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The Economics of Ecosystems and Biodiversity (TEEB)

Promoting a Sustainable Agriculture and Food Sector

INDIA

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TEEB
The Economics of Ecosystems & Biodiversity

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I. INTRODUCTION

India has achieved two significant transitions in the agriculture sector over the last 40-50 years: the shift from scarcity to self-sufficiency due to the Green Revolution; and the transition from self-sufficiency to surplus. Today, India is a leading agricultural producer and agriculture is a crucial sector, accounting for 16 per cent of India's GDP and providing employment to about 52 per cent of the population, especially in rural areas (India, Ministry of Agriculture and Farmer's Welfare 2024).

As India looks towards 2030 and beyond, its food system confronts a myriad of challenges, including heightened pressure on natural resources, the impact of climate change, land fragmentation, increasing urbanization, high rates of malnutrition among children and impacts of chemical inputs on human health (Gulati *et al.* 2023). Major concerns around natural resources include the decline in yields, soil fertility, soil organic carbon (SOC), and water scarcity. 86 per cent of the farmers in India are small and marginal – 126 million farmers with an average holding of 0.6 hectares (India, Ministry of Agriculture and Farmer's Welfare 2019) – posing challenges for access to improved technologies, extension services, credit, and markets that would enable them to mitigate and adapt to these challenges. Women are particularly affected by these challenges given that the agriculture sector has the highest share of women workers (62.9%) of all industries in India (India, Ministry of Labour and Employment 2023).

Many of these concerns in the agriculture sector, as is the case globally, have arisen from a tendency to measure the success of agricultural and food policies through a narrow lens such as 'yield per hectare' or 'per capita production' that fails to consider agriculture and food systems in a holistic manner, ignoring the links between food systems, the environment and human wellbeing. If not amended, these can have long-term deleterious effects on not just food supply but also on human health and nature.

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Rice farmers in Uttar Pradesh

II. FOOD SYSTEMS TRANSFORMATION AND PRO-NATURE OPTIONS

The United Nations has identified Food Systems Transformation as a part of six main transitions needed for accelerating the achievement of the Sustainable Development Goals (SDGs). Food systems must be transformed to become more sustainable, efficient and resilient, for better production, better nutrition, a better environment and a better life (United Nations 2023). These efforts are being undertaken through the formulation of national food systems transformation pathways. For India, it is vital to increase the sustainability of food systems to deliver affordable, healthy food and advancing equitable livelihoods [1] to a population estimated to reach 1.66 billion by 2050 (United Nations 2022). India's G20 Presidency noted that "sustainable, diversified and resilient agriculture and food systems offer significant opportunities to address climate change, land degradation, over-exploitation of water resources, biodiversity and forest loss while providing long-term solutions to tackle hunger and malnutrition"[2].

Reform of foods systems is a complex undertaking that impacts upon myriad aspects of economy, society and environment. The costs, benefits and impacts of changes to foods systems are often 'invisible' in the sense that they are not captured by standard financial and economic decision-making tools. Pro-nature options such as organic farming and agroforestry can appear suboptimal without consideration of huge hidden costs and benefits of agriculture and food systems, which need to be unravelled, understood, and evaluated in the determination and implementation of transition pathways.

'True Cost Accounting' (TCA), the theme for both the 2023 and 2024 FAO Flagship State of Food and Agriculture (SOFA) reports, is increasingly being applied to support decision-making on food systems transformation as it allows for the assessment of positive and negative externalities that natural, human and social capital can have on our economies.

1. www.unfoodsystemshub.org/docs/unfoodsystemslibraries/national-pathways/india/2021-09-22-en-fss_dialogue_convener_report-prepared-by-prof-ramesh-chand-member-niti-aayog.pdf?sfvrsn=c9580ca7_1
2. https://g20.in/content/dam/gtwenty/gtwenty_new/document/AMM-ODCS.pdf

III. THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY FOR AGRICULTURE AND FOOD (TEEBAGRIFOOD): BRINGING EVIDENCE TO THE FORE FOR DECISION MAKING

The Economics of Ecosystems and Biodiversity (TEEB) initiative, hosted by UNEP, is a type of TCA, with an aim to draw attention to the invisibility of nature in the economic choices made across international, national, and local policymaking, public administration, and business [3]. TEEB emphasizes understanding the interconnectedness and interdependencies among various elements, namely natural, produced, human, and social capitals. By evaluating changes in these different capitals both quantitatively and qualitatively, TEEB provides a comprehensive assessment of the consequences of policy choices, enabling more informed decision-making.

TEEB for Agriculture and Food (TEEBAgriFood) was launched in 2018 and aims to contribute a framework approach for better understanding and managing the impacts and externalities of agriculture and food value chains, and to bring together a global network of scholars and decision-makers dedicated to disclosing and valuing those impacts. The TEEBAgriFood Framework offers a structured approach to valuation that helps decision-makers recognize the wide range of benefits provided by ecosystems and biodiversity, demonstrate their values in economic terms and where appropriate, capture those values in decision-making

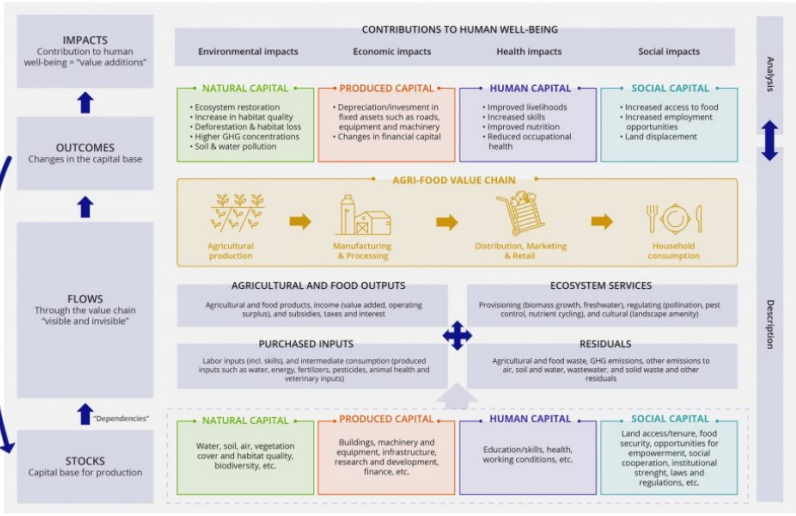


Figure 1: Schematic of the TEEBAgriFood Framework

3. The TEEB India initiative was launched in 2011 focusing on forests, inland wetlands, and marine and coastal ecosystems. The overall study report was released at the 21st session of the UNFCCC COP held in 2015 in Paris.

IV. TEEBAGRIFOOD APPLICATION IN INDIA

India has introduced forward looking policies and interventions on sustainable agriculture under the umbrella of the National Mission on Sustainable Agriculture (NMSA), which also contributes towards meeting its international commitments on climate and biodiversity, and domestic priorities including enhancing farmers' incomes.

As a part of the UNEP global project titled "The Economics of Ecosystems and Biodiversity: Promoting a Sustainable Agriculture and Food Sector" funded by the European Union and implemented in seven countries from 2019-2023, UNEP supported the Indian government in generating evidence for scaling sustainable agriculture practices in India through economic valuation. As per the need identified by the Project Steering Committee (PSC), co-led by the Ministry of Agriculture and Farmers Welfare (MoAFW) and Ministry of Environment Forest and Climate Change (MoEFCC), the TEEBAgriFood framework has been applied towards assessing and valuing the environmental and socioeconomic implications of scaling organic farming and agroforestry in Uttarakhand, Uttar Pradesh and Assam.

UNEP partnered with the Indian Council of Agricultural Research – Indian Institute of Farming Systems Research (ICAR-IIFSR), ICAR – Central Agroforestry Research Institute (CAFRI) and G.B. Pant University of Agriculture and Technology (GBPUAT) for implementation of the project in Uttar Pradesh, Assam and Uttarakhand respectively. The results of the project were shared periodically with a range of stakeholders [4] including the NITI Aayog and the Ministry of Jal Shakti (Water Resources) and State Agriculture and Forest Departments to assess their usability for evidence-based decision-making on sustainable food and agriculture systems in India. The assessment included modeling and economic valuation exercises for various scenarios from 2020 till 2050 - six scenarios, evaluating three options (Business-as-Usual (BAU), Optimistic and Pessimistic policy scenarios) under two IPCC climate scenarios (RCP 4.5 and RCP 8.5).

V. SELECTION OF STUDY AREAS

The Ganga Basin was identified as a priority area for assessment, not only because of its importance in India's food production, but also considering the important synergy with flagship programmes and policies [5]of Government of India and State Governments that seek to promote the uptake of organic farming and agroforestry and address concerns over inter alia farmers' livelihoods, nutrition and declines in the natural resource base.

4. TEEBAgriFood India stakeholder consultation reports: https://teebweb.org/our-work/agrifood/country-implementation/eupi2019/india/
5. Programmes and policy interventions of the Government of India assessed include Paramparagat Krishi Vikas Yojana (PKVY), Namami Gange Initiative, Rashtriya Krishi Vikas Yojana (RKVY), National Agroforestry Policy, MOVCD-NER, National Bamboo Mission

Five districts in Uttar Pradesh and two watersheds comprising three districts of Uttarakhand were identified for the study in 2020. Subsequently in 2022, in view of the strong impetus for organic farming and agroforestry in Northeast India, the TEEBAgriFood application was extended to Assam, to bring further clarity for holistic evidence-based policy and programme design on sustainable agri-food systems in the country. An important consideration was the need to select study areas that represented different ecological zones, namely warm sub-humid Western Himalayas in Uttarakhand; hot humid (dry) and hot semi-arid of Uttar Pradesh and hot sub-humid (moist) in Assam, as this would allow the analysis to contribute to the policy discourse in similar agro-ecological zones across the State and in other States. The selected States offered the following perspectives on the diverse effects of expanding organic farming and agroforestry.

Uttar Pradesh

- Implications of scaling organic farming and agroforestry given that Uttar Pradesh is the most populated Indian State which plays a vital role in India's agricultural production.
- Concerns around large-scale groundwater exploitation through tube wells used to irrigate 70.18 per cent of the total irrigated area in the State (Sinha 2021)
- Variation in demographic pressures between districts – 5 districts representing diverse trends in urbanization, demographic pressures and agroecologies were identified for assessments.

Uttarakhand

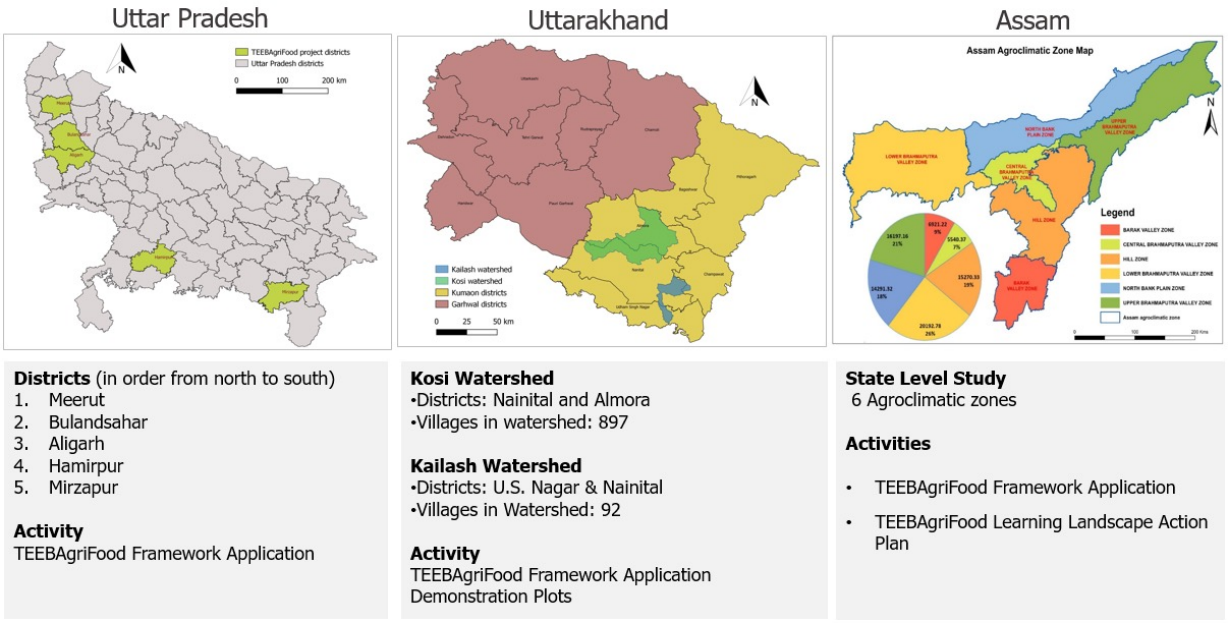
- Forward-looking policies of the State on organic farming – Uttarakhand Vision 2030 targets 100 per cent organic cultivation by 2030
- Variation in the State's geography and forest resources – Uttarakhand is 86 per cent mountainous, (Uttarakhand, Department of Horticulture 2024) with forests covering 63.5 per cent of the geographical area (Forest Survey of India 2021)
- Concerns on outmigration from hill regions and increasing urbanization in the lowlands of Uttarakhand.

Assam

- Implementation of the Mission Organic Value Chain Development – Northeast Region (MOVCD-NER) with an aim to make the Northeast Region of India an organic hub in the country

- Implications of scaling organic farming and agroforestry on improving agrobiodiversity given that Assam represents one of the most biodiverse States of India

- Positive initiatives taken in the State on agroforestry such as the establishment of the Assam Agroforestry Development Board in 2022



Districts (in order from north to south)
1. Meerut
2. Bulandsahar
3. Aligarh
4. Hamirpur
5. Mirzapur

Activity
TEEBAgriFood Framework Application

Kosi Watershed
•Districts: Nainital and Almora
•Villages in watershed: 897

Kailash Watershed
•Districts: U.S. Nagar & Nainital
•Villages in Watershed: 92

Activity
TEEBAgriFood Framework Application
Demonstration Plots

State Level Study
6 Agroclimatic zones

Activities

- TEEBAgriFood Framework Application
- TEEBAgriFood Learning Landscape Action Plan

Figure 2: Study areas under the TEEBAgriFood Project in India

VI. CAPITALS ASSESSED UNDER TEEBAGRIFOOD INDIA

The elements under various capitals that were prioritized for assessment under the project after multiple rounds of State-level consultations are illustrated in Fig 3.

Natural Capital	Produced Capital	Human Capital	Social Capital
Uttar Pradesh	Uttar Pradesh	Uttar Pradesh	Uttar Pradesh
• Carbon Sequestration • Soil Loss and Sediment Export • Water Provisioning (yield) • Agrobiodiversity	• Crop Production (Economic Yield) • Timber Production (Economic Yield)	• Human health (LULC based malaria infestation)	• Sustainable Livelihood Security Index (SLSI) • Women Empowerment
Uttarakhand	Uttarakhand	Uttarakhand	Uttarakhand
• Carbon Sequestration • Soil Loss & Sediment Export • Water Provisioning (quantity and quality) • Soil Health	• Crop Production (Economic Yield) • Timber Production (Economic Yield)	• Farmers' knowledge & training • Human Health (nutrition, occupational hazards)	• Livelihood security • Women Empowerment
Assam	Assam	Assam	Assam
• Carbon sequestration • Soil Health and Erosion	• Rice and Tea Yield • Bamboo production	• Workforce (quality) • Literacy	• Women Empowerment • FPOs/SHGs

Figure 3: Elements under the four capitals studied under TEEBAgriFood project in India

VII. FACTS AND FIGURES

Uttar Pradesh

- State Statistics: The gross cropped area spans 26.1 million hectares, with 68 per cent of the population relying on agriculture.
- Agrobiodiversity: Organic farming showed a 13.5 per cent rise in Agro Diversity Index (ADI) values compared to conventional farming practices.
- Carbon Sequestration: In Meerut, Aligarh, and Bulandshahr districts, there is an estimated increase in carbon sequestration potential for total land cover, between 0.7 and 1.3 million tons by 2050. This amounts to an increase in carbon stock between 7.1 and 11.4 per cent.
- Sustainable Livelihood Security Index: Transitioning from conventional farming to organic farming in the five districts of Uttar Pradesh holds the potential for up to a twofold increase (or 100 per cent increase) in ecological security.

Assam

- State Statistics: The state spans an area of 7.84 million hectares. The state's economy is largely agrarian, contributing about 20 per cent to the state's gross domestic product (GSDP) and providing livelihood support to about 75 per cent of the population.
- Agroforestry: The area under agroforestry has an estimated potential to expand from the current 0.70 million hectares to a projected 0.80 million hectares by 2050, with a notable positive impact on carbon stock—reaching 63 million tonnes by 2050 in the optimistic scenario.
- Potential zones for agroforestry: About 10 per cent of the total geographical area is recommended for agroforestry under riparian and restoration, and 27 per cent in non-flood zones. These can be utilised by State Government after ground truthing.
- Trend assessments indicate that there can be an increase in organic cultivated area to 20 per cent under the optimistic scenario by 2050, resulting also in increase in soil organic carbon to 59 million mg/ha as compared to 37 mg million/ha under BaU.

Uttarakhand

- State Statistics: State spans an area of 5.34 million hectares, with 86 per cent under mountains. Agriculture and allied sectors contribute 10 per cent to the state's GDP.
- Soil health: A 5-fold and 3.45-fold increase in microbial population was observed in demonstration plots laid in Sunkiya and Bidaura villages of Nainital and Udham Singh Nagar districts, respectively.
- Benefit-cost ratio was found to increase by 9 to 25 per cent in the demonstration sites at Sunkiya and Bidaura villages of Uttarakhand when organic agriculture practices for pea and onion cultivation were adopted by farmers.
- Soil Erosion: Scaling up organic farming and agroforestry practices could decrease soil erosion rates by 4.4 - 6.3 per cent by 2030 and 2050, respectively, under an optimistic policy scenario compared to the Business-As-Usual (BAU) scenario in Kosi and Kailash watersheds.

National Context

- Agriculture in India – 52 per cent of the total workforce are engaged in the sector (India, Ministry of Agriculture and Farmer's Welfare 2024), accounting for 18.6 per cent of Gross Value Added (GVA) at current prices in 2021-22 (India, Ministry of Agriculture and Farmer's Welfare 2023).
- Agriculture employs 75.9% of the rural women workforce in India (India, Ministry of Statistics and Programme Implementation 2022).
- About 6 million hectares land is under organic farming in India, as certified by the National Program for Organic Production (NPOP) and Participatory Guarantee System (PGS), placing it at 4th position in terms of certified area globally (India, Ministry of Agriculture and Farmer's Welfare 2022).
- As of 2021 agroforestry covers an area of 25 million hectares, approximately 8.7 per cent of the geographical area of India (Arunachalam *et al.* 2022).
- TEEB principles have been included in the syllabus of a new undergraduate degree course B.Sc. (Natural Farming) by Indian Council for Agricultural Research (ICAR). This is being offered in 4 Central Agriculture Universities from the current year and will be extended to 51 State Agriculture Universities from the coming academic session.

Terrace farming in Uttarakhand

VIII. POLICY SUPPORT OPTIONS

Some illustrative policy support options for upscaling organic farming and agroforestry arising from the project studies are summarized for their applicability in meeting domestic priorities as well as India's commitments to international conventions.

a. Supporting farmers during the transition to organic agriculture and agroforestry

Although the Indian Council of Agricultural Research (ICAR) – the apex institution for agriculture research and education – has developed several models for organic farming, integrated farming systems, and agroforestry that have demonstrated generation of enhanced incomes for farmers with co-benefits of climate resilience, the pace of adoption of these models by farmers has been relatively slow. A possible reason could be that a shift towards integrated, intercropped agriculture practices is often associated with a yield penalty of the main crop, though in totality the incomes are often found to increase (Maitra *et al.* 2021).

Results from the TEEBAgriFood applications demonstrate that **adoption of organic farming practices can increase yield over the long-term**. This adds to other TEEBAgriFood studies in India that have also concluded increase in yields with the adoption of agro-ecological practices [6]. Additional assessments are however required with reliable data on the change of soil health parameters and associated yields of organically grown crops to establish accurate long-term productivity forecasts. Further, the results demonstrate that the duration of short-term yield penalties can effectively be reduced by sustained efforts to assist farmers and access to quality organic inputs. **Farmer support including strengthened extension services with easy access to inputs, together with the development of robust markets for organic produce, certification and branding is recommended, to incentivize farmers to take up organic farming and agroforestry in an integrated approach**.

Under the Uttar Pradesh study, current crop yields of five districts were projected from 2020 to 2050 based on Business-As-Usual (BaU), optimistic and pessimistic scenarios for conversion of conventional farming to organic farming. The results show a significant decline in yields under BaU – up to 14.5 per cent by 2030 and 30 per cent by 2050, with climate change being the leading factor contributing to lower yields – which indicates that without intervention a significant decline in yields can be expected. However, modelling results under an optimistic scenario shows that yields can be recovered ranging from 9.4 per cent to 23.1 per cent as compared to BaU by 2050.

6. https://gistimpact.com/news-insights/groundbreaking-comparative-study-reveals-natural-farming-leads-for-yields-livelihoods-and-health/

Further, on-site assessments of demonstration plot studies on organic agriculture models for the hill and plain regions of Uttarakhand reveals that sustained efforts on handholding of farmers can minimize the decrease in yield. A comparative on-site study of yield of pea and onion farming over an 18-month period, in Sunkiya (hill region) and Bidaura (plain region) villages of Nainital and Udham Singh Nagar districts, showed an increase of approximately 5-6 per cent in pea yield and 4-5 per cent in onion yield as compared to the conventional farming methods employed by the farmers. It is to be noted that throughout the demonstration plot studies, direct engagement with farmers to enhance their knowledge and skills, along with the distribution of organic inputs was undertaken by implementing partners

b. Restoration of land resources through agroforestry and organic farming

Soil plays a central role in the provision of ecosystem services: 90 per cent of food production relies on soil; soil serves as a major carbon sink for the earth, holding more than the atmosphere and vegetation combined, and forms a critical habitat for below ground biodiversity that is integral to maintaining life on earth (United Nations Environment Programme [UNEP] 2021). Land management practices, or the absence thereof, have led to increasing trends in degradation and loss of soil, causing fertile land to become increasingly scarce. The mapping and assessment of degraded lands in India (Indian Space Research Organization 2021) reports that an expanse of 94.53 million hectares in the country is experiencing land degradation, constituting 29.32 per cent of India's total geographical area. Degradation of agricultural lands is of major concern given that it may undermine food security.

The TEEBAgriFood applications indicate that landscape-level ecological restoration of agricultural land through **the adoption of sustainable agriculture practices such as organic farming and agroforestry needs to form a key strategy for meeting land restoration and Land Degradation Neutrality targets in India [7].**

TEEBAgriFood studies highlight that the adoption of organic farming and agroforestry can positively contribute to reducing soil loss and degradation through soil erosion control and maintaining soil health.

7. As a signatory to the UN Convention to Combat Desertification (UNCCD), India has set a target of reducing land degradation and desertification by restoring 26 million hectares of degraded land by 2030. UNCCD defines LDN as a state whereby the amount and quality of land resources, necessary to support ecosystem functions and services and enhance food security remains stable or increases within temporal and spatial scales and ecosystems and also included in SDG 15.

Soil Erosion Control: Modelling of soil erosion under RCP4.5 and RCP8.5 climate scenarios [8] in the Kosi and Kailash watersheds of Uttarakhand highlights that soil erosion, which is already a major cause of concern in the hills, currently incurs a combined cost of USD 9.15 million for soil erosion control services in both watersheds. Scenarios highlight that this is expected to worsen due to climate change [9].

The TEEBAgriFood study found that upscaling organic farming and agroforestry practices could decrease erosion rates and associated costs for soil erosion control services by 4.2 – 11.0 per cent (2030 projections) and 4.6 – 16.8 per cent (2050 projections) in the two watersheds of Uttarakhand, when the optimistic and BaU scenarios are compared. This reduction of erosion in both watersheds could lead to an estimated savings on soil erosion control services of up to USD 0.85 million.

Soil Health: The on-site demonstration plot studies conducted in Uttarakhand highlighted that a shift to organic farming can contribute significantly towards the improvement of soil health by increasing soil nutrient mineralization [10], microorganism abundance, diversity as well as soil physical properties. On-site measurements show improvements in soil microbial population, enzymatic activity and microbial functional activity in both Bidaura (plains) and Sunkiya (hills) villages after the implementation of organic farming practices. Soil organic carbon in both villages showed a two-fold increase. There was a notable increase in the soil microbial population with a five-fold increase measured in Sunkiya and a 3.5-fold increase in Bidaura. Further, a two-fold increase of in soil enzymatic activity was observed. The findings in functional populations in Bidaura are particularly of note as measurements prior to the adoption of organic farming practices indicated an absence of nitrogen-fixers; Udham Singh Nagar is amongst the districts with the highest consumption of fertilizers in Uttarakhand state. Short-term changes have fostered the revival of lost microbial diversity.

8. Modelled using the Revised Universal Soil Loss Equation (RUSLE) model. Values for soil obtained from the Environmental Valuation Look-up Tool developed by UNEP, MoSPI and UNSD. Cost of soil erosion control services is calculated as = (soil erosion rate in tonnes per sq.km / weight of soil) X watershed area in sq. km. X INR 243/1.2m3
9. The rugged terrain of the Kosi watershed contributes to higher erosion rates and costs
10. Soil nutrient mineralization is the conversion of a nutrient from organic form to the inorganic form, occurring when organic matter like soil organic matter, manure, plant residue etc. are decomposed by microorganisms. The nutrient released becomes available for uptake by plants <nrcca.cals.cornell.edu>

c. Enhancing carbon sequestration through agroforestry and organic farming

At the 26th session of the Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, India expressed its commitment to intensify climate action contributions and took forward the commitment of the creation of additional carbon sink of 2.5-3 billion tonnes CO2e by 2030 (NDC Goal 5). Assessments undertaken on carbon sequestration potential in India highlights that upscaling agroforestry is the second most cost-effective investment for carbon sequestration, after restoration of impaired forests (Forest Survey of India 2021). TEEBAgriFood assessments, that include projections based on RCP4.5 and RCP8.5 climate pathways, strengthen evidence on the significant role that scaling organic farming and agroforestry practices can make in carbon sequestration while maintaining agricultural production and without compromising food security or farmers' livelihoods.

Towards enhancing carbon sequestration and the welfare of small and marginal farmers, Integrated Organic Farming Systems (IOFS models developed by ICAR need to be promoted through national government programmes on agro-ecological practices such as organic farming, agroforestry, Rainfed Area Development, Green India Mission etc. The recent initiatives of Green Credit of MoEFCC and the Voluntary Carbon Market Framework for the Agriculture Sector by Ministry of Agriculture & Farmer's Welfare and evolving policies on climate resilient agriculture will provide impetus to the adoption of sustainable agriculture practices. Simultaneous on-ground assessments can be conducted at the farm level for translation into financial gains.

As an illustration, modelling and economic valuation of carbon sequestered in Meerut district, Uttar Pradesh highlights that expanding area under agroforestry and organic farming can increase carbon sequestration potential by 7.5 per cent by 2050 with a total economic value of USD 203.9 million [11]. Notably, land under bund-based agroforestry systems is expected to make a substantial contribution throughout, accounting for 37 per cent of the total carbon sequestered by 2030 and 36 per cent by 2050.

11. Based on Social Cost of Carbon. The benefit of the Ecosystem service "carbon sequestration" is that it removes carbon dioxide (CO2) from the atmosphere, and therefore avoids the respective damages caused by global warming. To assign a monetary value to one unit of CO2 sequestered by an ecosystem, a direct method involves determining the value of the damages that this unit could otherwise cause—referred to as the "social cost of carbon."

Similarly, TEEBAgriFood assessments in Assam indicate that with an increase in area under agroforestry from the current 0.70 million hectares to 0.80 million hectares by 2050, improvement of soil carbon stock up to 63 million tonnes, i.e. an increase of 14.5 per cent as compared to BaU, by the year 2050 under an optimistic scenario is achievable.

Further, trend assessments indicate that, in an optimistic scenario for adoption of organic farming practices (up to 20 per cent gross cropped area under organic), Assam can witness an increase up to 59 million Mg/ha as compared to the BaU scenario (37 Mg/ha).

d. Strengthening measures on water conservation through sustainable agriculture

Estimates for India indicate that the share of agriculture in total water use is between 80 - 90 per cent (D'Souza, Ghosh, and Suri 2022). This is compounded with increasing evidence of variations of water availability with the impacts of the climate crisis and warrants strengthened measures on water use efficiency and conservation in the agriculture sector.

Analysis of changes in water yield in Uttar Pradesh under an optimistic scenario of organic farming and agroforestry uptake, in contrast to the Business-As-Usual (BAU) scenario indicates higher water yield by up to 6 per cent under RCP 4.5 and between 11 – 28 per cent under RCP 8.5 for 2030. This implies **a positive contribution of organic farming and agroforestry on the increasing water holding capacities and watershed health** compared to BaU. By 2050, the analyses further indicate that there is stark increase in water yield of up to 61 per cent under RCP 4.5 and between 33 – 56 per cent under RCP 8.5.

Similarly, results from Uttarakhand also show a positive impact of agroforestry and organic farming increasing water yield in the watersheds assessed. However, monthly water yield changes in the Kailash watershed indicate decreased stream flow from March to June and a significant increase during July and August, indicating more frequent and intense future rainfall events during this period. This highlights the urgency required to expand tree planting and **the potential of agroforestry in mitigating disaster risk, by increasing water holding capacity and soil erosion control and reducing surface runoff** in the eco-sensitive watersheds.

e. Improving agrobiodiversity through sustainable agriculture

According to the Convention on Biological Diversity (CBD), biodiversity supports livelihoods, mitigates environmental impact through essential ecosystem services, and contributes to food and nutritional security. Despite its importance, the 2023 Global Risks Report by the World Economic Forum ranks biodiversity loss as the fourth most critical global risk (World Economic Forum 2023).

Many farmers, especially those in environments where high yield crop and livestock varieties are not successful, rely on a wide range of crop and livestock types. This diversity aids in sustaining livelihoods amidst challenges such as pathogen infestation, uncertain rainfall and fluctuation in the price of cash crops, socio-political disruption and the unpredictable availability of agro-chemicals (Food and Agriculture Organization of the United Nations [FAO] 2004).

Under the TEEBAgriFood study in Uttar Pradesh, the Agro-diversity Index (ADI) was used to assess impacts of scaling organic farming and agroforestry systems in the State. The ADI is calculated by measuring the number of crops grown in a particular area, and the relative importance of each crop. A higher ADI signifies a more diverse and resilient agricultural system, reducing vulnerability to climate change, pests, diseases, and market fluctuations. The index, based on the quantification of 9 indicators, considered the number of crops and their distribution within the agricultural system. The ADI values computed for organic farming systems in the districts of Uttar Pradesh ranged from 51.35 to 57.74, while for conventional farming systems ranged from 41.95 to 50.86. Furthermore, the indicator values categorized the target districts according to their average agro-biodiversity status scores. Figure 4 below, which illustrates the variation of 9 normalized ADI indicators between organic and conventional farming systems, indicates higher agro-biodiversity resilience for organic farming systems with Meerut demonstrating a slightly higher agro-biodiversity resilience as compared to other districts.

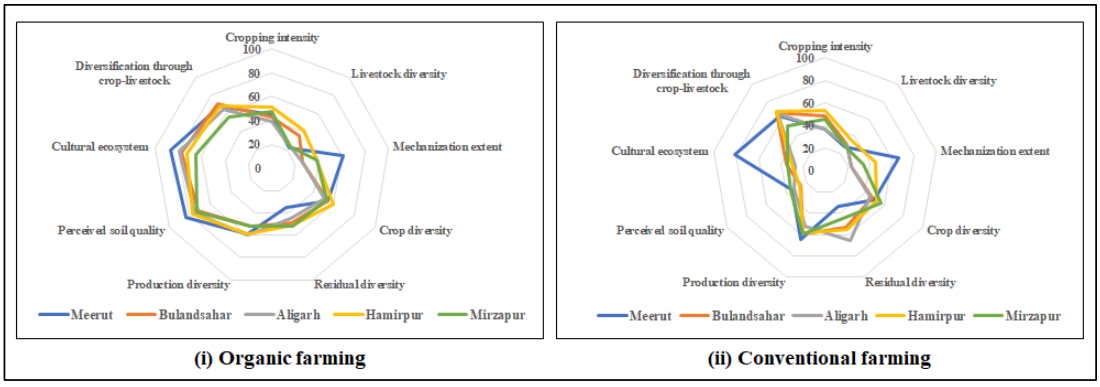


Figure 4: Variation of normalized ADI indicators for (i) Organic, and (ii) Conventional farming systems for the target districts in Uttar Pradesh

f. Improvement in livelihood security through organic farming

Given the emphasis placed on enhancing livelihoods of farmers by India, TEEBAgriFood studies also aimed at generating evidence of adopting organic farming and agroforestry. The Social Livelihood Security Index (SLSI)[12], which encompasses ecological, economic, and social dimensions of agricultural sustainability, was used to provide a comprehensive reflection of the ecology-economic-equity interface of organic farming and agroforestry. SLSI is a cumulative value of three indices—Ecological Security Index (ESI), Economic Efficiency Index (EEI), and Social Equity Index (SEI).

Based on a two-year study period, the findings from Uttar Pradesh reveal that while economic returns from organic farming are comparable to conventional farming, with variation across the 5 districts assessed, its contribution to ecological security surpasses that of conventional farming. This leads to an overall higher contribution in both visible and invisible economic terms compared to conventional farming.

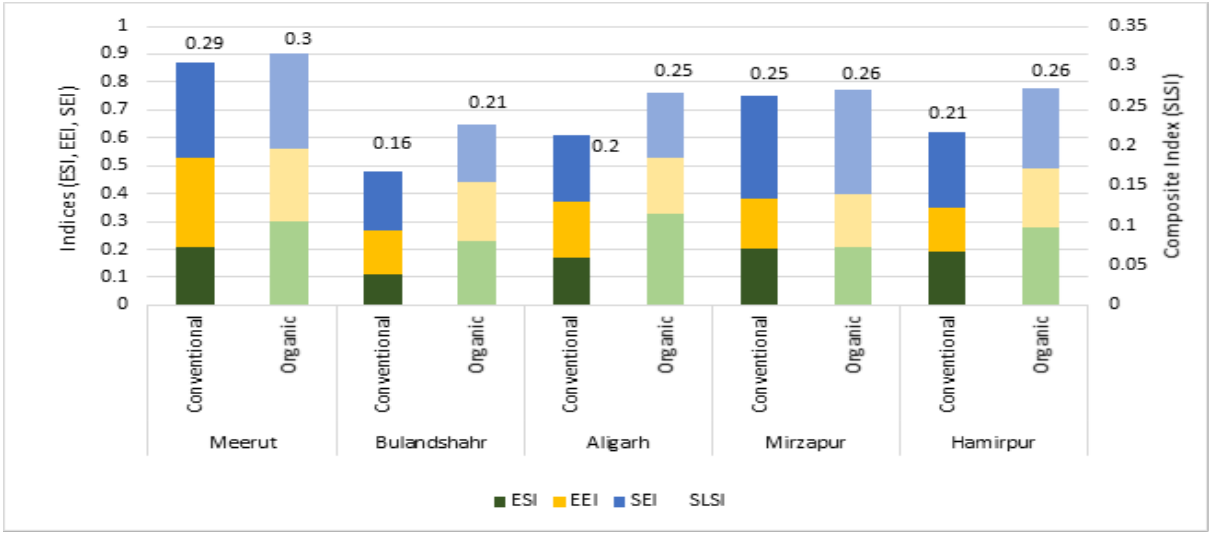


Figure 5: Sustainable Livelihood Security Index scores for conventional vs. organic farming in Uttar Pradesh

g. Sustainable agriculture empowering women

More than 70 per cent of women working in agriculture in India are engaged in crop production, livestock rearing and other allied activities. However, women are deprived of land rights and seldom participate in marketing of crops where production is translated into income. As per the Agriculture Census 2015-16, 11.72 per cent of the total agricultural operation area was operated by women operational holders (India, Ministry of Agriculture and Farmers Welfare 2021). This highlights the need of addressing the gender gap to promote economic development.

12. Methodology introduced by Ravisankar et al. (2022), a comprehensive indicator reflecting the ecology-economic-equity interface of sustainable development, as previously proposed by Alary et al. (2020) and MSSRF (1993)

Organic farming practices have been found to have a positive impact on livelihood of women farmers and their empowerment through improved health, food security, higher decision making on agricultural income and diversification of sources of income for women farmers (Kumar and Rechanna 2020). TEEBAgriFood analysis in Uttar Pradesh reinforces these findings, using the Appraisal of Women Empowerment (WE) [13] to assess the role of women in decision making and participation in agricultural activities.

The study indicates that 43 per cent were involved in decision making on crops to be sown in organic farming as compared to 21 in conventional farming. However, the study found that more women participated in decision making with regards to marketing and storage activities in conventional (91 per cent) as compared to organic farming (26 per cent), indicating the need to gender specific barriers and address structural inequalities to increase access and opportunity for women. Women-led and managed Farmer Producer Organizations [14] (FPOs) serve as successful models [15] for ensuring equal access and opportunity and can be strengthened by convergence with Self-Help Groups (SHGs) and livelihood programmes such as the DAY-National Rural Livelihoods Mission.

Recognizing and valuing women's contributions is essential for promoting sustainable practices. Moreover, **evolving policies on Climate Resilient Agriculture within the agricultural sector presents a substantial opportunity to enhance a gender-specific and gender-sensitive approach to knowledge dissemination and capacity building, ensuring that women have equal access to information, training, and participation in decision-making forums.** This approach can empower women workforce in agriculture to play a transformative role in bolstering India's rural economy.

13. WE is based on employment days generated under various farm operations viz land preparation, intercultural operations, harvesting, threshing, and packaging and transport.
14. A Farmer Producer Organisation (FPO) is a legal entity formed by primary producers, namely farmers, milk producers, fishermen, weavers, rural artisans, craftsmen. A FPO can be a producer company, a cooperative society or any other legal form which provides for sharing of profits/benefits among the members.
15. Success stories on Women Farmer Producer Organizations documented by the National Institute of Agricultural Extension Management (MANAGE) available at: www.manage.gov.in/publications/knowledgeseries/womenFPOs.pdf

IX. WAY FORWARD

As per the NITI Aayog, India finds itself today at a position where considerations can be made on shifting two per cent of its cropped area each year to sustainable farming practices without creating any shortfall in meeting domestic demand for food, potentially resulting in 20 per cent of the cultivated land transitioning to sustainable farming practices by 2030, up from the current coverage (Chand and Singh 2023). Given that India is at an important juncture of its agriculture development, where addressing critical overarching questions on the costs and benefits of a transition requires strong scientific evidence to guide decisions, TEEBAgriFood provides a robust framework to precisely address these concerns. As demonstrated in the three pilot project States, the application of the TEEBAgriFood framework has provided important insights into benefits and trade-offs of scaling organic farming and agroforestry not only across natural, produced, human and social capitals but also with regards to changing climate scenarios.

Moreover, towards strengthening the linkages between economy and environment, the Ministry of Statistics and Program Implementation (MoSPI) has prepared a Strategy for Environmental Accounting 2022-26, recommending adherence to the System of Environmental Economic Accounting – Ecosystem Accounting (SEEA-EA) adopted by UN Statistical Commission in March 2021. The office of the Comptroller and Auditor General of India is ensuring that the SEEA accounts are aligned with the Government budgets statements and system of national accounts wherever applicable. The application of the TEEBAgriFood framework lends itself to strengthening the SEEA-Ecosystem Accounting initiatives in India and demonstrates the significance of constructing such accounts at the national and sub-national level.

It is against this backdrop, together with the acknowledgement of evolving policies on sustainable agriculture in India, that a summary of potential use of the results and future applications of the framework is presented below:

A. Application of TEEBAgriFood framework

a) Inclusion of TEEBAgriFood principles in the policy framework for Climate Resilient Agriculture of the Ministry of Agriculture and Farmers Welfare, and the Green Credit Programme [16] of the Ministry of Environment Forest and Climate Change to assist in their implementation in the States.

b) Calibration of the Voluntary Carbon Market Framework for the Agriculture Sector [17] (India, Ministry of Agriculture and Farmers Welfare 2024) based on True Cost Accounting /

16. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1967476
17. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2000331#:~:text=In%20his%20address%2C%20 Shri%20Munda,avail%20benefits%20of%20carbon%20cre

TEEBAgriFood.

c) Application of the TEEBAgriFood framework to capture variability of natural resources at the farm and landscape levels, such as:

    i) To contiguous clusters of farmers (FPOs) and Self-Help Groups (SHGs) to assess the benefits beyond direct economic outcomes. This approach would also propagate the cultivation of organic produce over larger areas rather than targeting individual (small) land parcels.

    i) To Integrate Organic Farming System (IOFS) and agroforestry models developed by ICAR in various agroclimatic zones to strengthen evidence and boost adoption of models. The Research Advisory Committee of ICAR-IIFSR has recommended the application of the TEEBAgriFood framework in various agro-ecological zones in India.

d) Establish demonstration sites. The TEEBAgriFood Learning Landscape (TAFLL) [18] is one such initiative already planned for Assam.

di) An initiative to establish State Level Federations of FPOs has been initiated by Small Farmers Agribusiness Consortium (SFAC), an organization under the Ministry of Agriculture and Farmers Welfare. Eight such State Level Producer Companies (SLPC) have been set up, including one in Uttar Pradesh. Infusion of best practices into SLPCs backed by scientific inputs and evaluation could inform other States.

dii) Evaluation of values associated with biodiversity and ecosystems as the process of revision of the National Biodiversity Action Plan (NBSAP) takes place, as per the commitments made by the Government of India under the Kunming Montreal Global Biodiversity Framework.

diii) India tabled the first UNEA resolution on Sustainable Nitrogen Management at UNEA 4, leading to the second resolution at UNEA 5. The project studies on soil erosion and nutrient delivery can inform the works of India's Committee on Nitrogen Management chaired by Ministry of Environment Forest and Climate Change.

18. TAFLL will be a physically demarcated area for introducing associated farmers and farmer groups to the best practices on organic farming and agroforestry that will also serve on ground validation of TEEBAgriFood results and can be translated to other project sites in India as well as other countries. TAFLL Action Plan for Assam was launched in November 2023 by the Government of Assam along with UNEP.

e) Application of TEEB Principles in the National Mission for Clean Ganga to evaluate impacts holistically beyond agriculture and food systems. This can be piloted in the two project States Uttar Pradesh and Uttarakhand which are in the beginning of the Ganga Basin.

B. Support for Policy Formulation

a) **Organic farming** has been shown to have multiple benefits (such as increases in income) both in scenario modeling studies as well as in the demonstration plots of Uttarakhand, thereby providing evidence for the extension of the Integrated Organic Farming System IOFS) models developed by IIFSR-ICAR to farmers in similar agroclimatic zones.
The Self-Help Groups of the Ministry of Rural Development and Farmer Producer Organisations of the Ministry of Agriculture and Farmers Welfare can take this agenda forward. An integrated approach will be a step towards improving agrobiodiversity, an imperative for climate resilient agriculture.

b) **To promote the consumption of organic produce** in the formative years of children and for pregnant women, the Ministry of Education and the Ministry of Women and Child Development might mandate a certain percentage of local procurement from farmers practicing organic farming in the Mid-Day Meals in schools and rations given in the Anganwadis [19]. respectively. This would revive local 'forgotten' produce and reduce the carbon footprint of transporting foodstuffs from far off places. A convergence in views and a shared commitment between national and State Agriculture Departments would drive this initiative.

c) **Robust markets** with branding and easier access to certification and direct marketing would propel farmers to adopt organic farming on a larger scale via the Farmer Producer Organisations formed for organic farming.

d) **Contract farming by wood based and other tree produce based industry,** including bamboo, could be strengthened to establish assured markets and prices for farmers and availability of feedstock of the quality and quantity required by industry. This would contribute to the national objective of 'a tree on every bund'.

19. Anganwadi translates to "courtyard shelter" – a typical Anganwadi centre in India provides care for mothers and young children in rural areas

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