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Sustainable Agriculture in India 2021

What We Know and How to Scale Up

Niti Gupta, Shanal Pradhan, Abhishek Jain, and Nayha Patel

Executive Summary | April 2021

Diversified crop-livestock systems can make incomes larger and resilient, while improving farmers' nutrition.

Image: Atul Loke for Panos Pictures/Food and Land Use Coalition

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Organisations: The **Council on Energy, Environment and Water** (CEEW) is one of Asia's leading not-for-profit policy research institutions. The Council uses data, integrated analysis, and strategic outreach to explain – and change – the use, reuse, and misuse of resources. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with wider public. In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report*. The Council has also been consistently ranked among the world's top climate change think tanks. Follow us on Twitter @CEEWIndia for the latest updates.

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The Council on Energy, Environment and Water (CEEW) is one of Asia's leading not-for-profit policy research institutions. **The Council uses data, integrated analysis, and strategic outreach to explain — and change — the use, reuse, and misuse of resources**. The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public.

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In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report*, including being ranked as **South Asia's top think tank (15th globally) in our category for the eighth year in a row**. CEEW has also been ranked as South Asia's top energy and resource policy think tank for the third year running. It has consistently featured among the world's best managed and independent think tanks, and twice among the world's 20 best climate think tanks.

In ten years of operations, The Council has engaged in 278 research projects, published 212 peer-reviewed books, policy reports and papers, created 100+ new databases or improved access to data, advised governments around the world nearly 700 times, promoted bilateral and multilateral initiatives on 80+ occasions, and organised 350+ seminars and conferences. In July 2019, Minister Dharmendra Pradhan and Dr Fatih Birol (IEA) launched the CEEW Centre for Energy Finance. In August 2020, Powering Livelihoods — a CEEW and Villgro initiative for rural start-ups — was launched by Minister Mr Piyush Goyal, Dr Rajiv Kumar (NITI Aayog), and H.E. Ms Damilola Ogunbiyi (SEforAll).

The Council's major contributions include: The 584-page *National Water Resources Framework Study* for India's 12th Five Year Plan; the first independent evaluation of the *National Solar Mission*; India's first report on global governance, submitted to the National Security Adviser; irrigation reform for Bihar; the birth of the Clean Energy Access Network; work for the PMO on accelerated targets for renewables, power sector reforms, environmental clearances, Swachh Bharat; pathbreaking work for the Paris Agreement, the HFC deal, the aviation emissions agreement, and international climate technology cooperation; the concept and strategy for the International Solar Alliance (ISA); the Common Risk Mitigation Mechanism (CRMM); critical minerals for *Make in India*; modelling uncertainties across 200+ scenarios for India's low-carbon pathways; India's largest multidimensional energy access survey (ACCESS); climate geoengineering governance; circular economy of water and waste; and the flagship event, Energy Horizons. It recently published *Jobs, Growth and Sustainability: A New Social Contract for India's Recovery*.

The Council's current initiatives include: A go-to-market programme for decentralised renewable energy-powered livelihood appliances; examining country-wide residential energy consumption patterns; raising consumer engagement on power issues; piloting business models for solar rooftop adoption; developing a renewable energy project performance dashboard; green hydrogen for industry decarbonisation; state-level modelling for energy and climate policy; reallocating water for faster economic growth; creating a democratic demand for clean air; raising consumer awareness on sustainable cooling; and supporting India's electric vehicle and battery ambitions. It also analyses the energy transition in emerging economies, including Indonesia, South Africa, Sri Lanka and Viet Nam.

The Council has a footprint in 21 Indian states, working extensively with state governments and grassroots NGOs. It is supporting power sector reforms in Uttar Pradesh and Tamil Nadu, scaling up solar-powered irrigation in Chhattisgarh, supporting climate action plans in Gujarat and Madhya Pradesh, evaluating community-based natural farming in Andhra Pradesh, examining crop residue burning in Punjab, and promoting solar rooftops in Delhi and Bihar.

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13th April, 2021

Foreword

Agriculture in India goes beyond merely meeting our food needs; it plays a central role in our economy and employs almost half of our population. The green revolution has characterised India's agriculture over the last few decades — transforming it from a food-scarce to a food-secure nation. But its positive impacts are saturating, and its fallouts have become apparent in recent years.

Despite being calorie-secure, 22 per cent of Indians are undernourished. Agriculture incomes are the slowest growing compared to all other economic sectors, making the farmers relatively poorer over time. The response ratio of fertilisers fell by more than three-and-a-half times between the 1970s and 2005. As a result, fertiliser use has intensified further, with imbalance widening. Increasing soil salinity, rapid desertification of lands, and declining water tables in the irrigated regions have made it much harder to sustain India's agricultural output. To compound the challenges, the climate crisis poses an unprecedented threat to our increasing population's nutrition security.

An alternative approach to agriculture, comprising various sustainable practices, show promise to transform the vicious cycle of prevailing agricultural practices into a virtuous one — by increasing farm incomes, improving nutrition security through diversification, and reducing environmental challenges. Taking note, the Ministry of Agriculture and Farmers Welfare initiated the National Mission for Sustainable Agriculture in 2014-15 to make agriculture more productive, remunerative and climate-resilient. NITI Aayog also aims to further sustainable agriculture in India through the *Bharatiya Prakritik Krishi Paddhati Programme* (BPKP) with natural farming principles at the core, dove-tailed with other practices as per the local ecological and social context of various agroclimatic regions in the country.

This report by the Council on Energy, Environment and Water (CEEW) is a pioneering effort to fill information gaps about the adoption, on-ground prevalence and impact of sustainable agriculture. In my view, this report would serve as a handbook for all stakeholders — including policymakers, administrators and philanthropic civil society organisations — to make evidence-backed decisions to mainstream sustainable agriculture and help it gain scale in India. I congratulate CEEW for this initiative to catalyse a reorientation of perspectives related to this major economic sector of the country and look forward to more insights from such progressive studies.

(Rajiv Kumar)

स्वच्छ भारत
एक कदम स्वच्छता की ओर

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The authors of this study would like to thank the Food and Land Use (FOLU) Coalition for their support in carrying out this study.

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The authors extend their immense gratitude to Fiona Hinchcliffe for her sound editing and critical feedback on the report's content and structure. We acknowledge our research interns' contribution, Gayatri Hari and Priyanka (CEEW), in supporting some of the practices and helping with back-end data formulation and synthesis tables. Finally, we thank the Outreach team at CEEW, notably Alina Sen, Communications Specialist, for her support throughout this report's publication.

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Niti, a former Programme Associate at The Council, works on assessing and establishing research evidence for agroecological practices to support their scale-up. Her research interest lies in studying the linkage between sustainable agriculture and nutrition and using behavioural economics to examine agricultural policy implementation's efficiency and equity critically. Niti holds a master's degree in Development Studies, with a major in Economics of Development from the International Institute of Social Sciences (ISS), Erasmus University.

"With this handbook, we draw the attention of policy makers and philanthropic organisations to sustainable agriculture's scale and challenges in India. We hope the gathered insights and recommendations will contribute to strengthen the agroecological movement across the country."

Niti managed the research; prepared the methodological framework and CSO survey questionnaire; conducted the literature review, stakeholder consultations; and drafted chapters for six of the sixteen SAPSs; co-authored introduction and synthesis chapters; reviewed and edited all the practice chapters.

Shanal Pradhan
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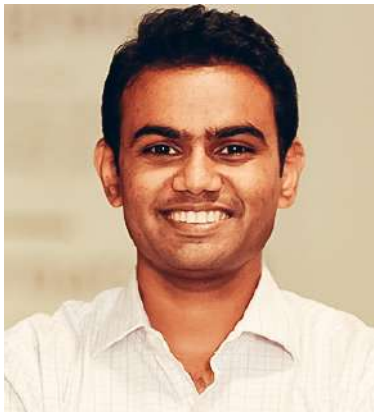
A Research Analyst at CEEW, Shanal's focuses on sustainable agriculture, food, and land-use systems in the context of the changing climate. This includes intersecting science, policy and practice to inform food system transformations that support healthy diets and sustainable food production and consumption. She holds a master's degree in Environmental Management from the National University of Singapore and a postgraduate degree in Geography from Bangalore University.

"This study is dedicated to understanding different agricultural practices, their sustainability features and explore if they can be scaled up, and what it will take to scale them up. The urgency lies in the fact that sustainable agrarian practices have to be incentivised because the cost of inaction is taking its toll on farmers' livelihoods as well as our natural wealth."

Shanal conducted the literature review, stakeholder consultations, and drafted chapters for ten of the sixteen sustainable agricultural practices and systems (SAPSs); co-authored the executive summary and research approach chapters; analysed civil society organisations (CSO) survey data; designed graphs and maps for all the practices.



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As a Fellow, Abhishek built and leads The Council's practices on energy access, rural livelihoods, and sustainable food systems. He is directing 'Powering Livelihoods', an USD 3 million initiative. He co-conceptualised and leads CEEW's flagship research on ACCESS (Access to Clean Cooking energy and Electricity— Survey of States). With more than nine years of experience, Abhishek has worked on multiple issues at the confluence of energy, economics, and the environment. He is an alumnus of the University of Cambridge and IIT Roorkee.

"Scaling-up sustainable agriculture is imperative to meet India's nutritional security in a climate-constrained world. This report will help decision-makers filter signals from the noise to make informed decisions to scale-up sustainable agriculture in India."

Abhishek conceptualised the entire research, co-authored the executive summary, introduction, and synthesis chapters; guided research at every stage; reviewed and edited the manuscript.

Nayha Patel
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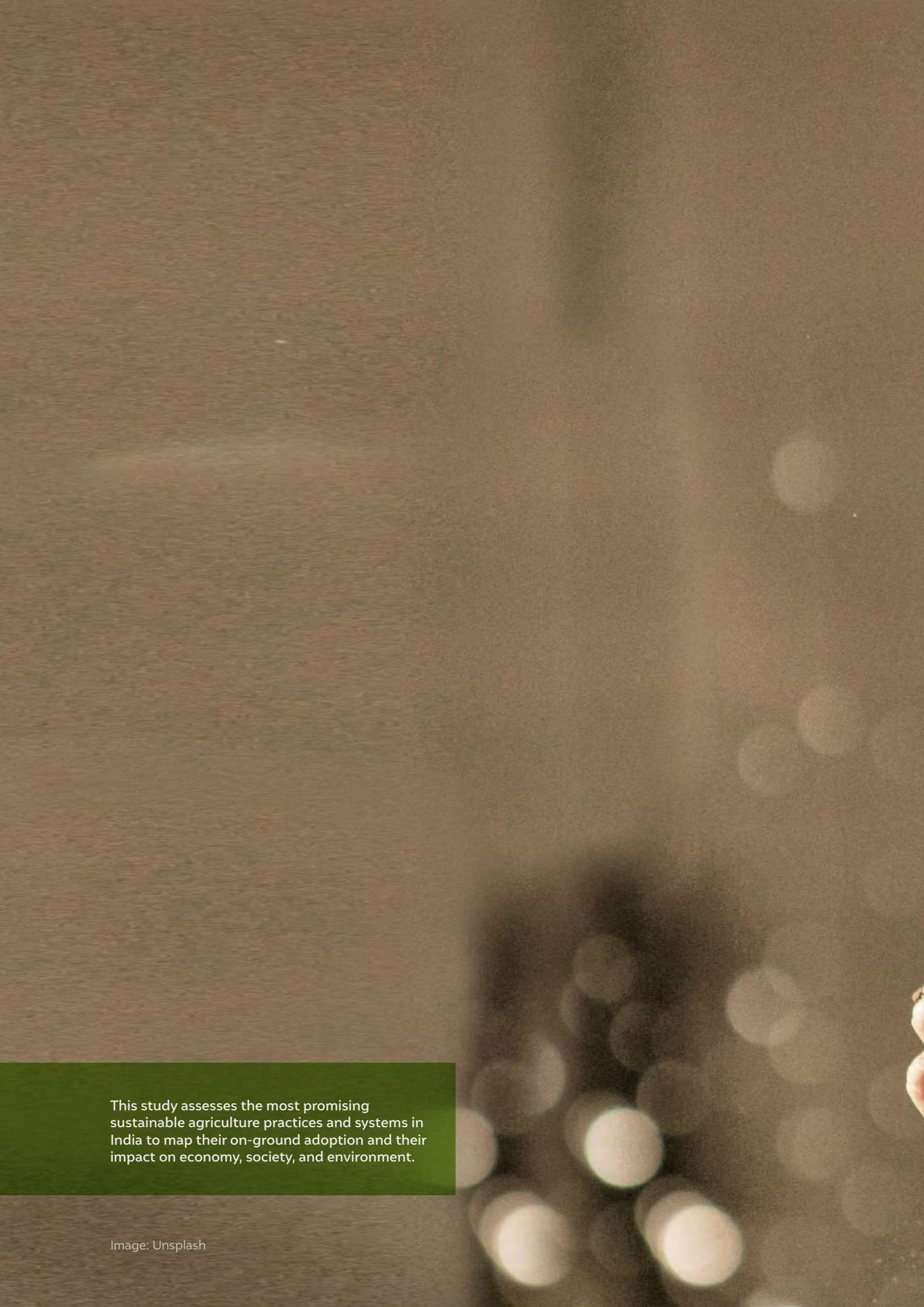
Nayha was an intern at SYSTEMIQ. She assisted the FOLU Coalition team in research-based tasks for the China and India platforms in 2020. Nayha is currently completing her degree, BSc Geography and Economics, at the University of Exeter.

"Sustainable agricultural practices encourage innovation within the sector and present the promise of scalability across India. As the impacts of climate change continue to intensify these practices have the ability to ensure the nation's food security, while conserving the natural environment."

Nayha conducted the literature review for four of the sixteen practices.



This study assesses the most promising sustainable agriculture practices and systems in India to map their on-ground adoption and their impact on economy, society, and environment.

Image: Unsplash

Contents

Read the full report here: https://www.ceew.in/publications/sustainable-agriculture-india-2021

Sustainable agriculture

Navigating the myriad terminologies

Sustainable agriculture, agroecology, regenerative agriculture, organic farming, natural farming are some of the most common terms used to describe various sustainable agriculture approaches. One might ask why so many different terminologies refer to these respective but related concepts. Perhaps it is not essential to bother about the various terms as long as we know what we mean conceptually. However, in the absence of universally accepted definitions of each of these terms, everyone has their interpretation of them. It also means that two different individuals may interpret or even apply the underlying philosophy or concept differently while using the same term.

What do internet searches tell us about the popularity of these terms?

A Google search of these terms indicates their relative popularity. Organic farming tops the charts (18.8 million search results), followed by sustainable agriculture (9.9 million), then agroecology (5.2 million), natural farming (1.5 million), and finally regenerative agriculture (0.9 million). **A comparison over the 16 years since 2004** (since Google started documenting its search trends) **of these search terms' relative popularity indicates that organic farming, followed by sustainable agriculture, remains consistently the most popular** (Figure ES1). Both natural farming and agroecology have remained equally famous, but much less so than sustainable agriculture and organic farming. However, since 2015, natural farming as a term has gained more search interest than agroecology. Between 2004 and 2019, regenerative agriculture remained the least popular term among the five. However, since mid-2019, regenerative agriculture has also gained more interest than agroecology.

Origins and evolving use of these terms

As we look at the evolution of these terms, we see that most of them only started appearing in twentieth-century literature.

Organic farming

Organic farming entered into the mainstream environmental movement with the publication of *Silent Spring* by Rachael Carson in 1962. Gradually the emerging demand for organic food and environmental awareness in the 1960s and 1970s gave fuel to the organic industry that led to organised marketing and certification agents for quality assurance.[1] In India, the first national gathering of promoters and practitioners of organic farming was held at Gandhi's Sevagram in 1984. The *Organic Farming Source Book* (Other India Press) provides a good account of India's organic farming movement. It played a crucial role in building a nationwide network, which officially culminated in creating the Organic Farmers Association of India (OFAI).

Sustainable agriculture

The term started gaining prominence in the US in the 1980s, with a formal mention in US legislation for the first time in 1985. This led to a programme on Low Input Sustainable Agriculture (LISA). In 1990, the US Congress formally addressed and defined 'sustainable agriculture' under the law. Over the years, civil society, the private sector, multilateral institutions, and various national and sub-national governments have used the term 'sustainable agriculture.' In India, the national government initiated the *National Mission for Sustainable Agriculture* (NMSA) in 2014-15, which formally defines sustainable agriculture in the Indian context and has identified ten underlying dimensions.[2]

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1. Kuepper, P. 2010. "A Brief Overview of the History and Philosophy of Organic Agriculture. Kerr Center for Sustainable Agriculture. http://kerrcenter.com/wp-content/uploads/2014/08/organic-philosophy-report.pdf.
2. Department of Agriculture & Co-operation. 2014. "National Mission for Sustainable Agriculture Operational Guidelines." New Delhi. https://nmsa.dac.gov.in/pdfdoc/NMSA_Guidelines_English.pdf.

Regenerative agriculture

Regenerative agriculture as a term has started gaining prominence in the past decade with the rising concern about climate change. The term has been predominantly used to talk about ecological restoration, emphasising soil conversation, carbon sequestration in the topsoil, and enhancing biodiversity, among other aspects. Proponents of regenerative agriculture advocate that while sustainable agriculture merely sustains the status quo, we need to restore rapidly degrading ecological systems. Unlike sustainable agriculture or agroecology (which governments or intergovernmental organisations use in their official documents such as policies and laws), regenerative agriculture has predominantly been used by civil society organisations.

Natural farming

Natural farming origins can be traced to when Mokichi Okada proposed the concept of "nature farming" in 1935. While Masanobu Fukouka popularised the term *shizen noho* (meaning natural farming in English), Okada was the first to introduce farming without fertilisers and pesticides.[3] Though natural farming has its origins in Japan, similar approaches are followed in different parts of the world, including fertility farming in the United States, and *Rishi Kheti* (agriculture of the sages) and Zero Budget Natural Farming (ZBNF) in India.[4] Rishi Kheti was promoted by the NGO Friends' Rural Centre[5], whereas Subhash Palekar developed ZBNF.

Agroecology

The term agroecology was first used by agronomist Basil Bensin at the beginning of the twentieth century to refer to ecological methods used in agriculture.[6] Later, Tischler published a book *Agrarökologie* (agroecology) that combined ecology and agronomy for integrated agricultural management. After the concept of "agroecosystems" was introduced by the U.S. biologist, Eugene Odum, agroecology expanded to include whole agroecosystems. In the 2000s agroecology further expanded to include entire food systems. The subject's scope broadened from ecology to include economic and social dimensions.[7] Civil society groups have mainly promoted agroecological movements like *La Via Campesina* (the peasants' way), and *Rede Ecovida* (Ecovida network) in Southern Brazil.

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3. Miyake, Y., and Kohsaka, R. 2020. "History, ethnicity, and policy analysis of organic farming in Japan: When nature was detached from organic". In Journal of Ethnic Foods (Vol. 7, Issue 1, p. 20). BioMed Central Ltd. https://doi.org/10.1186/s42779-020-00052-6.

4. Dastogeer, K. M. G., Oshita, Y., Yasuda, M., Kanasugi, M., Matsuura, E., Xu, Q., & Okazaki, S. 2020. "Host specificity of endophytic fungi from stem tissue of nature farming tomato (Solanum lycopersicum Mill.) in Japan". Agronomy, 10(7), 1019.

5. Norris, R. 2014. "Revisiting Masanobu Fukuoka's revolutionary agriculture". Permaculture News, June 23, 2014. https://www.permaculturenews.org/2014/06/23/revisiting-masanobu-fukuokas-revolutionary-agriculture.

6. Wezel, A., & Soldat, V. 2009. "A quantitative and qualitative historical analysis of the scientific discipline of agroecology". International Journal of Agricultural Sustainability, 7(1), 3–18. https://doi.org/10.3763/ijas.2009.0400.

7. Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., & David, C.2009. "Agroecology as a science, a movement and a practice. A review". Sustainable Agriculture, 2(December), 1–991. https://doi.org/10.1007/978-94-007-0394-0.

A diverse set of sustainable agriculture practices are followed in India, but basic statistics about their area coverage, locations, and adoption are lacking in national or state databases and information systems.

Image: Unsplash

Executive summary

Green Revolution-led agriculture in a climate changing-world

Arguably, the Green Revolution remains the most defining phase of Indian agriculture in the last century. An input-intensive and technology-focused approach helped India avert potential famines and meet its food security needs by reducing food imports. While the Green Revolution has ensured India's self-sufficiency for our cereal needs and has touched most Indian farmers, its long-term impacts are now visibly evident. Be it degrading topsoil, declining groundwater levels, contaminating water bodies, and reducing biodiversity. Crop yields are unable to sustain themselves without increased fertiliser use. Fragmented land holdings and associated low farm incomes are pushing many smallholders towards non-farm economic activities. Maturing climate change science is making it evident that input-intensive agriculture is both a contributor and a victim of climate change.

With increasing extreme climate events, examples of crop resilience are emerging from the ground, highlighting sustainable agriculture's potential

Sustainable agriculture: a promising way-forward?

In the face of increasing extreme climate events—acute and frequent droughts, floods, desert locust attacks—examples of resilience are emerging from the ground, highlighting sustainable agriculture's potential. For instance, in Andhra Pradesh, during the Pethai and Titli cyclones of 2018, the crops cultivated through natural farming showed greater resilience to heavy winds than conventional crops. While such examples are emerging, the overall understanding of the state of sustainable agriculture at a pan-India level is missing. For example, what sustainable agricultural practices are prevailing across India? Where are they being practised? How many farmers have adopted them? Which organisations are promoting such practices? What impact has such practices had on farm incomes, environment and social outcomes? If impact evidence is not available, then what are the gaps in our current knowledge?

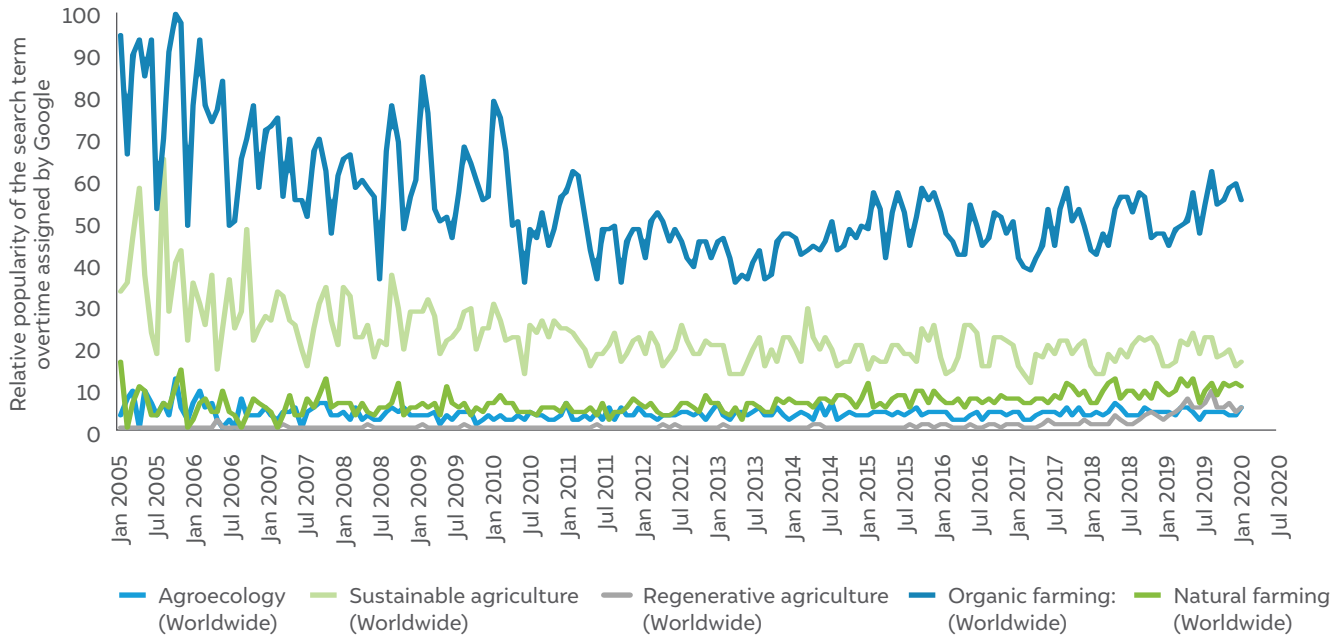
This study attempts to answer such questions to help **policymakers, administrators, and philanthropic organisations**, among others, to make evidence-backed decisions to scale-up sustainable agriculture practices in India as appropriate.

Sustainable agriculture: terminologies and the agroecology lens

It is important to understand what 'sustainable agriculture' is before identifying specific sustainable agricultural practices. As a concept, sustainable agriculture is dynamic with wide variations in its definition and practice. In our efforts to reconcile the concept, we encountered almost 70 definitions of the term. Multiple terms are used to refer to underlying

concepts of sustainable agriculture. Let us consider the Google search trends of the last 15 years. Organic farming is the most popular term, followed by sustainable agriculture, agroecology, natural farming, and then regenerative agriculture (Figure ES1).

Figure ES1 Google trends show organic farming as the most popular term worldwide



Source: Authors' adaption from (Google Trends)

Among various definitions, we selected **agroecology** as a lens of investigation in our study, as it adequately captures all the three dimensions of sustainability—economic, environmental, and social. Broadly, it refers to less resource-intensive farming solutions, provides more diversity in crops and livestock, and allows farmers to adapt to local circumstances.

Research approach

1 **Review**
literature to understand sustainable agriculture concepts and terminologies.

2 **Identify**
sustainable agriculture practices and systems (SAPSs).

3 **Screen**
SAPSs using FAO's agroecological framework.

4 **Collate**
key information about the scale of the prevalence of each SAPSs.

5 **Systematic literature review**
to assess available impact evidence associated with each SAPSs.

6 **Primary survey**
of 180 civil society organisations (CSOs) promoting sustainable agriculture.

7 **Consultations**
with government, agriculture institutions, and CSOs.

Key findings

State of sustainable agriculture in India

In all, we identified 30 sustainable agriculture practices (SAPs) prevalent in India. Some are focused only on one aspect of agriculture (we call them practices). In contrast, others are more holistic concerning the overall agriculture or most aspects of it (we call them systems). We collectively refer to them as sustainable agriculture practices and systems (SAPSs). Many practices have overlaps among themselves, and some individual practices are also advocated under a few systems (Table ES1).

Sustainable agriculture practices and systems (SAPSs)	
System	Practice
Permaculture*	Vermicompost*
Organic farming*	Drip irrigation/sprinkler*
Natural farming*	Crop rotation*
System of rice intensification (SRI) *	Intercropping*
Biodynamic agriculture*	Cover crops*
Conservation agriculture*	Mulching*
Integrated farming system (IFS) *	Contour farming*
Agroforestry*	Rainwater harvesting-artificial recharge of groundwater *
Integrated pest management (IPM) *	Floating farming*
Precision farming*	Plastic mulching
Silvipastoral systems	Shade net house
Vertical farming	Alternate wetting and drying technique (for rice)
Hydroponics/Aeroponics	Saguna rice technique
Crop-livestock-fisheries farming system	Farm pond lined with plastic film
	Direct seeding of rice
	Canopy management
	Mangrove and non-mangrove bio-shields

Table ES1
Thirty identified sustainable agriculture practices and systems

Source: Authors' compilation

**Selected for an in-depth review*

We find that sustainable agriculture is far from mainstream in India. Barring a couple of exceptions, most SAPSs have less than five million (or four per cent) farmers practising them. For many, the practising farmers are less than one per cent of the total Indian farmers. We summarise the current status of the adoption of these practices in Table ES2.

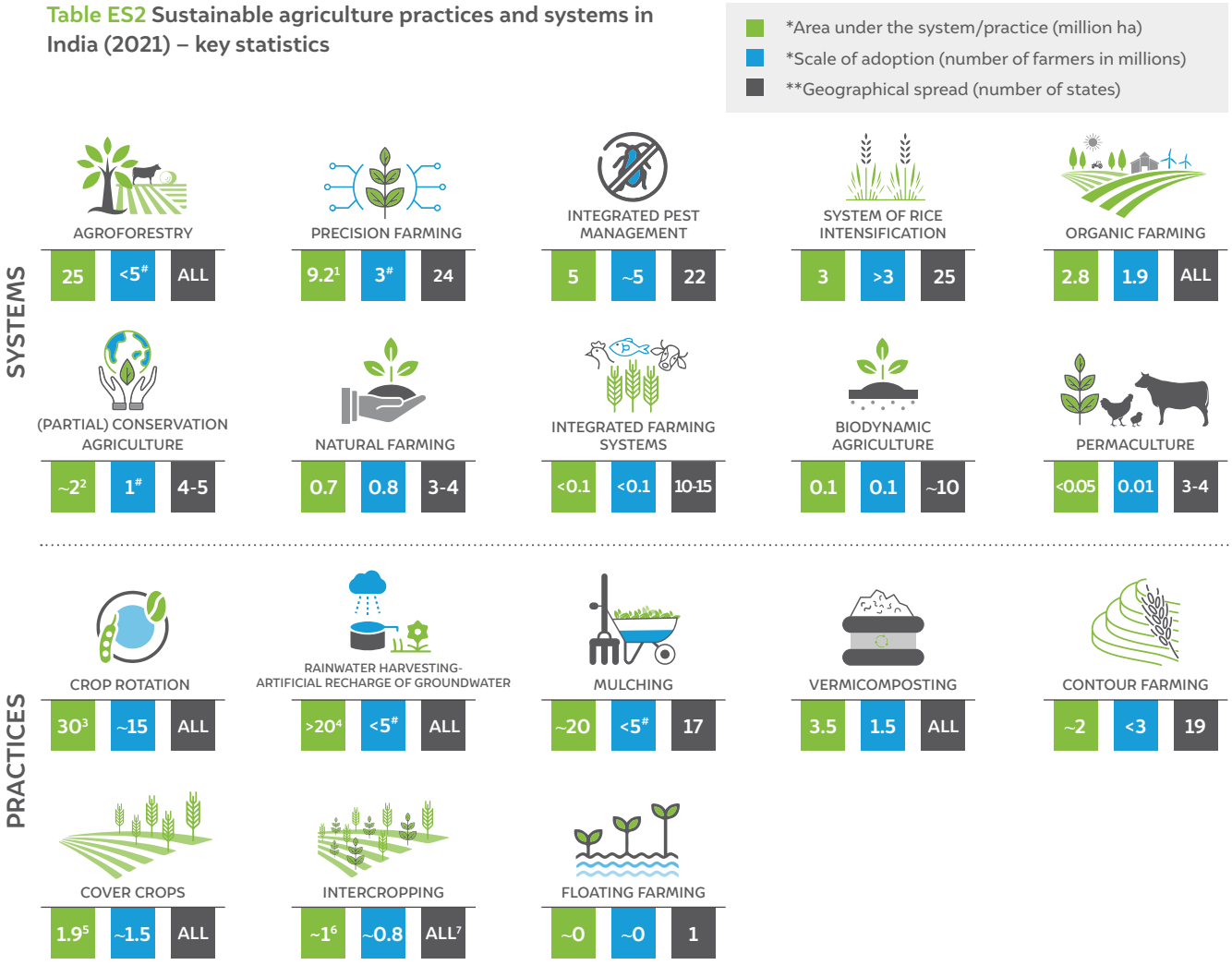
Crop rotation, one of the elementary SAPSs, is the most popular across the country, covering about 30 million hectares and ~15 million farmers. Practices like **agroforestry** and **rainwater harvesting**, which got significant attention in national programmes, also have higher coverage. While agroforestry covers a large area, the practice is mainly popular among large cultivators. Documented information around the prevalence of **mulching** is very limited; however, one stakeholder suggested that it covers an area of about 20 million ha.

The area under **precision farming** may seem large (nine million ha); however, it primarily consists of the area under micro-irrigation, an aspect of precision farming. Over the years, the *National Mission on Micro Irrigation* has significantly promoted micro-irrigation in the country. **Integrated Pest Management** has a low coverage of 5 million ha, despite being promoted for decades. **Intercropping** is more common in the country's southern and western regions and covers nearly one million ha. However, the estimate does not include intercropping areas in horticultural crops due to the lack of reliable estimates.

We find that sustainable agriculture is far from mainstream in India. Barring a couple of exceptions, most SAPSs have less than five million (or 4%) farmers practising them

Despite government policy support, **organic farming** currently covers only two per cent of the country's total net sown area (140 million ha). India has about two million certified organic producers, but reliable information about uncertified organic farmers is not available. **Biodynamic agriculture**, a variant of organic farming, has an estimated coverage of 0.1 million ha (where biodynamic inputs are explicitly used along with organic farming practices). **Natural farming** has witnessed a faster rate of adoption in the last two to three years. Close to one million farmers practise natural farming, mostly in Andhra Pradesh, Karnataka, Maharashtra, and Himachal Pradesh. The associated area is about 0.7 million ha as it has been mainly popular among small and marginal farmers so far. The popularity of the **system of rice intensification (SRI)** has also rapidly increased in the last five years, with an estimated area of around 3 million ha across the country. The area under **partial conservation agriculture (CA)** is estimated to be around 2 milllion ha, mostly in a few states in the Indo-Gangetic Plains (IGPs).

Table ES2 Sustainable agriculture practices and systems in India (2021) – key statistics



Source: Authors compilation from literature, stakeholder consultations, and estimations thereof.

**The area and adopters can be updated with newer information if available.*

Note:
** Based on estimates from literature and stakeholder discussions*
***The geographic spread is the indicative number of states where a non-negligible number of farmers adopts a SAPSs (say, at least a thousand farmers)*
 # No of adopters (farmers) are deduced from the area under that SAPSs divided by the average landholding size for the kind of farmers majorly undertaking that SAPSs
1: Primarily comprises estimates pertaining to micro-irrigation
2: Estimates include areas under partial CA.
3: For crop rotation, estimates include cereal-cereal rotation
4: Estimates are based on the water conservation activities allocated under the Integrated Watershed Management Programme. The area estimates pertain to the watershed development area and not only the farm area.
5: Includes plantation crops having leguminous cover crops
6: Excludes intercropping in horticultural crops
7: Includes states that practice mixed cropping

Impact literature on India's sustainable agriculture

From the systematic review of literature, we find that agroforestry, CA, and SRI are the most popular among researchers assessing the impact of SAPSs on various outcomes (Figure ES2). In contrast, the impact evidence around permaculture and floating farming in the Indian context is almost non-existent. The impact evidence of biodynamic agriculture is also very limited currently. Regarding different areas of outcomes, most of the SAPSs have many publications focusing on environmental indicators followed by economic and social ones. However, organic farming, natural farming, and integrated farming systems have many publications focused on economic outcomes.

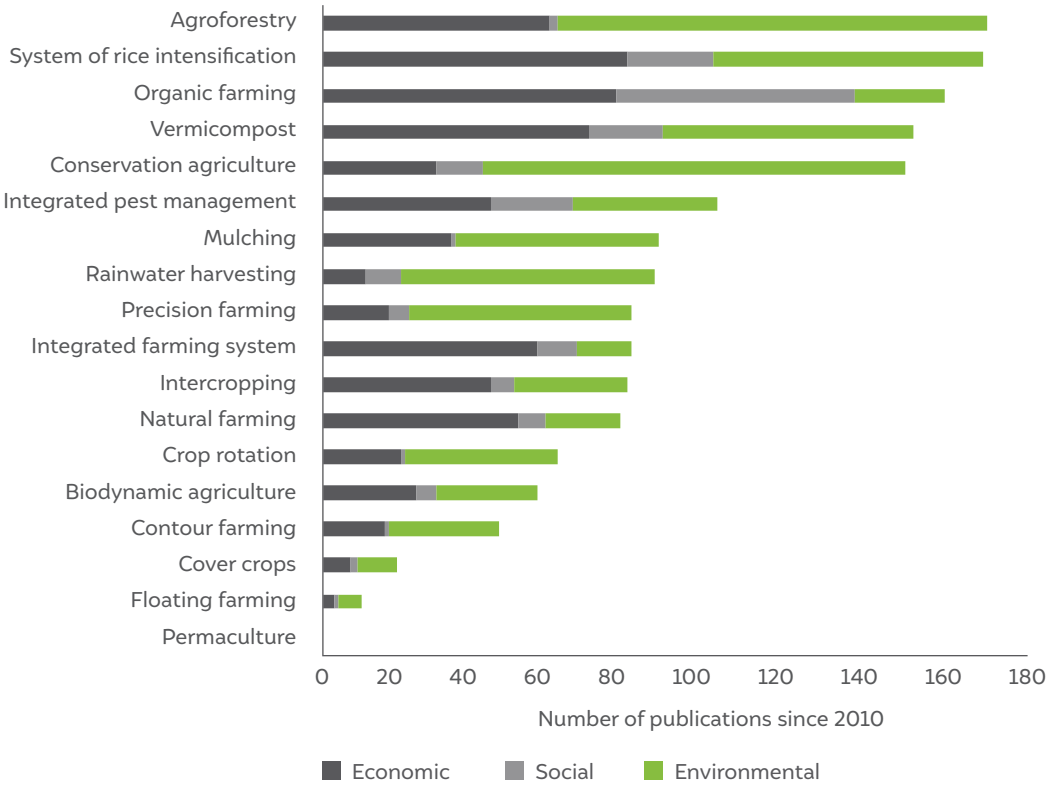
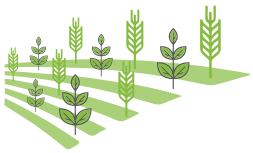


Figure ES2
Various SAPSs received different level of interest among researchers over the last decade

Source: Authors' compilation; based on several types of publications (peer reviewed journals, reports, articles/case studies, etc) of which only those papers which clearly established the evidence for different indicators were selected.

- **The literature critically lacks long-term impact assessments of SAPSs across all three sustainability dimensions.** Short-term (0.5 – 3 years long) assessments mainly dominate the literature. These are not helpful to understand the long-term impacts of transitioning to SAPSs. Few practices, such as CA, have long-term impact studies, primarily focused on environmental outcomes in Indo-Gangetic plains'.
- **Impact studies are mostly limited to plot-level trials, while assessments at a landscape/regional/agroecological-zone level are mostly missing**, except for agroforestry. We find that the cost of long-term and larger studies is the biggest reason for these research gaps.
- **Most publications evaluate a SAPSs impact on only a single dimension of interest (such as water, soil, gender, or yields)**.
- **Yields, income, soil health, and water find the most interest as a subject area among researchers across all the three sustainability dimensions**. Impacts of SAPSs on biodiversity, ecosystem services, health, and gender are least researched.

- **Conventional approaches to measuring farm productivity are often not adequate for SAPSs**. For yields, the studies tend to compare a single crop yield between sustainable and conventional practices. Crop-diversification through inter-cropping or multi-cropping is common under various SAPSs, and the productivity discussions in literature often ignore outcomes across other crops. Similarly, various SAPSs commonly promote livestock integration, but the evidence capturing total farm productivity, including livestock output, is limited.



Crop-diversification through inter-cropping or multi-cropping is common under various SAPSs

Sustainable agriculture's impact evidence in India

- **Income**: The evidence around SAPSs' impact on farmers' incomes remains insufficient, both in terms of geographical coverage as well as the number of long-term assessments. Notwithstanding this critical limitation, the literature indicates the potential of a few SAPSs to enhance income through a reduction in production costs (CA, natural farming), diversification of agricultural production (IFS, intercropping), and premium prices (organic produce).

- **Yields**: Notwithstanding the conceptual limitations to adequately estimate farm productivity, we find some emerging patterns for yields under a few SAPSs. For organic farming, at least in the short-term (2-3 years), yields are lower than conventional farming. Beyond this period, some studies show equal and even higher yields for some crops, particularly once the soil form and structure evolve after a few years of applying biological inputs. The short-duration studies of natural farming indicate no statistically significant changes in yields for most crops. For SRI, yield impacts are well documented, showing a statistically significant increase in various paddy varieties. Resource-conserving practices, such as vermicomposting, agroforestry, and crop diversification, have positively impacted yields. However, the lack of studies documenting the long-term impacts of SAPSs on yields makes it difficult to generalise results.

- **Water-use**: Several studies in literature capture the impact of various SAPSs on water-use efficiency. In particular, SRI, CA, precision farming, rainwater harvesting, contour farming, cover crops, mulching, crop rotation, and agroforestry have positively impacted water conservation. Rainwater harvesting and SRI appeal to smallholder farmers because of their ease of adoption. Pre-monsoon dry sowing in natural farming is considered a break-through in the drought-prone regions of Andhra Pradesh, warranting further assessments.

- **GHG emissions**: Among SAPSs, agroforestry, SRI, and CA have the most evidence for climate mitigation. Evidence associated with agroforestry's carbon-sequestering abilities (above and below ground) is well established. A growing body of evidence suggests that the SRI promotes aerobic soil conditions reducing methane emissions. However, intermittent irrigation, an intrinsic component of SRI, can increase nitrous oxide emissions. Overall, long-term carbon sequestration impacts of the SAPSs need evaluation in India.

- **Biodiversity**: Several SAPSs like agroforestry, IFS, permaculture, natural farming, organic farming, conservation agriculture, and crop diversification strategies (rotation, intercropping, mixed) tend to increase the spatial, vertical, and temporal diversity of species at a farm (and landscape) level. While research articles mention the impact on biodiversity, studies offering substantive empirical evidence are missing.

- **Health**: We only find anecdotal evidence mentioning positive health impacts of various SAPSs, mainly through dietary diversity and less exposure to harmful chemicals such as pesticides. Empirical studies comparing SAPSs with conventional agriculture for health outcomes are missing.

A few SAPSs can enhance income through a reduction in production costs (CA, natural farming), diversification of agricultural production (IFS, intercropping), and premium prices (organic produce)

- **Gender**: Women contribute more than 70 per cent of the labour force in Indian agriculture. However, research studies focusing on gender outcomes of SAPSs are minimal. A few practices like vermicomposting, organic farming, IFS, and rainwater harvesting define women's roles, but the evidence on women's impact is missing. We need further research to understand the impact of various SAPSs on women's workloads, income, empowerment, and employment.

Merely 0.8% of the Ministry of Agriculture and Farmers Welfare budget is allocated to *National Mission for Sustainable Agriculture* indicating a significant scope to support sustainable agriculture further

Policy ecosystem for sustainable agriculture in India

Since 2014-15, India has had a *National Mission for Sustainable Agriculture* (NMSA) to promote sustainable agriculture. It consists of several programmes focusing on agroforestry, rainfed areas, water and soil health management, climate impacts, and adaptation. Beyond NMSA, the *Pradhan Mantri Krishi Sinchai Yojana* promotes the adoption of precision farming techniques such as micro-irrigation, and the *Integrated Watershed Management Programme* supports rainwater harvesting.

However, merely 0.8 per cent of the Ministry of Agriculture and Farmers Welfare (MoAFW) budget is allocated to NMSA. Beyond the INR 142,000 crore (USD 20 billion) budget of MoAFW the Central government also spends about INR 71,309 crore (USD 10 billion) annually on fertiliser subsidies.[1] So, while the Indian government recognises the importance of promoting sustainable agriculture, the focus remains heavily skewed towards green revolution-led farming.

Among SAPSs, eight of the 30 practices receive some budgetary support under various Central government programmes. These include organic farming, integrated farming system, rainwater harvesting, contour farming (terraces), vermicomposting, mulching, precision farming, and IPM. Among these, organic farming has received the most policy attention as the Indian states have also formulated exclusive organic farming policies.

Civil society action on sustainable agriculture in India

Similar to the policy side, organic farming gets the most interest among CSOs. Whereas very few CSOs deal with precision farming, integrated farming systems, and biodynamic agriculture (Fig ES3).

Across States, Maharashtra is the most popular among the CSOs. Rajasthan, Madhya Pradesh, and Odisha are the next in order. We find very few CSOs active in states like Punjab and Haryana (Fig ES4).

These CSOs provide various support to promote SAPSs, including training, capacity building and awareness generation of farmers, support for inputs preparation and seed management, field demonstration activities. A few are also involved in technology transfer.

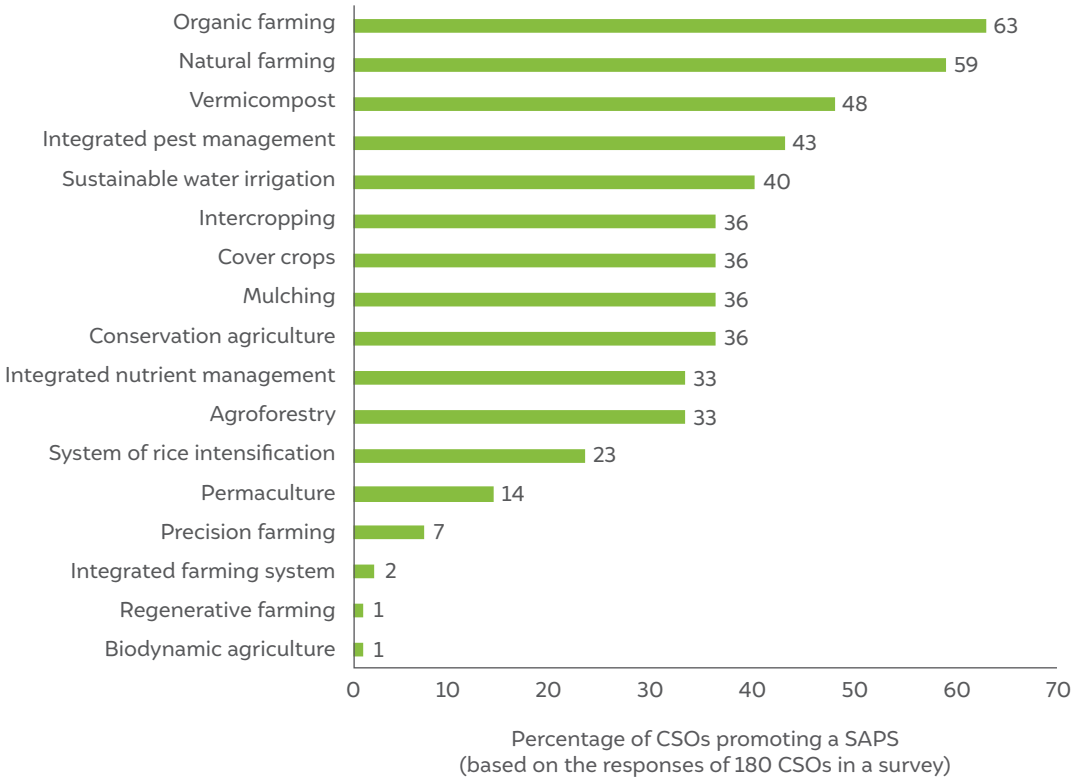


Figure ES3

Most CSOs surveyed were found promoting organic and natural farming

Source: Authors' analysis based on the CSO survey

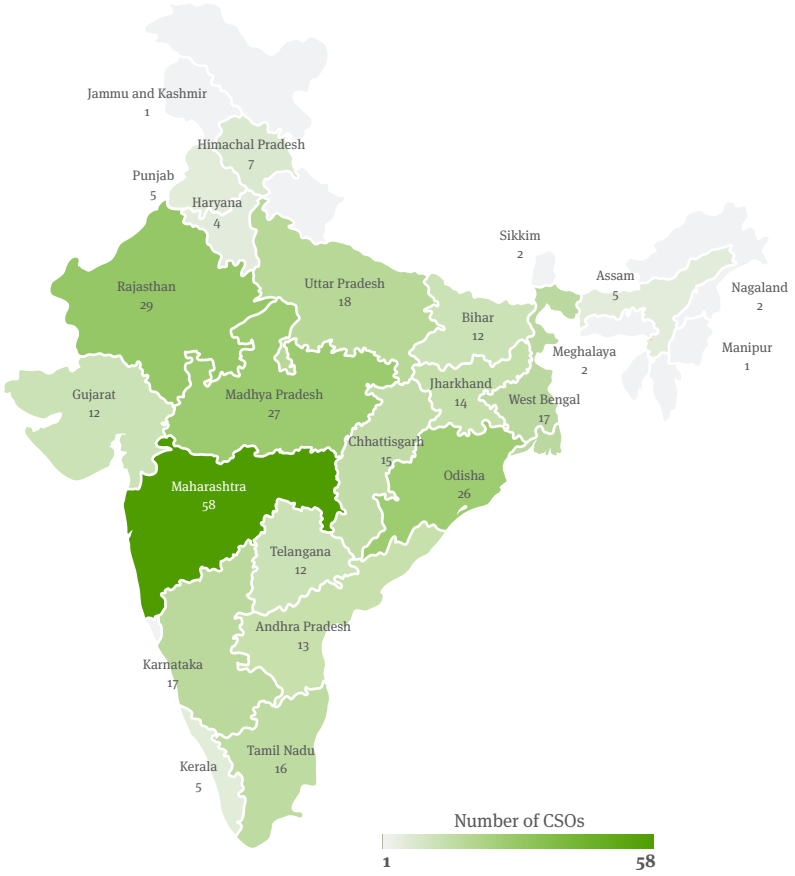


Figure ES4

Most CSOs reported being active in Maharashtra, Rajasthan, and Madhya Pradesh

Source: Authors' analysis based on the CSO survey

Key emerging themes in India's sustainable agriculture

This section discusses the key cross-cutting themes that emerged during our research and are central to the discussion on sustainable agriculture in India.

- **The role of knowledge**: Most SAPSs are knowledge-intensive and need knowledge exchange and capacity building among farmers to enable their successful adoption.
- **The reliance on farm-labour**: Given the practices are niche, the mechanisation for various input preparations, weed removal, or even harvesting in a mixed cropping field is not mainstream yet – increasing the reliance on labour for various on-field activities. Labour-intensiveness may pose a barrier to the adoption of some of the SAPSs among medium to large farmers.
- **Motivation to adopt SAPSs**: First, conventional agriculture's long-term negative impacts are pushing farmers to look for alternatives. Second, where farmers are in a resource-constrained environment, such as rain-fed areas, and not using significant external inputs, anyway, and hence are willing to make the incremental shift to adopt SAPSs.
- **SAPSs' role in food and nutrition security**: Most SAPSs promote crop and food diversity through intercropping, mixed cropping, crop rotation, agroforestry, or IFS. One, it improves the farmer's food security by diversifying their food and income sources. Secondly, by improving the diversity of available nutrition, it enhances the nutrition security for agriculture families which could possibly solve the country's underlying malnutrition problems. However, both these aspects are hardly studied in the available literature and thus warrant future research.

By promoting crop diversification through mixed cropping, intercropping and IFS, most SAPSs can potentially address the malnutrition challenges of India's vulnerable populations

Way forward to scale-up sustainable agriculture in India

Based on the gathered insights, we propose the following next steps towards an evidence-backed scale-up of sustainable agriculture in India.

Focus on knowledge exchange and capacity building among farmers and agriculture extension workers on SAPSs. Leveraging and building-on the extensive prevailing on-ground CSO capacity would be a great first step.

Restructure the government support to farmers. Instead of encouraging resource-intensive cultivation through inputs-based subsidies, align incentives towards resource conservation while rewarding outcomes (such as total farm productivity, enhanced ecosystem services) and not merely outputs such as yields. It will allow a multitude of farming approaches, including SAPSs, to flourish.

Support rigorous evidence generation through long-term comparative assessment (between resource-intensive and sustainable agriculture) in view of changing-climate to inform long-term resilient approaches to nutrition security. It would help enable an evidence-backed and context-relevant scale up of SAPSs.

Broaden perspectives of stakeholders across the agriculture ecosystem to consider alternative approaches, as they are only exposed to resource-intensive agriculture for the last six decades. A suite of strategies spanning evidence-driven narratives to on-ground field visits would help.

Adopt transition support plans to extend short-term transitionary support to those who would get adversely impacted by a large-scale transition to sustainable agriculture.

Make sustainable agriculture visible by integrating data and information collection on SAPs in the prevailing agriculture data systems at the national and state level. In the absence of reliable data, it is difficult to ascertain the scale and extent of sustainable agriculture in India.

Restructuring government's support to farmers to incentivise resource conservation and reward outcomes (such as annual farm productivity and not merely yields) would help scale up sustainable agriculture

Conclusion

While states like Sikkim and Andhra Pradesh are leading the way on sustainable agriculture in India, the adoption remains on the margins at an all-India level. Likewise, the impact evidence about its outcomes on the economic, social and environmental front is limited.

At one end, we must generate more long-term evidence. Alongside, we should leverage existing evidence to scale-up context-specific SAPSs. The scale-up could start with rainfed areas, as they are already practising low-resource agriculture, have low productivities, and primarily stand to gain from the transition. As the positive results at scale would emerge, farmers in irrigated areas will follow suit.

At the budgetary level, significantly increase allocation to sustainable agriculture enabling its evidence-backed scale-up across the country. At the tactical level, focus on region- and practice-wise priorities, which span a wide variety: from technological innovation to help mechanise labour-intensive processes to farmers' capacity building in knowledge-intensive practices.

Finally, broaden the national policy focus from food security to nutrition security and yield to total farm productivity. It would help recognise the critical role that sustainable agriculture could play to ensure India's nutrition security in a climate-constrained world.

Women contribute more than 70% of the labour force in Indian agriculture, yet impact studies focusing on gender outcomes of SAPSs are minimal.

Image: iStock

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