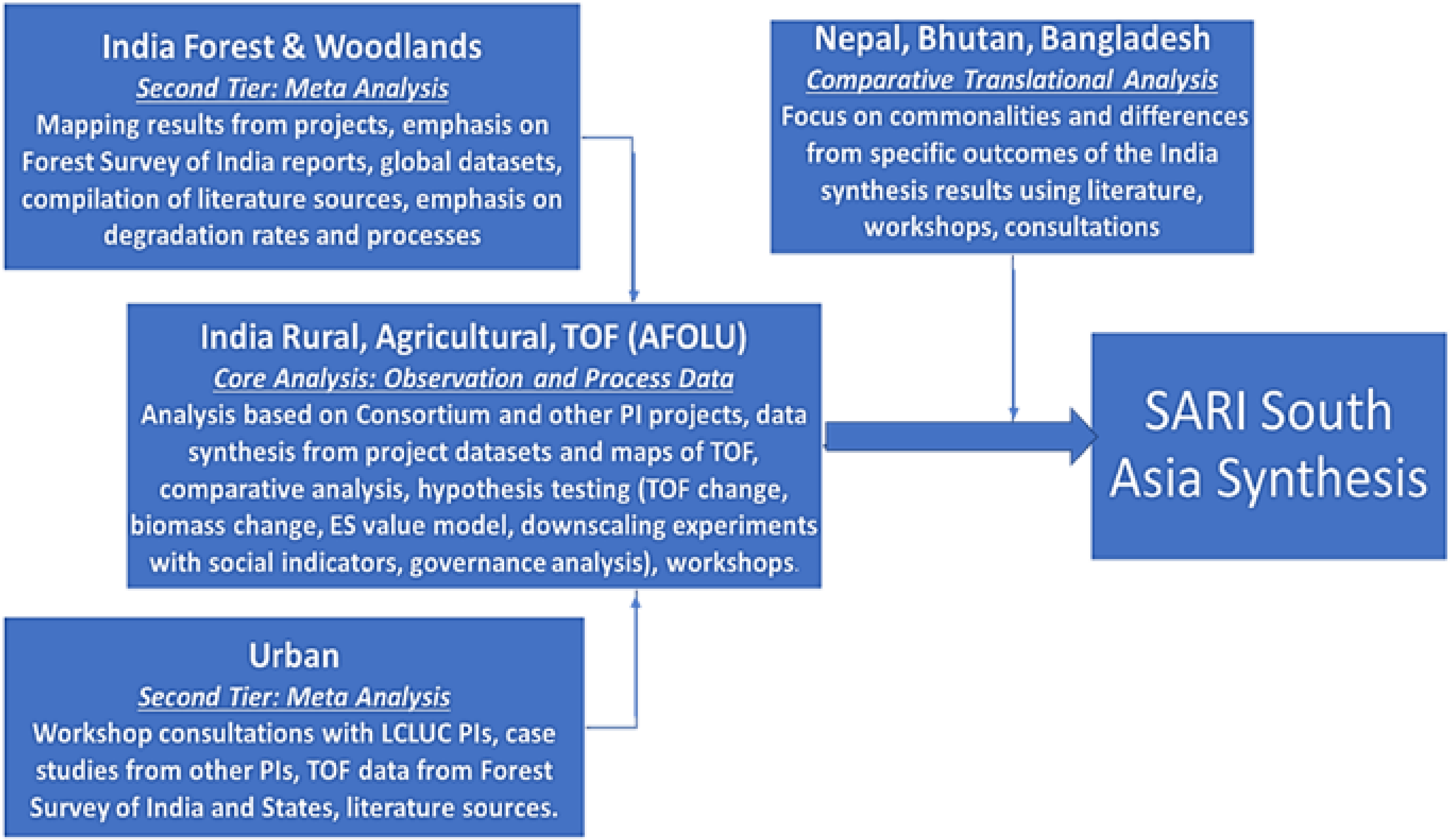
NbS, LCLUC Systems, and Net Zero



Context: LCLUC, Climate Change Policy



Actionable Science:
providing the evidence basis for climate change policy
through Nature-based Solutions


India Forest & Woodlands
Second Tier: Meta Analysis
Mapping results from projects, emphasis on Forest Survey of India reports, global datasets, compilation of literature sources, emphasis on degradation rates and processes
Nepal, Bhutan, Bangladesh
Comparative Translational Analysis
Focus on commonalities and differences from specific outcomes of the India synthesis results using literature, workshops, consultations
India Rural, Agricultural, TOF (AFOLU)
Core Analysis: Observation and Process Data
Analysis based on Consortium and other PI projects, data synthesis from project datasets and maps of TOF, comparative analysis, hypothesis testing (TOF change, biomass change, ES value model, downscaling experiments with social indicators, governance analysis), workshops.
SARI South Asia Synthesis
Urban
Second Tier: Meta Analysis
Workshop consultations with LCLUC PIs, case studies from other PIs, TOF data from Forest Survey of India and States, literature sources.

1. From a synthesis of the empirical and observational data and reporting.
    1. By synthesizing the current data from remote sensing and inventories, what has been the trend in Land Cover and Land Use Change in the SARI region, and what do the best projections tell us about future directions in forests, trees outside of forests and agricultural cover and use?
    2. Given recent preliminary evidence of trends in the region and globally of increasing tree cover, are there landscapes and "hot spots" where we observe significant increases in biomass and carbon stocks from tree cover, and would they be quantitatively important now or in the future for removals of atmospheric carbon dioxide?
    3. Given already sophisticated capabilities for monitoring dense forest cover, what are future methodological advances to further improve capabilities – what is the current state of practice for large scale monitoring, measuring, and mapping TOF cover and biomass, and how can tree-based landscapes best be monitored using remotely sensed data?
2. From a synthesis of current process-level understanding of the drivers of the observations from monitoring.
    1. What is the relationship between tree-based (TOF) landscapes and livelihoods, primarily in rural areas, and how do these relationships differ from landscapes in the absence of tree-based systems?
    2. Consistent with some preliminary evidence from the region and elsewhere, are observed increases in TOF directly and actively promoted by farmers, and does this coupling between biophysical response and socio-economic drivers relate to decisions based on livelihood strategies, incomes, and/or benefits from ecosystem services values?
    3. How do policies, governance, or farm level decision-making impact the formation and retention of tree-based landscapes and increased levels of biomass in different non-forest landscapes?