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Sustainable Agriculture in India 2021

What We Know and How to Scale Up

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

Report | April 2021

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

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

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CEEW Report
April 2021
ceew.in

Suggested citation: Gupta, Niti, Shanal Pradhan, Abhishek Jain, and Nahya Patel. 2021. *Sustainable Agriculture in India 2021: What We Know and How to Scale Up*. New Delhi: Council on Energy, Environment and Water.

Cover image: Twig Designs.

Peer reviewers: Dr Seth Cook, Associate, Systemiq, Vijay Kumar, Distinguished Fellow (TERI) and Lead, Food and Land Use Coalition-India, Dr Bindu Mohanty, Research Coordinator, Revitalising Rainfed Agriculture Network, Dr Srijit Mishra, Professor, Indira Gandhi Institute of Development Research (IGIDR) and Dr Vaibhav Chaturvedi, Fellow, CEEW.

Publication team: Alina Sen (CEEW), Fiona Hinchcliffe, Twig Designs, and Friends Digital.

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About CEEW

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.

Rkumar

(Rajiv Kumar)

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Acknowledgments

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

Sincere thanks to all our peer reviewers, whose names and affiliations are listed inside the front cover. We sincerely acknowledge the support of domain experts whom we consulted for each of the sustainable agricultural practices described in the report. They include Dr A.K. Handa, Principal Scientist, Indian Council of Agricultural Research-Central Agroforestry Research Institute, Anshuman Das, Programme Manager, Welthungerhilfe, Dr K.K. Agrawal, Professor, Jawaharlal Nehru Agricultural University, Jabalpur, Dr B. Venkateswarlu, Ex-Director, Indian Council of Agricultural Research-Central Research Institute for Dryland Agriculture, Dr Bipin B. Panda, Principal Scientist, Indian Council of Agricultural Research - National Rice Research Institute, Dr B.V. Chinnappa Reddy, Professor & University Head (Rtd), University of Agricultural Sciences, Bangalore, Dr Girish Chander, Senior Scientist, ICRISAT Development Center, G. Muralidhar, Senior Consultant, Rythu Sadhikara Samstha (RySS), Jagannath Chatterjee, Documentation Manager, Regional Centre for Development Cooperation, Dr Kanchan Saikia, Principal Scientist, Indian Council of Agricultural Research-National Rice Research Institute, Dr Mohammad Shahid, Senior Scientist, Indian Council of Agricultural Research-National Rice Research Institute, Dr N. Ravisankar, Principal Scientist, Indian Council of Agricultural Research-Indian Institute of Farming Systems Research, Dr S.S. Suresh, Senior Hydrogeologist, Central Ground Water Board, Sundeep Kamath, Consultant, Biodynamic Association of India, and Dr Tek B. Sapkota, Agricultural Systems and Climate Change Scientist, International Maize and Wheat Improvement Center, Mexico. They shared many insightful perspectives with us, with some of them providing access to valuable data that enriched this study further.

We extend our appreciation to FOLU India partners - WRI, TERI, RRAN for their valuable feedback and suggestions, especially Dr Seth Cook and FOLU India coordinator Dr K.M. Jayahari. We also like to thank Minhaj Ameen for extending his support on civil society survey.

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, worked 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.

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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.

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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."

Nahya 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

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Acronyms

BDA	biodynamic agriculture
CAFRI	Central Agroforestry Research Institute
CLCC	customized leaf colour chart
CSOs	civil society organisations
DAC&FW	Department of Agriculture, Co-Operation & Farmers Welfare
FAO	The Food and Agriculture Organization
GHG	greenhouse gas(es)
ICAR	Indian Council of Agricultural Research
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-arid Tropics
IFS	integrated farming systems
IGP	Indo-Gangetic Plain
INR	Indian rupee
IPM	integrated pest management
IWMP	*Integrated Watershed Management Programme*
MoAFW	Ministry of Agriculture and Farmers Welfare
Mt	million tonnes
NITI	National Institution for Transforming India
NMSA	*National Mission for Sustainable Agriculture*
NRRI	National Rice Research Institute
PF	precision farming
RCDC	Regional Centre for Development Cooperation
RWH	rainwater harvesting
RySS	Rythu Sadhikara Samstha
SAPSs	sustainable agricultural practices and systems
SRI	System of Rice Intensification
SWAD	Society for Women Action Development
ZBNF	Zero Budget Natural Farming

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. DAC&FW. 2014. "National Agroforestry Policy of India. "Department of Agriculture Cooperation & Farmers Welfare, New Delhi.

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 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 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 titled "*Agrarökologie*" (agroecology) that combined ecology and agronomy for integrated agricultural management. After the concept of "agroecosystems" was introduced by 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, and Rede Ecovida in Southern Brazil.

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.
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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 its area 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 makes 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 in 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?

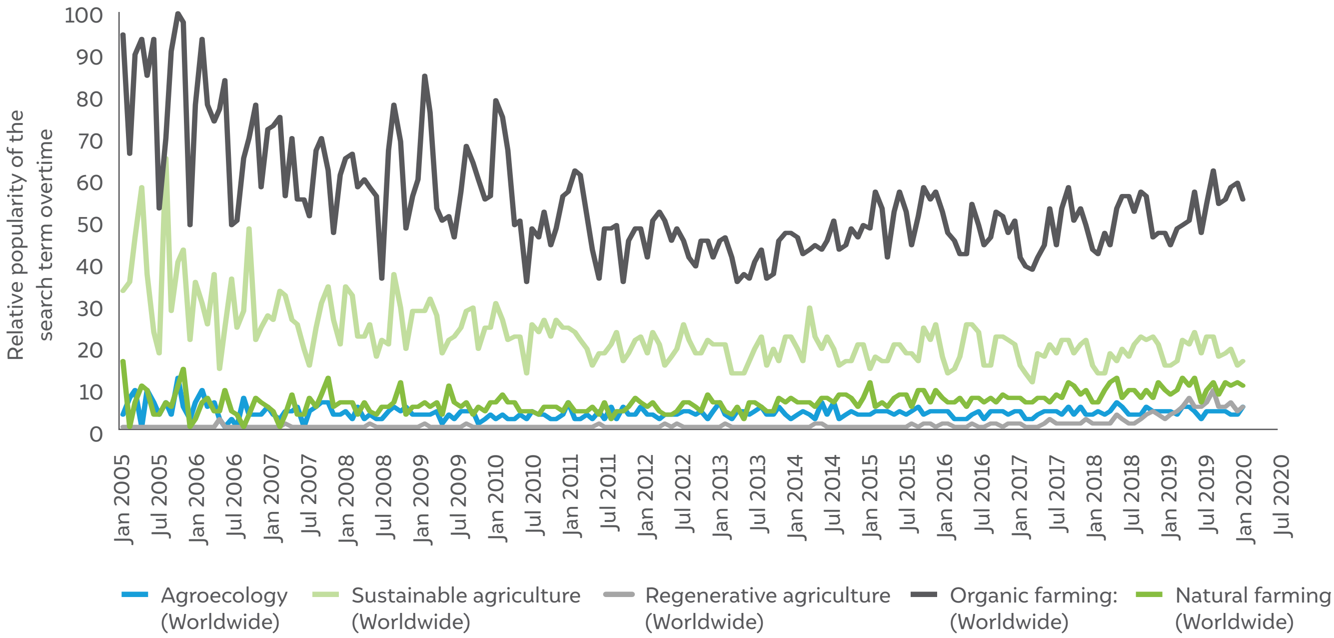
This study attempts to answer such questions to help **policymakers, administrators, and philanthropic organisations**, among others, to make evidence-backed decisions to scale-up sustainable agriculture practices in India as appropriate.

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** with 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).

Table ES1
Thirty identified sustainable agriculture practices and systems

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	Alternative wet 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

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

		*Area under the system/practice (million ha)	*Scale of adoption (number of farmers in millions)	**Geographical spread (number of states)
SYSTEMS	AGROFORESTRY	25	<5#	ALL
SYSTEMS	PRECISION FARMING	9.2[1]	3#	24
SYSTEMS	INTEGRATED PEST MANAGEMENT	5	~5	22
SYSTEMS	SYSTEM OF RICE INTENSIFICATION	3	>3	25
SYSTEMS	ORGANIC FARMING	2.8	1.9	ALL
SYSTEMS	(PARTIAL) CONSERVATION AGRICULTURE	~2[2]	1#	4-5
SYSTEMS	NATURAL FARMING	0.7	0.8	3-4
SYSTEMS	INTEGRATED FARMING SYSTEMS	<0.1	<0.1	10-15
SYSTEMS	BIODYNAMIC AGRICULTURE	0.1	0.1	~10
SYSTEMS	PERMACULTURE	<0.05	0.01	3-4
PRACTICES	CROP ROTATION	30[3]	~15	ALL
PRACTICES	RAINWATER HARVESTING-ARTIFICIAL RECHARGE OF GROUNDWATER	>20[4]	<5#	ALL
PRACTICES	MULCHING	~20	<5#	17
PRACTICES	VERMICOMPOSTING	3.5	1.5	ALL
PRACTICES	CONTOUR FARMING	~2	<3	19
PRACTICES	COVER CROPS	1.9[5]	~1.5	ALL
PRACTICES	INTERCROPPING	~1[6]	~0.8	ALL[7]
PRACTICES	FLOATING FARMING	~0	~0	1

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.

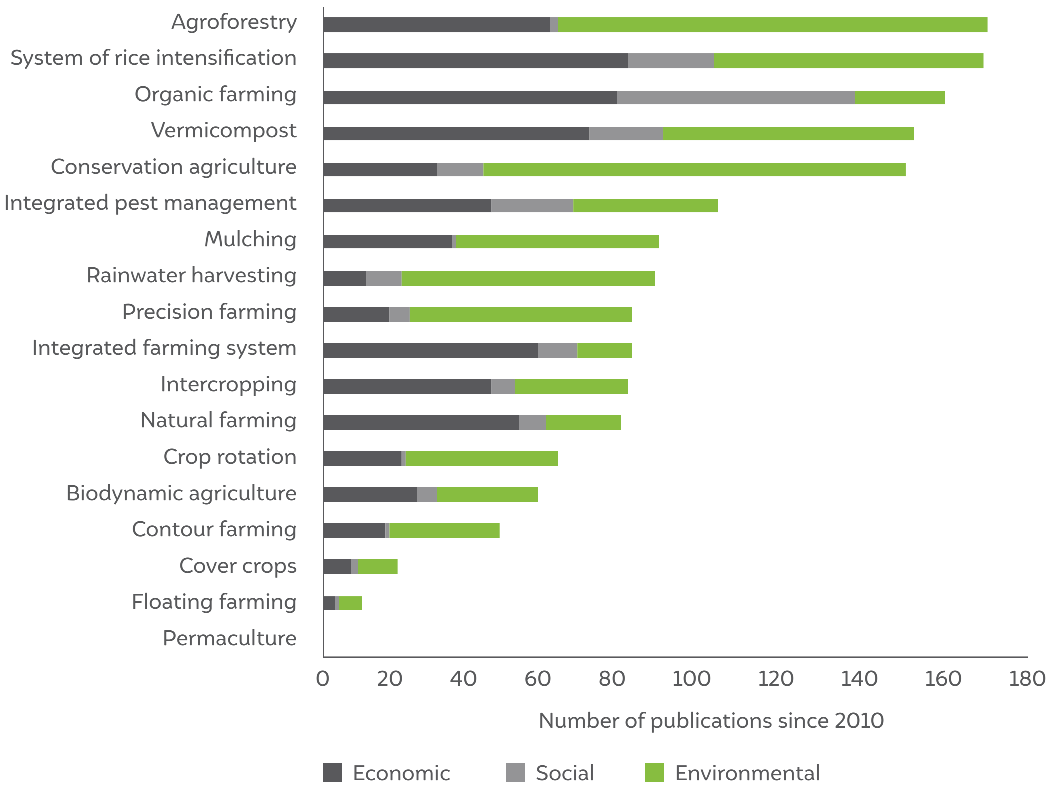
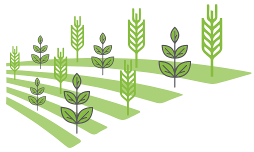


Figure ES2
Various SAPSs received different level of interest among researchers over the last decade

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.

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)

- **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.

- **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.

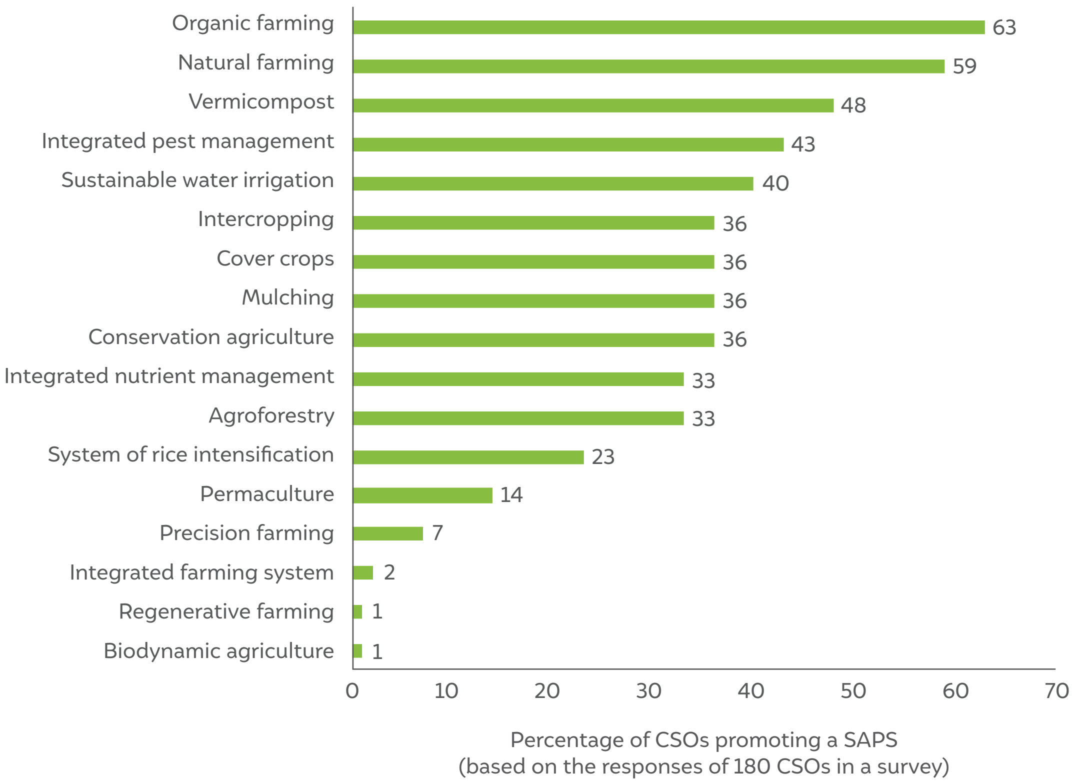


Figure ES3
Most CSOs surveyed were found promoting organic and natural farming

Source: Authors' analysis based on the CSO survey

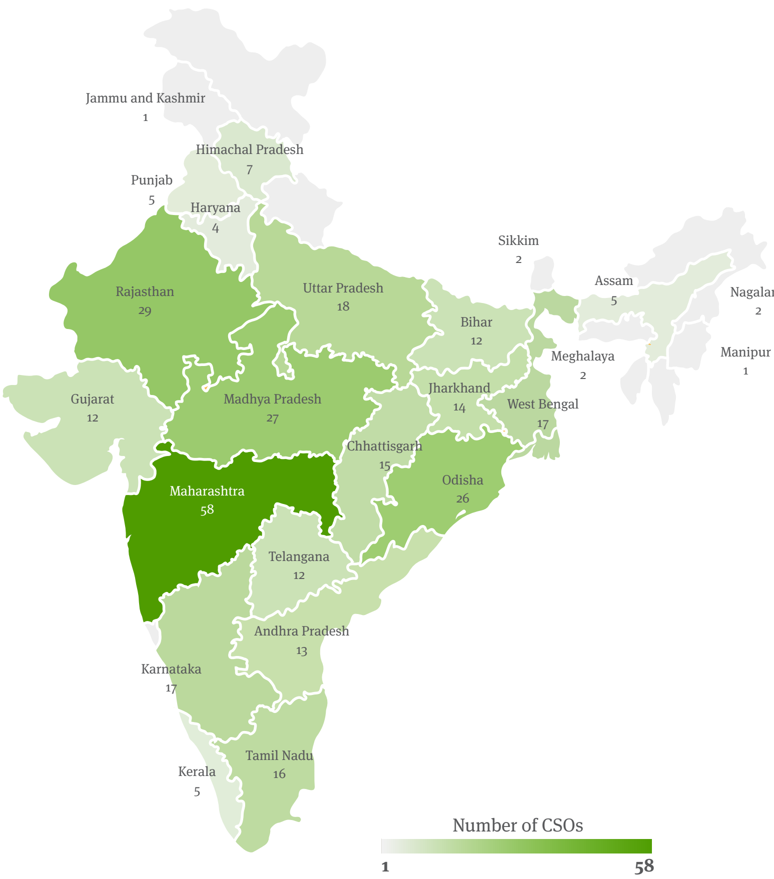


Figure ES4
Most CSOs reported being active in Maharashtra, Rajasthan, and Madhya Pradesh

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.

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

- **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.

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.

1. Introduction

Image: Chris de Bode for Panos Pictures/Food and Land Use Coalition

In the last few decades, India has achieved food security through increased production of rice and wheat. Still, attaining nutrition security remains a challenge. As per the NFHS-4, around 22 per cent of India's adult population (15 - 49 years) is undernourished and more than 58 per cent of Indian children (up to 5 years) are anaemic[2]. While the Green Revolution's promotion of high-yielding varieties of seeds and fertilisers did solve food-grain shortages, its drawbacks are now visible in the form of degraded land, soil, and water quality as farmers declining incomes due to a high dependency on external inputs. Between 2011-12 and 2015-16, the annual growth rate for all farmers' income declined from 5.52 per cent to 1.36 per cent, according to a paper by the NITI Aayog[3]. The latest report on *Accidental Deaths and Suicides in India 2019* by the National Crime Records Bureau suggests that at least 5,957 farmers and cultivators took their lives in 2019.[4]

The agro-ecosystems of the Indo-Gangetic plains, which have the most fertile soils in India and cover about 13 per cent of the total geographical area, are undergoing severe land degradation due to soil erosion & nutrient depletion. According to the Desertification and Land Degradation Atlas of India, 96.4 million ha, almost 30 per cent of the country's total geographical area, is undergoing land degradation/desertification[5]. Climate change poses another serious threat to Indian agriculture, which is largely rainfed and fundamentally dependent on climatic stability. With the projected 1.5-degree Celsius increase in the planet's average atmospheric temperature and the greater variability in summer monsoon precipitation, risks to food security, livelihoods, water supply, and human well-being are bound to increase.[6]

There is a need to investigate and invest in alternate sustainable agricultural methods and approaches tailored to local and agro-climatic conditions which can generate economic benefits for local communities, use natural resources more effectively, and focus on improving health and nutrition simultaneously. Such approaches can emphasise minimising inputs, and put the focus back on farmers while responding to the changing climate, reversing the deterioration of ecological systems, and increasing farmers' resilience and incomes. The path ahead must seek to improve agricultural productivity in a way that builds ecosystems and human health and is less intensive in its use of inputs, while contributing to the country's climate targets and goals.

1.1 What this report seeks to achieve

In India, much like in many other parts of the world, there is a wealth of alternate sustainable or regenerative agricultural practices. A few of them are indigenous or traditional approaches, while others are inspired by modern science. Some improve incomes and agricultural outputs; others focus on minimising resource use or environmental damage, while some aim to achieve both. Some are well studied and have significant literature behind them, while others are not well researched. Some are being adopted by millions of farmers, while only a handful practices others.

This study aims to shed light on the current state of sustainable agriculture in India. To achieve this, we (i) identify the most widespread sustainable practices and systems; (ii) assess them against the ten elements of agroecology; (iii) document the current state of adoption (geographic spread and scale) of these practices among farmers in India; (iv) tease out insights from the literature into the economic, social, and environmental impacts of these practices; (v) identify the gaps in the literature; and finally (vi) identify the main stakeholders/organisations associated with promoting these practices.

This report presents the information gathered and the insights in an easy-to-follow style to help policymakers, policy influencers, state-level administrators, philanthropic organisations, and donors make more informed decisions to scale-up. It does so by providing information on:

1. What sustainable agriculture practices (SAPSs) currently prevail in the country, regions, their impacts, contextual suitability, and the current scale of adoption.
2. The research areas on SAPSs should be prioritised to fill the existing impact evidence gaps.

2. Research approach

Images: CEEW

The research approach for the study rests on five methods: (i) a preliminary literature review to identify the sustainable agricultural practices and systems (SAPSs) in India; (ii) applying the FAO's agroecological principles to shortlist the SAPSs; (iii) an analysis of the literature on the shortlisted SAPSs to identify their scale and impact in India; (iv) stakeholder consultations; and (v) a primary survey. Each of these is discussed in turn in this section.

1. Preliminary literature review

Around 30 sustainable agriculture practices (SAPSs) were identified that were prevalent in India (Table ES1). Some are focused only on one aspect of agriculture (we call them practices), while 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 of these practices have overlaps among themselves, and some of the practices are also advocated under systems.

2. Applying the FAO's agroecological framework

Agroecology emerged as a concept and set of principles to understand traditional agricultural systems from an ecological and socio-economic perspective. While there are multiple definitions of agroecology, in a nutshell, it involves "the application of ecological concepts and principles to the design and management of sustainable agroecosystems."[7] It emphasizes enhancing soil organic matter through soil biotic activities, nutrient recycling, biological interactions among various organisms, maintaining biodiversity above and below ground, eliminating synthetic fertilisers. At the same time, it also places a strong emphasis on social and economic inclusion. Farmers are encouraged to diversify their on-farm incomes for greater financial independence and resilience, local diets and food promoted, and finally, equal opportunities for women, youth, tribal and indigenous groups created.

The three facets of agroecology

1. **As a scientific research approach** –Agroecology involves the integrative and holistic study of the ecology of the entire food system encompassing ecological, economic, and social dimensions.[8,9,10]
2. **As a set of practices and principles** – Agroecology enhances the resilience and ecological, socio-economic, and cultural sustainability of farming systems. The agroecological practices focus on improving the agroecosystem by harnessing natural processes, creating beneficial biological interactions and synergies among their components.[11]
3. **As a movement** – It promotes new ways to consider agriculture and its relationship with society.

Principles of agroecology

There is no one-size-fits-all prescription in agroecology for designing and managing sustainable agro-systems. Instead, it considers the surrounding ecosystem and regions to optimise the available resources. FAO has identified ten agroecology elements as an analytical framework or tool to help countries operationalise the approach[12] (Figure 1).

Figure 1
The ten elements of agroecology

Source: FAO (2019)

We used this framework to shortlist the practices and systems as it helps evaluate the social, economic, and environmental impacts in well-integrated manner. Of the ten agroecological elements in the framework, we selected eight elements against which to evaluate the SAPSs: diversity, synergies; efficiency; resilience; recycling; co-creation and sharing of knowledge, human and social values, culture and food traditions. We excluded 'responsible governance' and 'circular and solidarity economy' as these are more enabling conditions.

This assessment indicated that 30 farming practices and systems meet at least four of the FAO's agroecological elements (Table 1). Of these, we have subsumed eight within broader practices or systems, given their overlapping nature (light brown section of Table 1). Six practices were not considered for the study (in pink) as they did not meet the criteria, leaving 16 practices for in-depth review (in green).

Table 1
Selection of sustainable agricultural practice and systems

Source: Authors' analysis based on FAO's agroecological elements.

Sustainable agricultural systems/practices (SAPSs)	
16 SAPSs included in the study	Six excluded SAPSs
1. Organic farming	1. Plastic mulching
2. Natural farming	2. Shade net house
3. System of rice intensification	3. Vertical farming
4. Biodynamic agriculture	4. Hydroponics/Aeroponics
5. Conservation agriculture	5. Alternate wetting drying method
6. Integrated farming system	6. Soil solarisation
7. Permaculture	
8. Precision farming	Eight merged SAPSs
9. Agroforestry	1. Drip irrigation/sprinkler (included in precision farming)
10. Integrated pest management	2. Silvopastoral systems (included in agroforestry)
11. Crop rotation and intercropping	3. Saguna rice technique (included in conservation agriculture)
12. Cover crops and mulching	4. Crop-livestock-fisheries farming system (included in integrated farming systems)
13. Contour farming	5. Farm pond lined with plastic film (included in rainwater harvesting)
14. Rainwater harvesting-artificial recharge of groundwater	6. Direct seeding of rice (included in conservation agriculture)
15. Floating farming	7. Canopy management (included in agroforestry)
16. Vermicomposting	8. Mangrove and non-mangrove bio-shields (included in integrated farming systems)

3. Literature analysis

Next, we conducted a systematic assessment of the literature to map the evidence related to each SAPSs against a set of sub-themes (listed in Table 2). We developed a literature search strategy to identify and select the literature for each SAPSs. It involved selecting the search engines, inclusion or exclusion criteria, Boolean/keywords identification, and finalising the publication types (Table 3). The area and adopters were estimated for each practice (refer to ES2), and the estimation methods are provided in Annexure 1.

Table 2
Themes covered under each sustainable agricultural practice and systems

Source: Authors' analysis

Section	Sub-themes covered	Output
Key parameters	• Potential outcomes against agroecological elements • Definition • The area under adoption in India • The scale of adoption among farmers • Geographic spread • Major crops cultivated under the SAPS	Qualitative and quantitative findings synthesised from the assessed literature
Impact evidence	• Economic: yield; income • Social: health; gender • Environmental: soil; water; energy; carbon; nutrients; biodiversity	Qualitative and quantitative evidence collated for each indicator

Table 3
Systematic review method

Source: Authors' analysis

Section/topic	Description	Example
Database/ search engine	Online literature databases searched to identify relevant online references	Google Scholar Advanced search (for peer-reviewed/ journal publications) Google Advanced Search (for other publications)
Inclusion criteria	The inclusion of references is based on the criteria opposite	• Peer-reviewed publications and grey literature with some relevant information about the SAPS • Literature published between 2010 and 2020 • Literature published in English • Country of origin India and experiments based in/ relevant to India • The inclusion of references is based upon the abstract • The first 75 and 30 results were examined in Google Scholar Advanced Search and Google Advanced Search, respectively • Keyword search criteria confined to the title of the page/publication' in Google Scholar Advanced Search • Keyword search criteria confined to the title of the page' and 'anywhere in the page' in Google Advanced search
Publication types	Types of references documented and referred to in analysis	Journal paper; reports; case studies; articles; book chapters; guidelines and manuals; conference proceedings; thesis; working papers; web pages; technical bulletins
Search operators: Boolean operators	Boolean search operators using the plus (+) sign gave results that contain both the words or a combination of specific terms in search allowing for more focused and productive results. Boolean search modifiers using quotation marks (" ") located resources with the exact phrases in "quotation marks."	A representative indicative list to illustrate search operators used: "Integrated pest management "+income "integrated pest management "+yield "Integrated pest management"+ "human health" "Integrated pest management "+gender "Integrated pest management "+" women participation" "Integrated pest management "+soil "Integrated pest management "+water "Integrated pest management "+energy "Integrated pest management "+nutrient "Integrated pest management "+emission "Integrated pest management "+biodiversity

Table 3 contd

Section/topic	Description	Example
Keyword search criteria	Search criteria used in Google Scholar Advanced search:	• 2010-2020; English; in the title of the article; up to 75 articles examined
	Search criteria used in Google Advanced search:	• 2010-2020; English; India; in the title of the page; file type pdf; up to 30 articles examined • 2010-2020; English; India; anywhere in the page; file type pdf; up to 30 articles examined
Citation's storage method	Saved in the group, Mendeley	Folders created for each SAPS with cataloguing and tagging keywords per reference

Limitations: First, we only considered publications dated between 2010 and 2020 to keep the literature review manageable and focus on more contemporary evidence. However, this meant discounting literature published before 2010, even though it might have added additional insights.

Second, we limited the research scope to the first 75 and 30 publications in the Google Scholar Advanced Search and Google Advanced Search, respectively, to keep the literature review manageable. This means that we may not have found all the relevant publications, especially the information and documents collated by various civil society organisations working to promote these practices.

4. Primary survey

We used an online survey to identify the key actors, especially the civil society organisations (CSOs), involved in researching and implementing the various SAPSs in India. For maximum outreach, we floated this survey on RRAN (Revitalising Rainfed Agriculture Network) – a network of researchers, practitioners, and enablers working across regions and thematic areas for rainfed agriculture systems and beyond. We received responses from 180 CSOs and research institutions across 36 states and union territories.

We also used survey information to map the geographical spread and understand the scale of adoption for SAPSs where reliable government data were not available. We contacted few CSOs to understand more about their implementation and research challenges for each practice. The information was used to complement the indicators with qualitative insights.

5. Stakeholder consultation

We consulted multiple stakeholders from government, research and academic institutions, and CSOs (Figure 2) with expertise in the respective SAPSs or field of inquiry to fill in the study gaps. We conducted virtual consultations due to restrictions imposed by the COVID-19 pandemic and transcribed the discussions. In a few instances where stakeholders preferred, we provided questionnaires for which we received written responses.

Stakeholders consulted

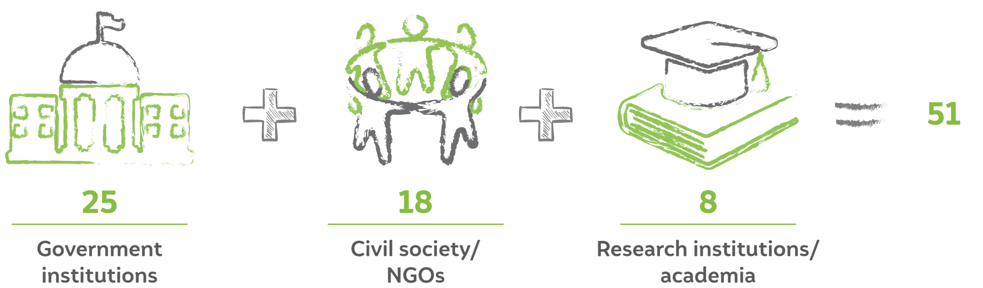


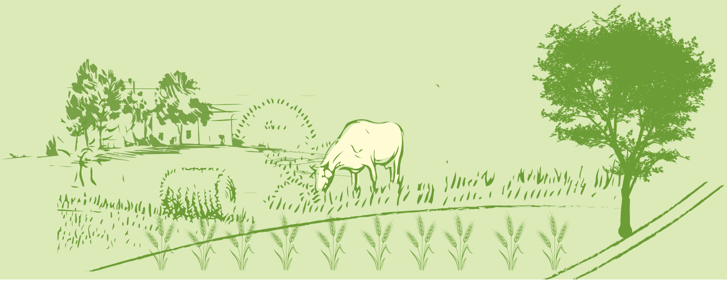
Figure 2
Types of stakeholders consulted for the study

Source: Authors' compilation

Image: iStock

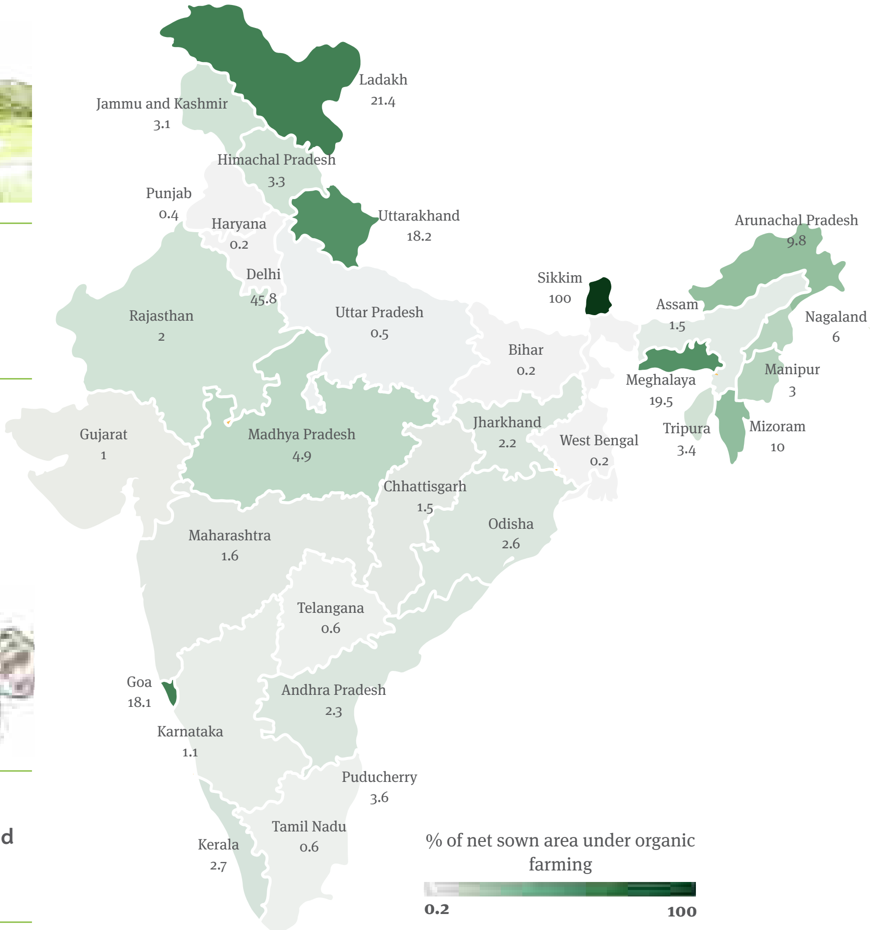
ORGANIC FARMING

Organic farming is a production system that prohibits the use of synthetically produced agro-inputs (fertilisers and pesticides). Instead, it relies on organic material (such as crop residues, animal residues, legumes, bio-pesticides) for "maintaining soil productivity and fertility and managing pests under conditions of sustainable natural resources and a healthy environment"[1].



2.8 MILLION ha
of area under certified organic farming (as of March 2020)[2]

1.9 MILLION
registered and certified farmers (as of March 2020)[3]



NO RELIABLE ESTIMATES
of uncertified organic farmers in India are available

A WIDE VARIETY OF CROPS
cereals, millets, cotton, fruits, vegetables, and more - are being cultivated using organic farming

Source: Lok Sabha 2019; Ministry of Agriculture & Farmers Welfare 2019

Note - State-wise organic coverage in proportion to the net sown area of the state

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Synergies | Efficiency | Recycling | Resilience | Human and social values | Diversity | Co-creation and sharing of knowledge | Culture and food traditions

Green: furthered by organic farming
Grey: no evidence of being furthered by organic farming

1. Ramanjaneyulu et al. 2020. Promotion of Organic Farming: Roles of key players. *Biotica Research Today* 2(8): 731-734.
2. Ministry of Agriculture & Farmers Welfare.2020. Lok Sabha Unstarred question no. 2063, 'Organic Farming' dated 3 March 2020, Government of India, http://164.100.24.220/loksabhaquestions/annex/173/AU2063.pdf.
3. Ministry of Agriculture & Farmers Welfare.2020. Lok Sabha Unstarred question no. 2063, 'Organic Farming' dated 3 March 2020, Government of India, http://164.100.24.220/loksabhaquestions/annex/173/AU2063.pdf.

KEY INSIGHTS & RECOMMENDATIONS

01 Reduced crop yields in the first 2-3 years, but comparable yields once the soil's biological activity is well-established. Focus needed on low resource endowed areas such as rainfed and hilly tracts for the initial scale-up.

02 Lack of assured market support and cumbersome certification process are major challenges for organic farmers. Policy support to tackle them would be necessary for any scale-up efforts.

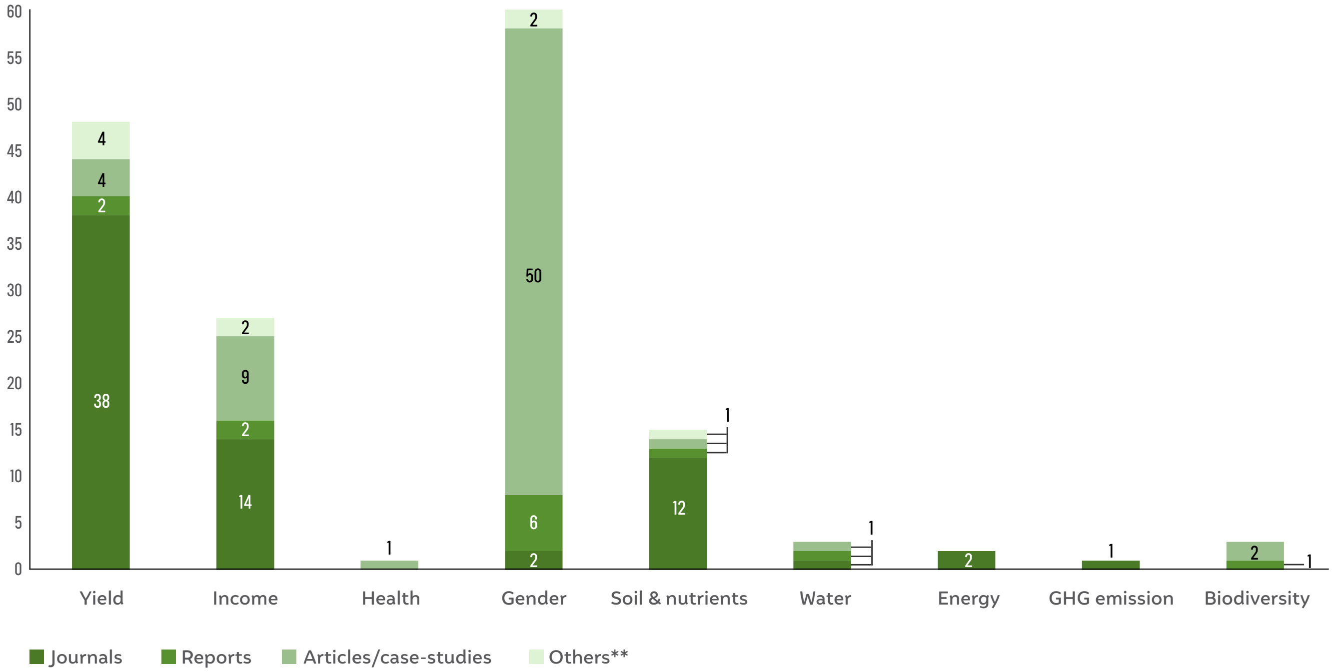
03 Women in organic farming face additional workload, especially for weeding. Support innovation in affordable and women-friendly technology implements needed for organic cultivation and manure production.

04 Support long-term assessments to study the impact on human health, biodiversity, and emissions.

05 Organic farming receives most policy attention among all SAPSs in India. Integration with state-level schemes and policies can further support the scale-up efforts.

06 Organic farming is the most prevalent SAP being promoted by CSOs. Sixty-three per cent of surveyed CSOs are active in organic farming in 25 states. Leverage their presence to scale-up the practice.

AVAILABLE RESEARCH ON THE IMPACT OF ORGANIC FARMING



Source: Authors' compilation

*** Thesis, guidelines, conference papers, etc.*

Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN ORGANIC FARMING

Government Institutions: National Centre of Organic Farming; Regional Centres of Organic Farming.

Research Institutions: Centre for Indian Knowledge Systems (CIKS); ICAR - Indian Institute of Farming Systems Research partnering with 11 State Agricultural Universities, 8 ICAR institutes and 1 Special Heritage University under All India Network Programme on Organic Farming; IIASD: Agriculture Institute India; National Organic Farming Research Institute, Sikkim.

NGOs/CSOs: Organic Farming Association of India; Sanjeevani; Organic Farmer Producer Association of India (OFPAI); DDS Krishi Vigyan Kendra; Alliance for Sustainable and Holistic Agriculture; Kheti Virasat Mission; Centre for Sustainable Agriculture; Equality Empowerment Foundation; Agragamee; PRADAN; People's Science Institute; Organic Ubuntu; Foundation for Ecological Security; SRIJAN; Manjari Foundation; UNNATI; SEWAM.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on organic farming here: https://www.ceew.in/sites/default/files/organic-farming.pdf

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

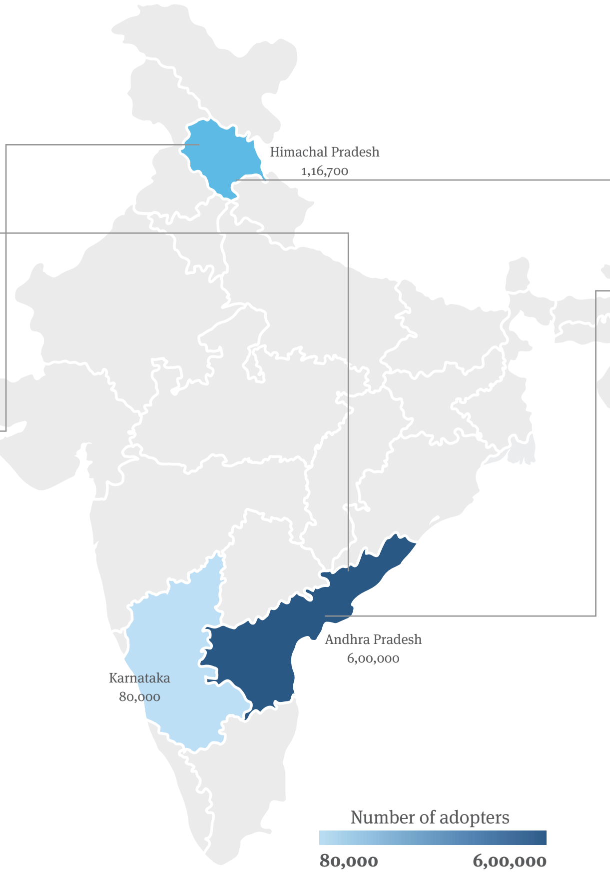
NATURAL FARMING

Natural farming in the Indian context (including zero-budget natural farming – ZBNF; Subhash Palekar natural farming; and community-managed natural farming) is a local low-input climate-resilient farming system that advocates the complete elimination of synthetic chemical agro-inputs. Instead, it encourages farmers to use low-cost, locally-sourced inputs such as natural mixtures made using cow dung, cow urine, jaggery, pulse flour. It also encourages mulch, crop covers, and symbiotic intercropping to stimulate the soil's microbial activities. Natural farming's main emphasis is on "enhanced soil conditions by managing organic matter and soil biological activity; diversification of genetic resources; enhanced biomass recycling; and enhanced biological interactions."[4]

6,52,000 ha
of area under natural farming across Andhra Pradesh, as of November 2020)[5]

6,377 ha
area under natural farming in Himachal Pradesh as of March 2021[6]

SMALL, MARGINAL, LANDLESS, TRIBAL FARMERS
are predominantly adopting natural farming



6,00,000 FARMERS
enrolled in the Andhra Pradesh state programme for natural farming, as of November 2020[7]

1,16,700 FARMERS
are practising natural farming under the Himachal Pradesh's *Prakritik Kheti Khushhal Kisan Yojna* as March 2021[8]

ALL TYPES OF CROPS
cereals, millets, and cotton to fruits, vegetables, and spices, are cultivated under natural farming

Source: Lok Sabha 2019; Ministry of Agriculture & Farmers Welfare 2019, RYSS Andhra Pradesh; Khadse et al. 2017

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Blue: furthered by natural farming

4. Gupta, N., Tripathi, S. and Dholakia, H.H. 2020. "Can Zero Budget Natural Farming Save Input Costs and Fertiliser Subsidies? Evidence from Andhra Pradesh." New Delhi: Council on Energy, Environment and Water.
5. Rythu sadhikara samstha, Andhra Pradesh.
6. Stakeholder Consultation, SNPF, Prakritik Kheti Khushhal Kisan Yojna, Himachal Pradesh.
7. Rythu sadhika samstha, Andhra Pradesh.
8. Stakeholder Consultation, SNPF, Prakritik Kheti Khushhal Kisan Yojna, Himachal Pradesh.

KEY INSIGHTS & RECOMMENDATIONS

01 

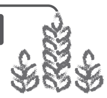
Short-term studies on the impact of natural farming on yields are inconclusive. Support long-term studies assessing the productivity, profitability, and ecological impacts of natural farming are required.

02 

Lower input cost and diversified cropping systems improve farmers' net income under natural farming. For the scale-up, ready-made inputs and market support for the diversified crops will be critical in maximising the returns.[9]

03 

Given natural farming is knowledge and skill-intensive, farmer's capacity building is critical to enable adoption. Leverage extension services and women and farmer cooperatives for knowledge dissemination and skilling.

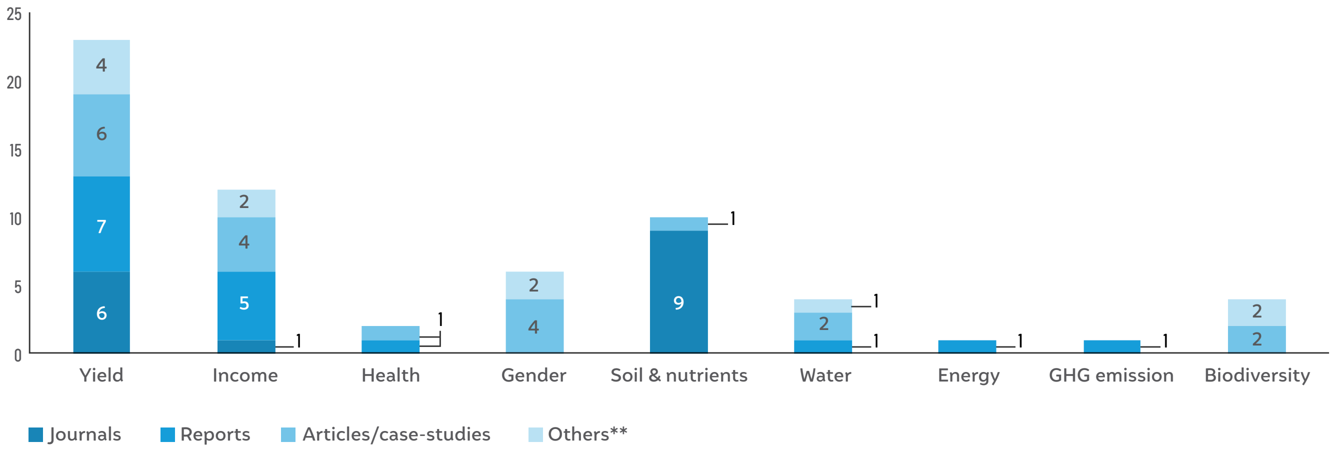
04 

Pre-monsoon dry sowing (PMDS) under natural farming is enabling additional cultivation in drought-prone regions of Andhra Pradesh, with more than 100,000 farmers adopting it so far. Support the upfront investment cost of cover crops to enable scale-up.

05 

Insignificant monetary allocation for natural farming, promoted as *Bhartiya Prakritik Krishi Paddhati Programme (BPKP)* under *Paramparagat Krishi Vikas Yojana (PKVY)*. Significant budgetary push required for states to adopt and scale natural farming.

AVAILABLE RESEARCH ON THE IMPACT OF NATURAL FARMING



Source: Authors' compilation

*** Thesis, guidelines, conference papers, etc.*

Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN NATURAL FARMING

Government Institutions: Rythu Sadhikara Samstha (RySS), Andhra Pradesh; Prakritik Kheti Khushhal Kisaan, Government of Himachal Pradesh; NITI Aayog.

Research Institutions: World Agroforestry Centre (ICRAF); Food and Agriculture Organization of the United Nations (FAO); United Nations Environment Programme (UNEP); University of Leeds; Center for Study of Science, Technology and Policy (CSTEP); Centre for Economics and Social Studies (CESS); HP Agricultural University; Centre for Science and Environment (CSE); Council on Energy, Environment and Water (CEEW).

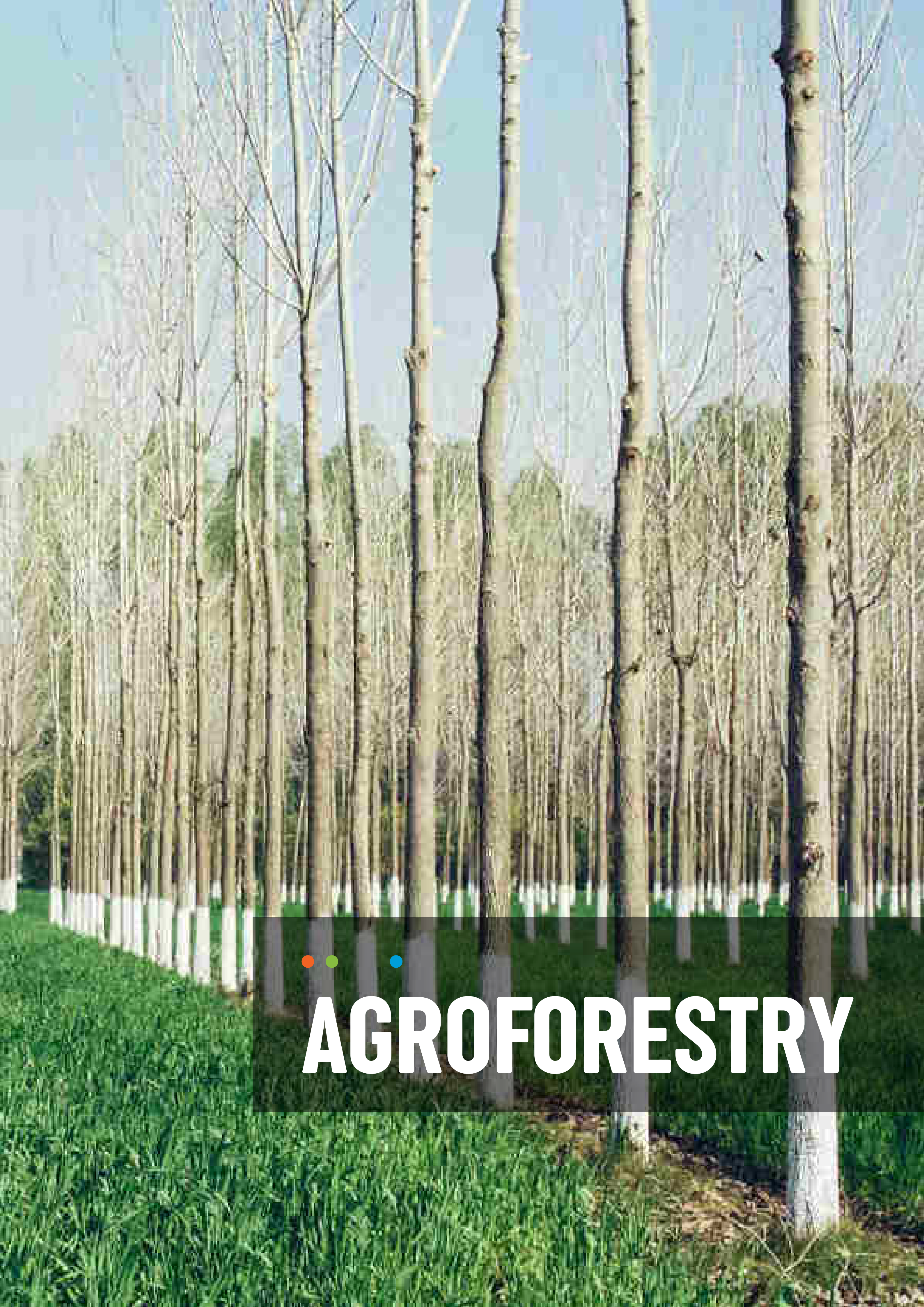
NGOs/CSOs: WASSAN; National Coalition on Natural Farming (NCNF); Centre for Sustainable Agriculture (CSA); Agragamee; Equality Empowerment Foundation; Samaj Pragati Sahayog (SPS); PRADAN; Smallholder Adaptive Farming and Biodiversity Network (SAFBIN); Gram Disha Trust; Lipok Social Foundation; Foundation For Ecological Security; SRIJAN; Utthan; JANAPARA Education and Rural Development society.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on natural farming here: https://www.ceew.in/sites/default/files/natural-farming.pdf

9. Galab, S et al. 2019. Impact Assessment of Zero Budget Natural Farming in Andhra Pradesh – Kharif 2018-19. Hyderabad: Centre for Economic and Social Studies.

Image: Dr Chhavi Sirohi, AICRP on AF, CCSHAU, Hisar



AGROFORESTRY

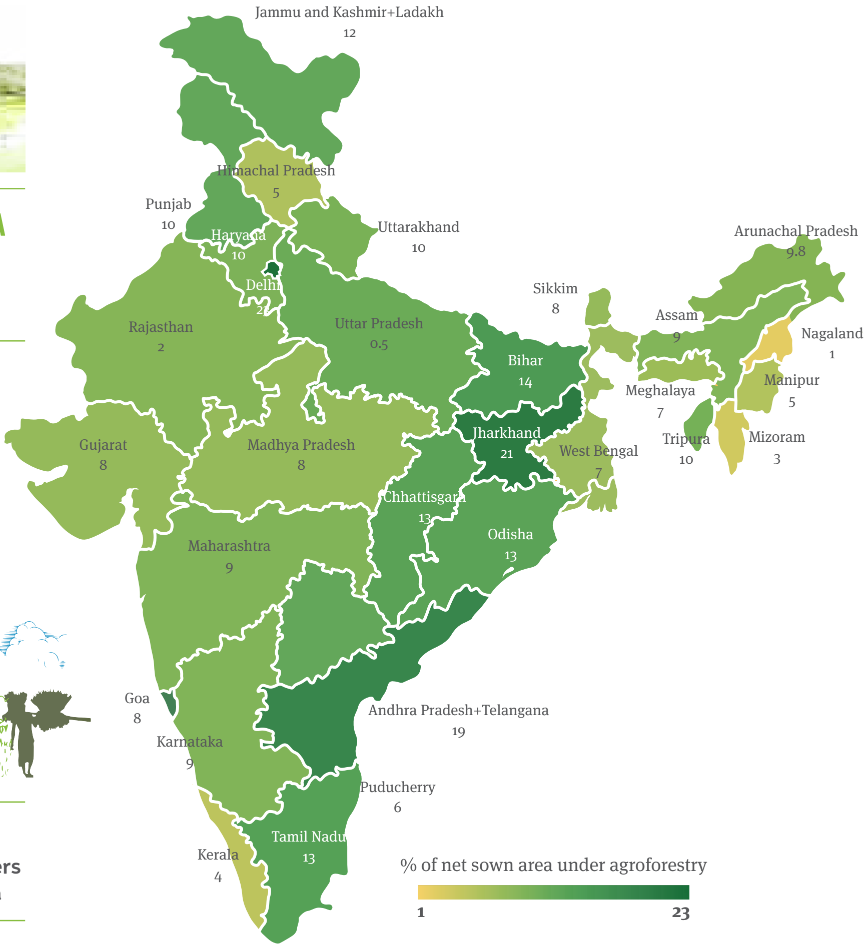
Agroforestry describes traditional and modern land-use systems where woody perennials (trees, shrubs, bamboos, palms) are integrated on purpose on the same land as crops and/or animals in various spatial or temporal arrangements. It is defined as the practice and science of the interactions between agriculture and forestry that involve farmers, trees (woody perennials), forests, and livestock at multiple scales.[10]

25 MILLION HA AREA

is under agroforestry across 15 agroclimatic zones[11]

<5 MILLION FARMERS

practise agroforestry across India[12]



LARGE FARMERS

are the primary adopters of agroforestry in India

POPLAR, EUCALYPTUS, MELIA, AND CASUARINA

are the popular trees integrated under agroforestry[13]

Source: Newaj et al. 2017

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS


Synergies


Efficiency


Recycling


Resilience


Human and social values


Diversity

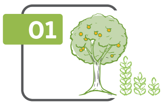

Co-creation and sharing of knowledge


Culture and food traditions

Green: furthered by agroforestry

10. R.H. Rizvi, A.K. Handa, K.B. Sridhar, Anil Kumar, S. Bhaskar, S. K. Chaudhari, A. Arunachalam, Noyal Thomas, S. Ashutosh, R. K. Sapra, Girish Pujar, Raj Kumar Singh, Sunil Londhe, Devashree Nayak, Atul Dogra, Rajendra Choudhary, S.K. Dhyani, Javed Rizvi, Tor-Gunnar Vagen, M. Ahmad, R. Prabhu, and Gaurav Dongre. 2020. *Mapping Agroforestry and Trees Outside Forest*. Jointly published by the ICAR, Central Agroforestry Research Institute (CAFRI), Jhansi and World Agroforestry (ICRAF), South Asia Regional Programme, New Delhi.
11. Indian Council of Agricultural Research - Central Agroforestry Research Institute.
12. No of adopters (farmers) are deduced from the area under agroforestry divided by the average landholding size for the kind of farmers majorly undertaking the practice.
13. Indian Council of Agricultural Research - Central Agroforestry Research Institute.

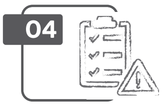
KEY INSIGHTS & RECOMMENDATIONS



Impact research indicates higher yield in fruits, timber, and crops under 20 different agroforestry models. In some cases, agroforestry can yield less output per hectare than field crops, especially in the short term.

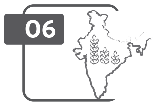
Additional income from the diversified livelihood sources (timber, fuelwood, and fodder) makes the practice lucrative for farmers.[15]

Lack of capital for the initial investment is the top constraint for small and marginal farmers. Integrating intercrops with trees can fetch immediate returns in the first two years.[16]



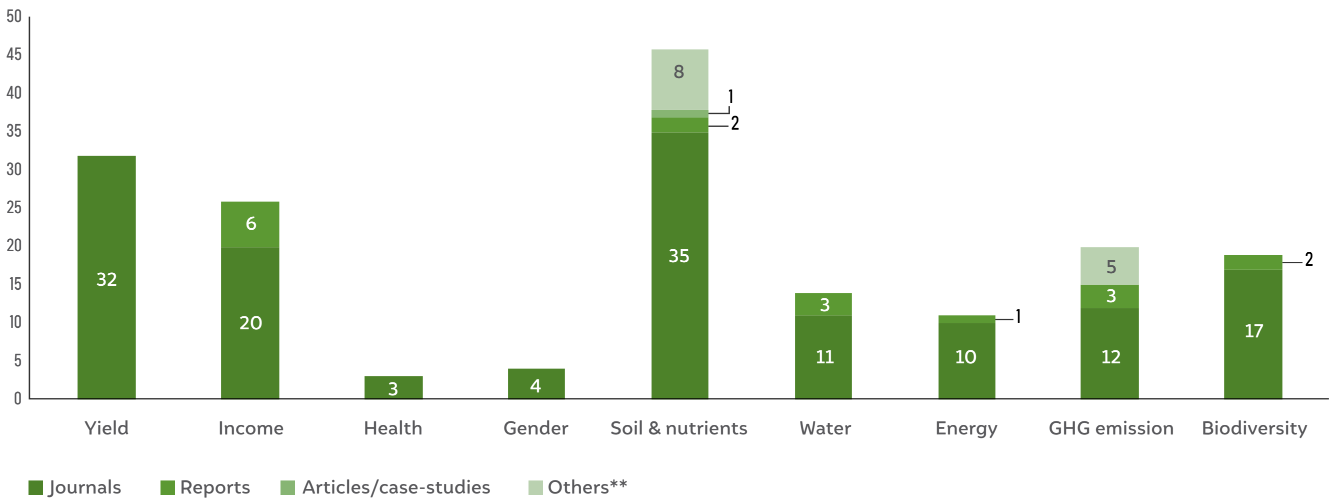
Agroforestry offers potential to sequester carbon in the soil when trees are sustained. Creating additional incentives in the form of carbon credits can support the scale-up.

Agroforestry creates a green corridor enabling sensitive species to move between different habitats.



In 2014, India became the first country to adopt a national agroforestry policy.

AVAILABLE RESEARCH ON THE IMPACT OF AGROFORESTRY



Source: Authors' compilation

*** Thesis, guidelines, conference papers, etc.*

Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN AGROFORESTRY

Government Institutions: Indian Institute of Forest Management, Bhopal.

Research Institutions: 37 All India Coordinated Research Project (AICRP) on agroforestry, 26 in State Agricultural Universities, 10 in ICAR and 1 in Indian Council of Forestry Research and Education (ICFRE); Forest Research Institute (FRI, Dehradun); World Agroforestry Centre (ICRAF); BAIF Development Research Foundation.

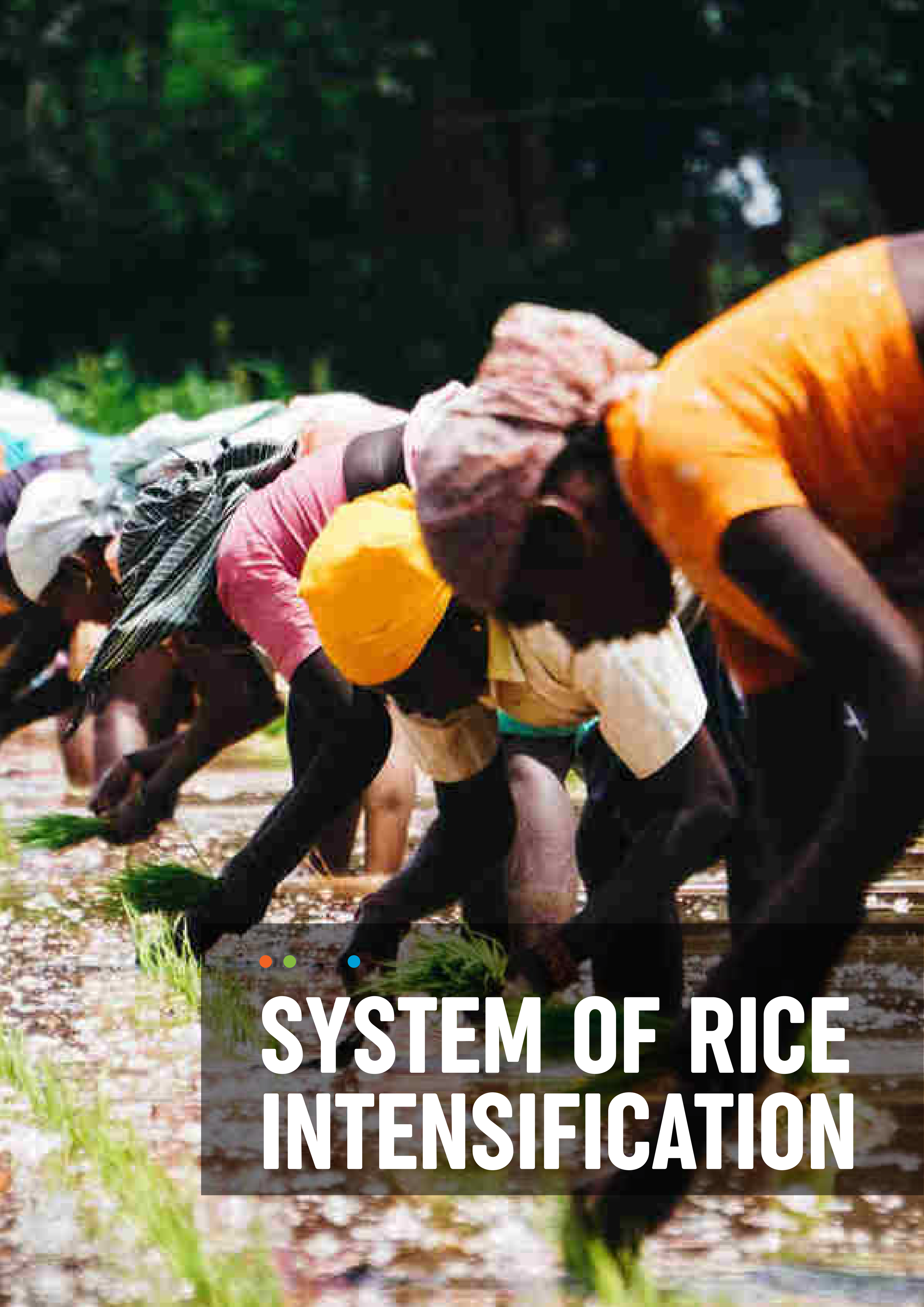
NGOs/CSOs: CARITAS INDIA; Indo-Global Social Service Society; PRADAN; Foundation for Ecological Security; Yuva Rural Association; SPWD; Self-Reliant Initiatives Through Joint Action (SRIJAN); Vaagdhara; Center for Agriculture and Rural Development (CARD); Grama Bharathi; CORD; Sequoia BioSciences Pvt Ltd; NIRMAN; Bundelkhand Sewa Sansthan.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on agroforestry here: https://www.ceew.in/sites/default/files/agroforestry.pdf

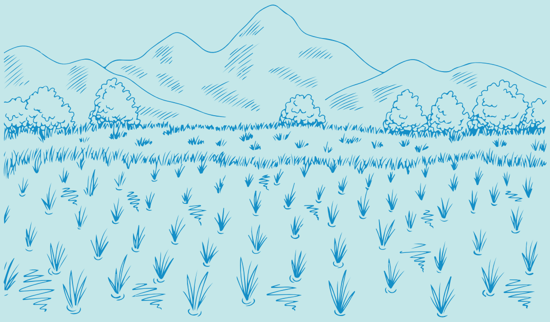
14. Handa, A K, S K Dhyani, and Uma. 2015. "Three Decades of Agroforestry Research in India: Retrospection for Way Forward." *Agricultural Research Journal* 52 (3): 1. doi:10.5958/2395-146x.2015.00028.9.
15. Handa A.K, Toky O.P, and Dhyani S.K, et al. 2016. "Innovative agroforestry for livelihood security in India". *World Agric* 7–16.
16. Srinivas, K. n,d. "Eucalyptus Based Agro Forestry Systems for Improving the Productivity of Arable Lands." Accessed March 12. https://krishi.icar.gov.in/jspui/bitstream/123456789/32963/1/KS3.pdf.
17. Dhyani S.K, Ram Asha, and Dev Inder. 2016. "Potential of agroforestry systems in carbon sequestration in India". Indian J Agric Sci 86:1103–1112.

Image: Unsplash



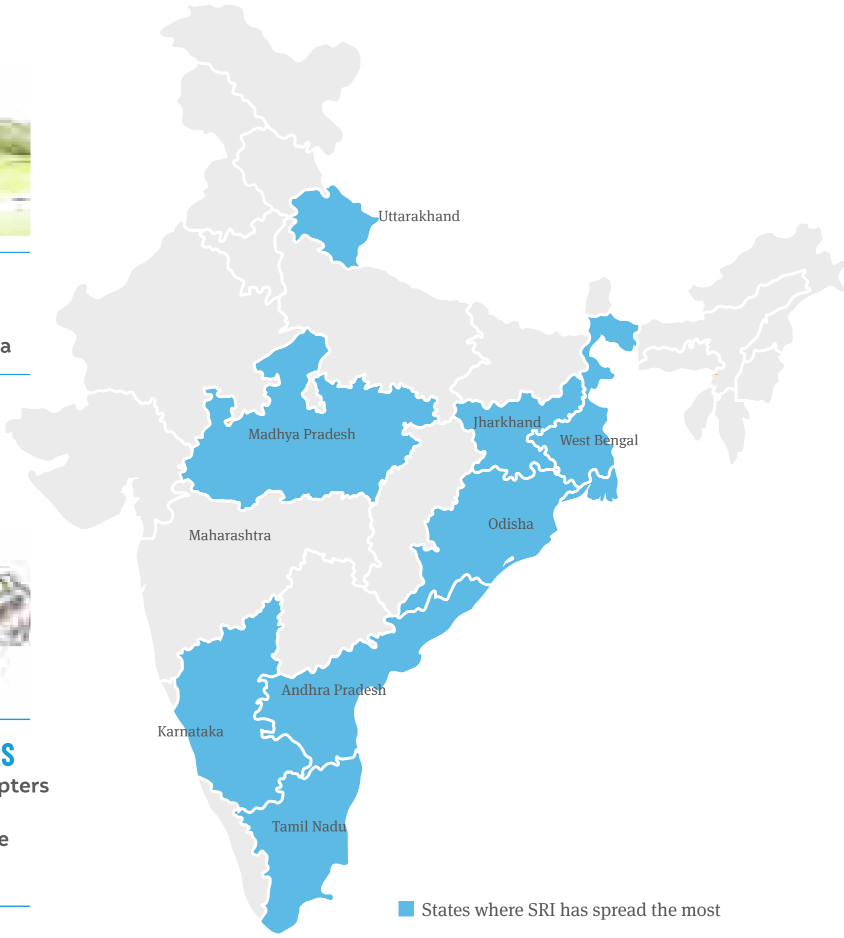
SYSTEM OF RICE INTENSIFICATION

The **system of rice intensification**, or SRI, is a climate-smart agroecological approach for increasing rice and other crops' productivity by changing the management of the plant, soil, water, and nutrients. SRI is based on four main principles that interact with each other: (i) early, quick, and healthy plant establishment; (ii) reduced plant density; (iii) improved soil conditions through enhancing soil organic matter; (iv) reduced and controlled water application.



3 MILLION ha
area under SRI across different states in India

>3 MILLION FARMERS
are estimated SRI adopters in India. However, no official data is available



BEYOND RICE,
the SRI principles are also being applied to wheat, sugarcane, and pulses

SMALL AND MEDIUM LANDHOLDERS
are the main adopters for SRI

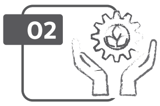
Source: SRI India Website

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Blue: furthered by SRI
Grey: no evidence of being furthered by SRI

KEY INSIGHTS & RECOMMENDATIONS

Increased rice yields, between 20-50 per cent[18], visible through larger root systems, more tillers, and longer panicles. Additional saving for farmers through significantly reduced seed cost.[19]

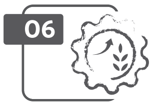


Being a knowledge-intensive practice, availability of skilled labour is a constraint to adoption. Focus on skilling and mechanisation for land levelling and transplanting.[20]

Smaller nurseries under SRI reduces the workload and drudgery for women farmers. Further focus needed on innovations for weeding implements to reduce drudgery.

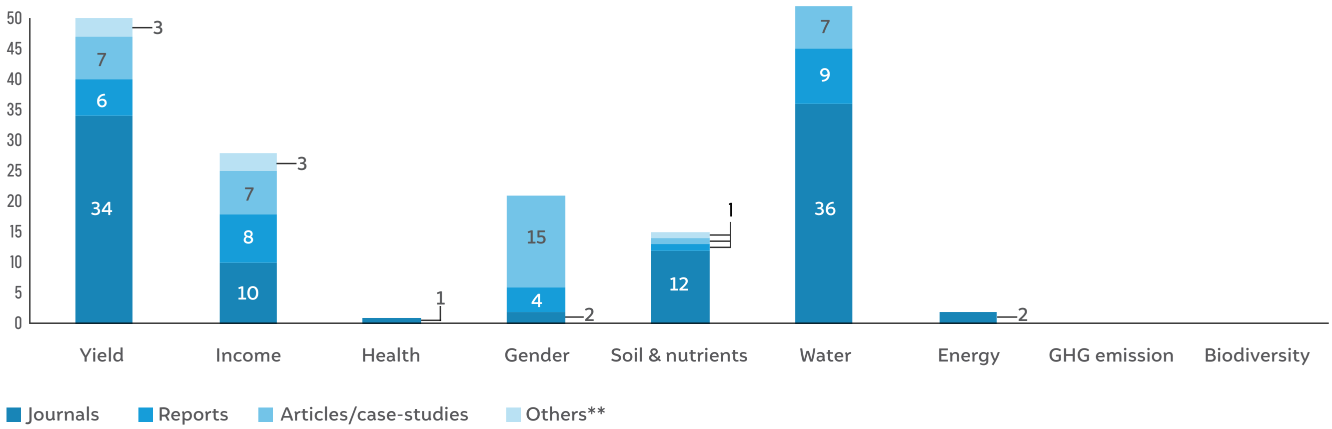
SRI grains are less prone to breakage during milling, improving the net edible output by about 10%.[21] Support focused assessments and documentation to account for this additional food production in the total yields.

Efficient water control, both for irrigated and rainfed conditions, is frequently mentioned as an SRI challenge in India.[22]



National Food Security Mission (NFSM) considers SRI a necessary means to boost national rice production in 133 food-insecure districts. Existing schemes like MGNREGS[23] by generating additional wage-days can facilitate transition of small farmers to SRI.[24]

AVAILABLE RESEARCH ON THE IMPACT OF SRI



Source: Authors' compilation
*** Thesis, guidelines, conference papers, etc.*
Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN SRI

Government Institutions: Indian Institute of Rice Research (IIRR) - Hyderabad; KrishiVigyan Kendra centres across India; National Bank for Agriculture and Rural Development (NABARD); Indian Council of Agricultural Research (ICAR); JAI SRI- AP (Joint Action Initiative on SRI - Andhra Pradesh).

Research Institutions: SRI, an ICRISAT-WWF initiative; ICRISAT - Patancheru; Tamil Nadu Agricultural University; M.S. Swaminathan Research Foundation.

NGOs/CSOs: Watershed Support Services and Activities Network (WASSAN); AME Foundation; Voice Trust; PRADAN; EKOVENTURE; Timbaktu Collective; Living farms; People's Science Institute; People First FOundation; SRIJAN; PRADAN; Nirmal social development trust; Unnati.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on system of rice intensification here: https://www.ceew.in/sites/default/files/system-of-rice-intensification.pdf

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18. Thakur, A.K., N. Uphoff, and W.A. Stoop. 2016. "Scientific underpinnings of the system of rice intensification (SRI): What is known so far?." Adv. Agron. 135:147–179. doi:10.1016/bs.agron.2015.09.004.
19. 5-8 kgs per hectare under SRI vs. 40-50 kgs per hectare under conventional rice-growing.
20. Thakur, A.K., and N. Uphoff. 2017. "How the system of rice intensification can contribute to climate-smart agriculture." Agron. J. 109:1–20 (2017) doi:10.2134/aronj2016.03.0162.
21. Ibid.
22. United Nations Environment Programme (UNEP), 2012. Avoiding Future Famines: Strengthening the Ecological Foundation of Food Security through Sustainable Food Systems. United Nations Environment Programme (UNEP), Nairobi, Kenya.
23. The Mahatma Gandhi National. Rural Employment Guarantee Act 2005 Ministry of Rural Development, Government of India.
24. PRADAN. 2013. Policy Consultation on System of Rice Intensification: Learnings and Strategies. NewsReach March–April 2013.

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

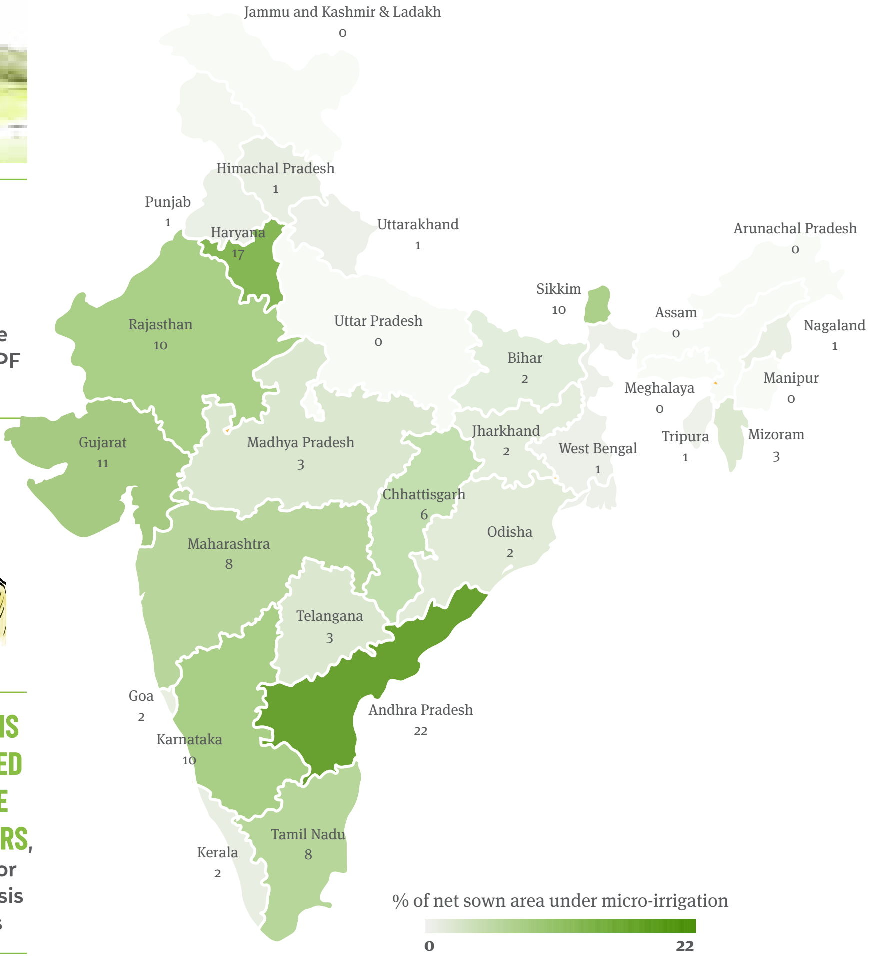
PRECISION FARMING

Precision farming (PF) is an approach to farm management that uses information technology to ensure that the crops and soil receive exactly what they need for optimum health and productivity.[25] Rather than applying similar inputs across the entire field, the approach aims to manage and distribute them on a site-specific basis to maximise long-term benefits and prevent waste.[26]

9.2 MILLION ha

has been covered under precise micro-irrigation techniques - drip and sprinkler, the two most widespread PF techniques in India[27]

PRECISION FARMING IS CURRENTLY PRACTISED BY MEDIUM TO LARGE PROGRESSIVE FARMERS, often on a single field or on an experimental basis or in commercial farms



3 MILLION FARMERS are estimated to have adopted PF techniques[28]

HIGH-VALUE COMMERCIAL AND HORTICULTURAL CROPS (fruit, vegetables, spices, flowers, medicinal and aromatic) are popular under PF

Source: Ministry of Agriculture & Farmers Welfare 2017

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Synergies | Efficiency | Recycling | Resilience | Human and social values | Diversity | Co-creation and sharing of knowledge | Culture and food traditions

Green: furthered by precision farming
Grey: no evidence of being furthered by precision farming

25. Mokariya L.K, and Malam K.V. 2020. "Precision Agriculture – A New Smart Way of Farming." *Agriculture and environment*, October.
26. Mandal S.K, and Maity A. 2013. "Precision farming for small agricultural farm: Indian scenario". *American Journal of Experimental Agriculture* 3(1):200–217.
27. DAC&FW. 2017. "Pocket Book of Agricultural Statistics 2017." New Delhi. https://eands.dacnet.nic.in/PDF/Agricultural_Statistics_2017.pdf.
28. No of adopters (farmers) are deduced from the area under that SAP divided by the average landholding size for the kind of farmers majorly undertaking that SAP.

KEY INSIGHTS & RECOMMENDATIONS

01 Beyond micro-irrigation, automated irrigation systems, laser land levellers (LLL), and customised leaf-coloured charts (CLCC) are other technologies gaining traction in India.

02 India's largest PF initiative indicates an increased yield,[29] particularly for horticultural crops.[30] Promote PF in high-value crops for commercial uses to have viable returns.

03 Adoption is slower in the rainfed areas due to resource constraints, apprehension of reduced yields, and hi-tech averseness. Support Custom Hiring Centres (CHCs) and awareness generation in rainfed areas to improve adoption.

04 CLCC is a widely used low-cost PF technology with an average cost of INR 110 (USD 1.50).[31] Research efforts and incentives to drive innovation towards cost-effective PF technologies are imperative for wider adoption.

05 Women farmers hesitate in approaching LLL service providers or hiring male contractors.[32] Support women-run CHCs and skill women to run LLLs.

06 Policy support is needed for technical assistance, and to develop pilots and models at the farm level, which can be replicated on a large scale.[33]

AVAILABLE RESEARCH ON THE IMPACT OF PRECISION FARMING

Source: Authors' compilation
*** Thesis, guidelines, conference papers, etc.*
Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN PRECISION FARMING

Government Institutions: National Committee on Plasticulture Applications in Horticulture (NCPAH); National Bank for Agriculture and Rural Development (NABARD); Central Institute of Agriculture Engineering (CIAE).

Research Institutions: Precision Farming Development Centres; ICAR-National Rice Research Institute; MS Swaminathan Research Foundation; Dryland Agriculture Project, University of Agriculture (UAS), Bangalore; National Institute of Technology; Navsari University, Gujarat; Indian Space Research Organisation (ISRO), Ahmedabad; National Institute of Technology.

NGOs/CSOs: Precision Agriculture for Development (PAD); Smallholder Adaptive Farming and Biodiversity Network (SAFBIN); Kalpavriksh, Environment Action Group; Indo-Global Social Service Society; ANANDI; Utthan; Grama Bharathi; AFARM Pune; Sai happy farms private ltd.; Samuhik Vikas Sansthan; reach52; Nature Environment and Wildlife Society.

Note – The stakeholders list is indicative and not exhaustive.

Read more details precision farming here: https://www.ceew.in/sites/default/files/precision-farming.pdf

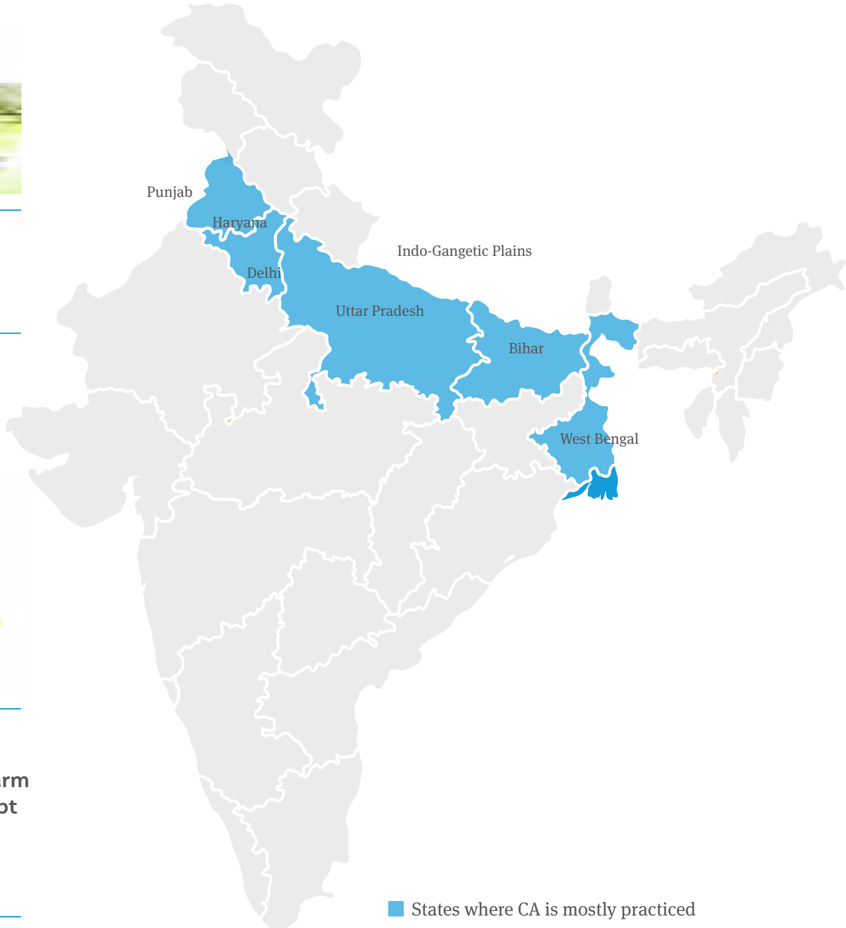
29. Averaged from 30 per cent to 200 per cent for different crops.
30. Ravikumar R, and Gopu J.A . 2016. "An overview of the implementation of precision farming projects in Tamil Nadu, India". *MPRA Paper* 73674, University Library of Munich, Germany.
31. Nayak, A. K., Sangita Mohanty, R. Raja, Mohammad Shahid, B. Lal, Rahul Tripathi, P. Bhattacharyya, et al. 2017. "Customized Leaf Colour Chart (CLCC): A Paradigm Shift in Real Time Nitrogen (N) Management in Lowland Rice."
32. Aryal, Jeetendra Prakash, Meera Bhatia Mehrotra, M. L. Jat, and Harminder Singh Sidhu. 2015. "Impacts of Laser Land Leveling in Rice–Wheat Systems of the North–Western Indo-Gangetic Plains of India." Food Security 7 (3): 725–38. doi:10.1007/s12571-015-0460-y.
33. Mungarwal, A.K.,SK Mehta.2019. Why farmers today need to take up precision farming.DowntoEarth. Available at <https://www.downtoearth.org.in/blog/agriculture/why-farmers-today-need-to-take-up-precision-farming-64659>

Image: CEEW

CONSERVATION AGRICULTURE

Conservation agriculture (CA) is an ecosystem approach to agricultural land management based on three interlinked principles: (i) minimum disturbance to soil through no-tillage or reduced tillage (maximum 25 per cent of the soil is disturbed); (ii) Permanent maintenance of soil mulch by retaining crop residues or cover crops on the field (minimum 30 per cent retention); (iii) Diversification of cropping systems through crop rotation and intercropping.[34]

~ 2 MILLION ha
is estimated under partial CA in India[35]



~ 1 MILLION FARMERS
are estimated to practise CA in India[37]

LARGE FARMERS
with better access to farm machinery tend to adopt (partial) CA more than the small and medium farmers[38]

RICE, WHEAT, SUGARCANE, AND MAIZE-BASED cropping systems are the popular crops under CA in India.

Source: Authors' compilation from the literature reviews and stakeholders' consultation

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Blue: furthered by conservation agriculture
Grey: no evidence of being furthered by conservation agriculture

34. Richards M, Sapkota T, and Stirling C et al. 2014. "Practice Brief - Climate Smart Agriculture". Food and Agriculture Organization of the United Nations, Rome. Available at http://www.fao.org/3/a-i4066e.pdf.
35. Stakeholders consultation.
36. A concept which considered the new methodology for area calculation devised by the CA proponents/experts where at least one crop has no-till, with or without residue retention).
37. No of adopters (farmers) are deduced from the area under CA divided by the average landholding size for the kind of farmers majorly undertaking CA.
38. Literature review and Stakeholder consultations.

KEY INSIGHTS & RECOMMENDATIONS

01 Only partial CA is prevalent in India. Farmers adopt mostly one or two of the three CA principles due to resource constraints or location-specific barriers.

02 Lower yields in the initial 1-2 years[39] after the transition due to 'nutrient or nitrogen immobility.'

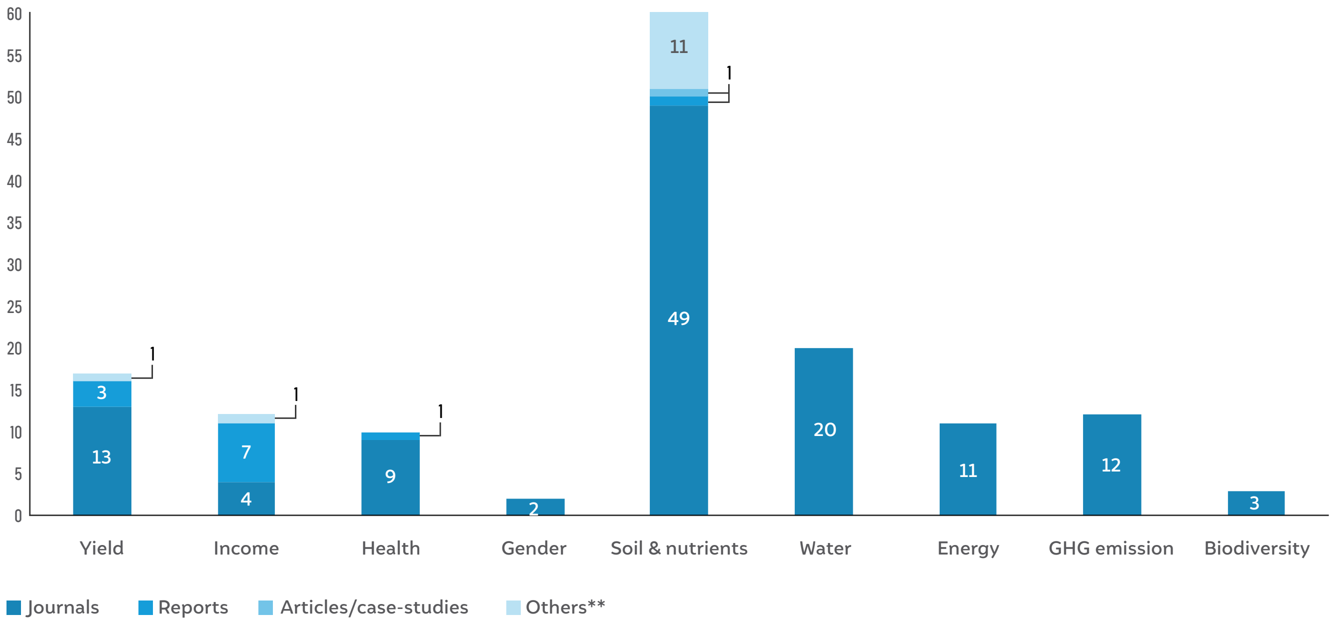
03 Difficult to evaluate overall impact of CA as only partial CA is prevalent in India.

04 Limited access to agricultural implements for residue management is a primary barrier to CA's adoption. Policy should support affordable access to implements through rental models to spur adoption.

05 Literature is limited to cereals-growing cropping systems of the Indo-Gangetic plains. Support CA impact studies in other agro-climatic regions and crops.

06 No specific policy support for conservation agriculture in India. *Sub Mission on Agricultural Mechanization* (SMAM) provides financial assistance for procurement of resource conservation equipment.

AVAILABLE RESEARCH ON THE IMPACT OF CONSERVATION AGRICULTURE



Source: Authors' compilation.
*** Thesis, guidelines, conference papers, etc.*
Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN CONSERVATION AGRICULTURE

Government Institutions: Department of Agriculture, Cooperation & Farmers Welfare (DAC&FW); ICAR - Indian Institute of Rice Research; ICAR - Directorate of Wheat Research, Karnal; ICAR - Central Research Institute for Dryland Agriculture; ICAR- Indian Institute of Soil Science.

Research Institutions: International Maize and Wheat Improvement Centre (CIMMYT); Borlaug Institute for South Asia (BISA); International Rice Research Institute - India; International Food Policy Research Institute (IFPRI); International Crops Research Institute for the Semi-arid Tropics (ICRISAT); Punjab Agricultural University (PAU).

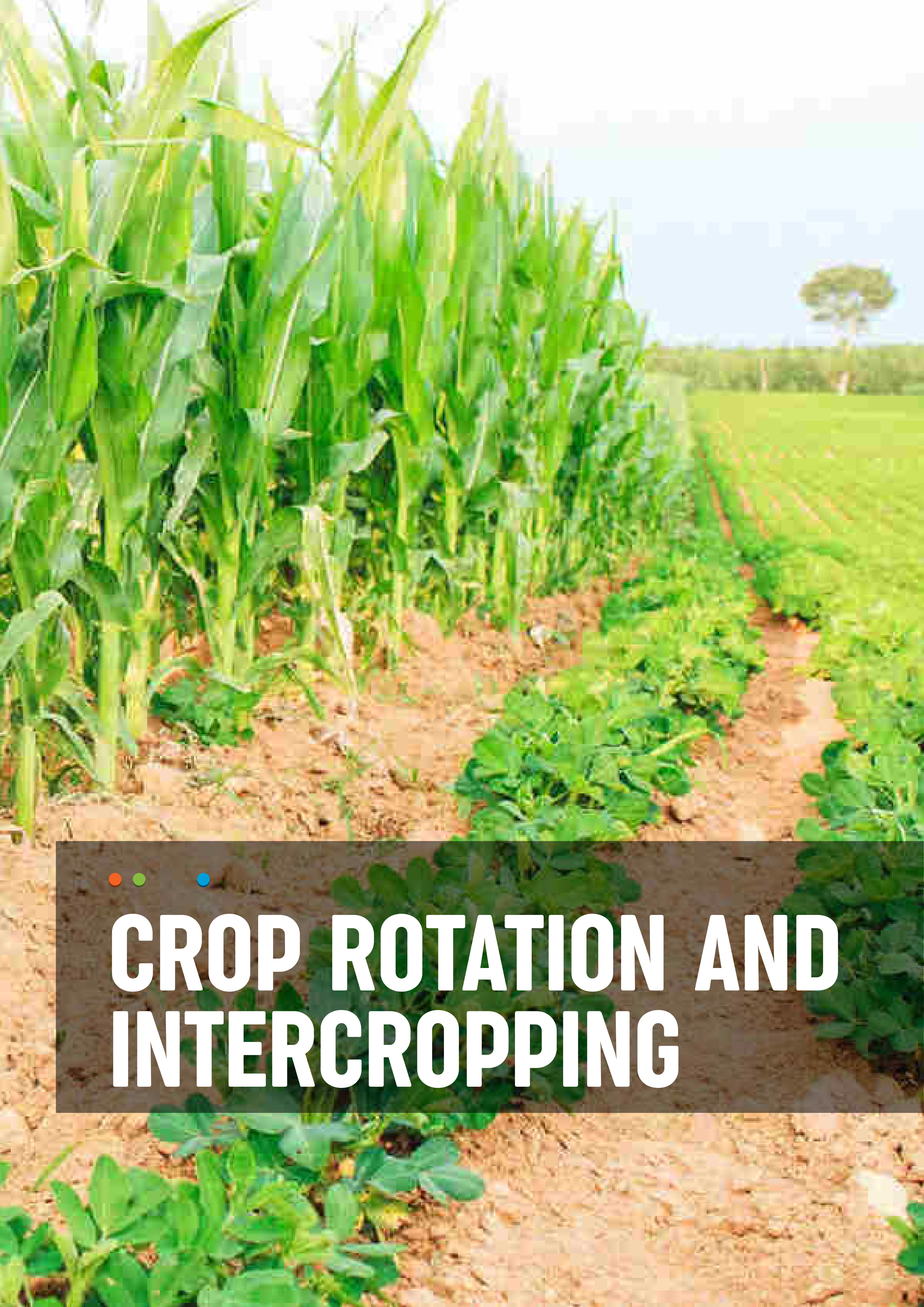
NGOs/CSOs: Centre for World Solidarity (CWS); Gram Disha Trust; Foundation for Ecological Security; SRIJAN; Nature Institute for Welfare of Society; ELA Agri Solutions; Kalpavriksh; Rural Technology and Development Centre (RTDC); Gram Vikas; Nuhaar Foundation.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on conservation agriculture here: https://www.ceew.in/sites/default/files/conservation-agriculture.pdf

39. Stakeholders consultation.

Image: iStock

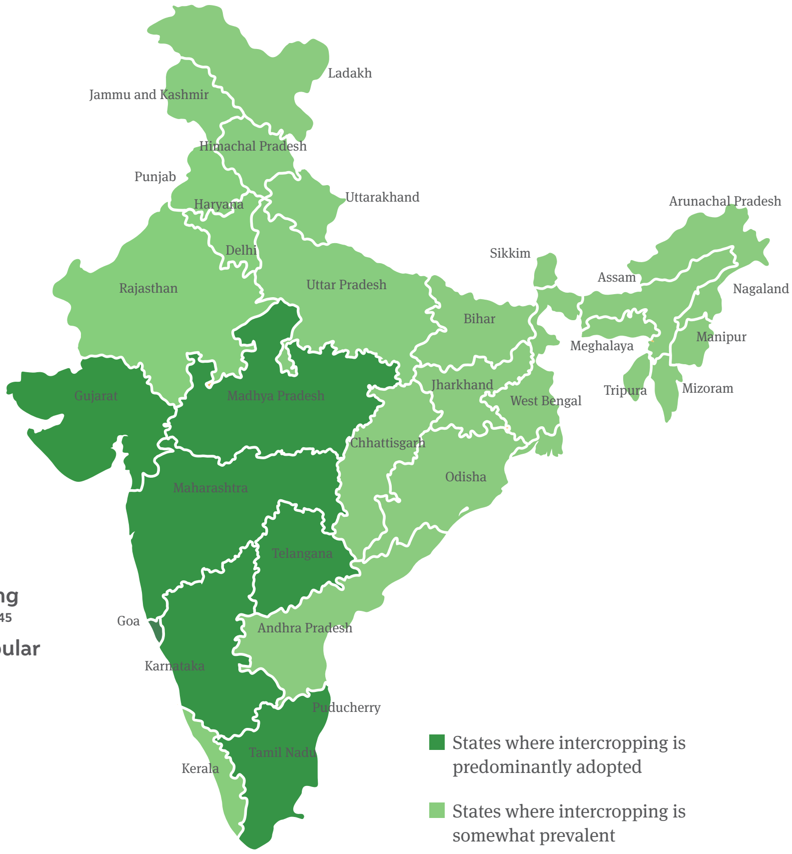


CROP ROTATION AND INTERCROPPING

Crop rotation is the practice of planting two or more crops sequentially on the same plot of land to improve soil health, optimise nutrients, and combat pest and weed pressure. Simple rotation may involve two or three crops, while a complex rotation may incorporate a dozen or more.[40] **Intercropping** is the growing of two or more crops simultaneously in the same field and can be of various types viz. mixed, row, strip, and relay intercropping.[41]

30 MILLION ha
area under crop rotation
~1 MILLION ha[42]
is under intercropping[43]

CROP ROTATION IS EQUALLY POPULAR among different size landholders[45]
intercropping is more popular among small farmers[46]



~15 MILLION
farmers practise crop rotation
~0.8 MILLION
farmers practise intercropping[44]

INTERCROPPING IS MOSTLY SUITABLE
for wide-spaced crops like maize, cotton, and sugarcane[48] and even horticultural crops are manageable for intercropping or interspaced planting[49]

CEREAL-CEREAL CROP ROTATION
such as rice-legume, rice-wheat, and maize-wheat are more common[47]

Source: Authors' compilation from literature reviews and stakeholder consultations

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Synergies | Efficiency | Recycling | Resilience | Human and social values | Diversity | Co-creation and sharing of knowledge | Culture and food traditions

Green: furthered by crop rotation and intercropping

40. Rodale Institute. 2020. Crop Rotations. Rodale Institute, Kutztown, PA. https://rodaleinstitute.org/why-organic/organic-farming-practices/crop-rotations/. Accessed 17 Oct 2020.
41. Das, A. Layek, J. Subhash Babu, R. Krishnappa, M. Thoithoi Devi, Amit Kumar, D.P. Patel, Ramkrushna G.I., G.S. Yadav, K. Sarika, A.K. Tripathi, P.K. Ghosh, and N. Prakash. 2019. Intercropping for Climate Resilient Agriculture in NEH Region of India. Technical bulletin No 1 (Online). ICAR Research Complex for NEH Region, Umiam – 793 103, Meghalaya.
42. Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (Modipuram).
43. Excludes intercropping in horticultural crops.
44. Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (Modipuram).
45. Indian Council of Agricultural Research - National Rice Research Institute.
46. Das A, and Ghosh P.K. 2012. "Role of legumes in sustainable agriculture and food security: An Indian perspective". Outlook Agric 41:279–284. doi: 10.5367/oa.2012.0109
47. Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (Modipuram).
48. Indian Council of Agricultural Research - National Rice Research Institute.
49. Murthy, Srinivas, Ashok Dalwai, Pawanexh Kohli, Raka Saxena, and Uday C Javali. 2017. "Report of the Committee for Doubling Farmers' Income Volume VIII 'Production Enhancement through Productivity Gains.'" New Delhi. https://farmer.gov.in/imagedefault/DFI/DFI Vol-8C.pdf.

KEY INSIGHTS & RECOMMENDATIONS

01 In India, rice-legumes crop rotation is predominant, for improving the soil health.[50]

02 Research needed to explore intercropping's impact on the ecosystem services beyond production. Systems-level understanding, climate-change mitigation, pest control, water and soil quality improvement, are less studied topics and deserve more attention.

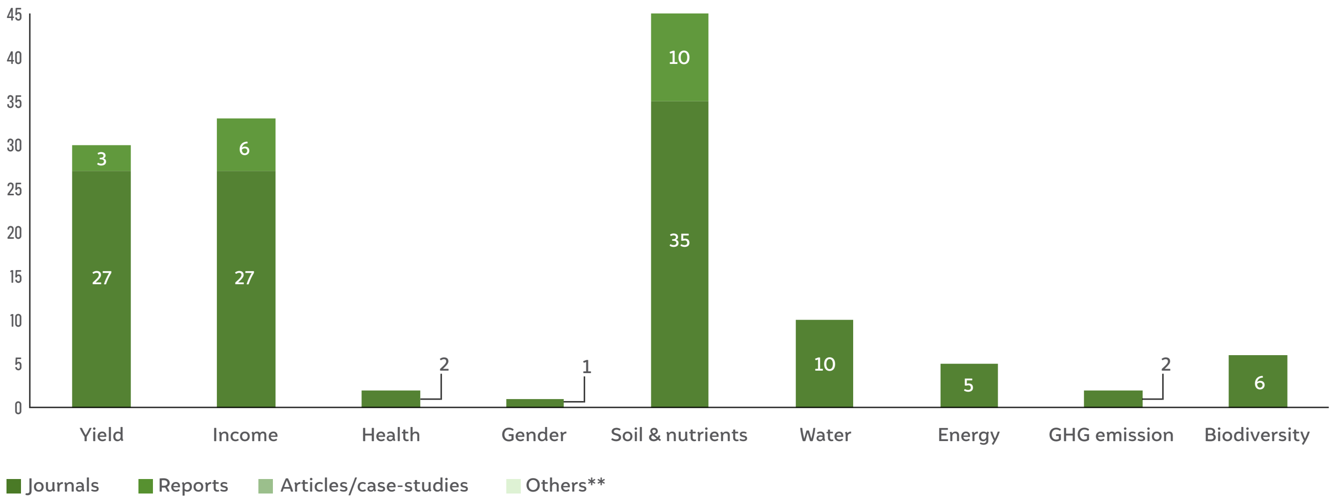
03 The 'legume effect'[52] is critical in both the practices for fixing atmospheric nitrogen. Also, the 'complementary intensive intercropping systems'[53] show potential in water-constraint conditions.

04 Intercropping is considered labour-intensive due to the additional manual labour for sowing and removing weeds.[54] Innovations in agricultural implements for weeding in intercropping will be imperative for its scale-up.

05 Intercropping legumes and vegetables contribute to improved diets and essential protein. Policy focus to end malnutrition should recognise the role of scaling-up intercropping.

06 ICAR has demonstrated intercropping in climate-vulnerable districts for livelihood security and resilience under the *National Innovations on Climate Resilient Agriculture (NICRA).*

AVAILABLE RESEARCH ON THE IMPACT OF CROP ROTATION AND INTERCROPPING



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KEY STAKEHOLDERS IN CROP ROTATION AND INTERCROPPING

Government Institutions: Department of Agriculture, Cooperation & Farmers Welfare (DAC&FW); ICAR - Indian Agricultural Research Institute; ICAR - National Rice Research Institute (NRRI); ICAR-Central Research Institute for Dryland Agriculture (CRIDA); ICAR - Indian Institute of Farming Systems Research (IIFSR), Modipuram; ICAR-Central Arid Zone Research Institute (CAZRI).

Research Institutions: Indian Head Agricultural Research Foundation; Punjab Agricultural University, Ludhiana; University of Agricultural Sciences, Bangalore.

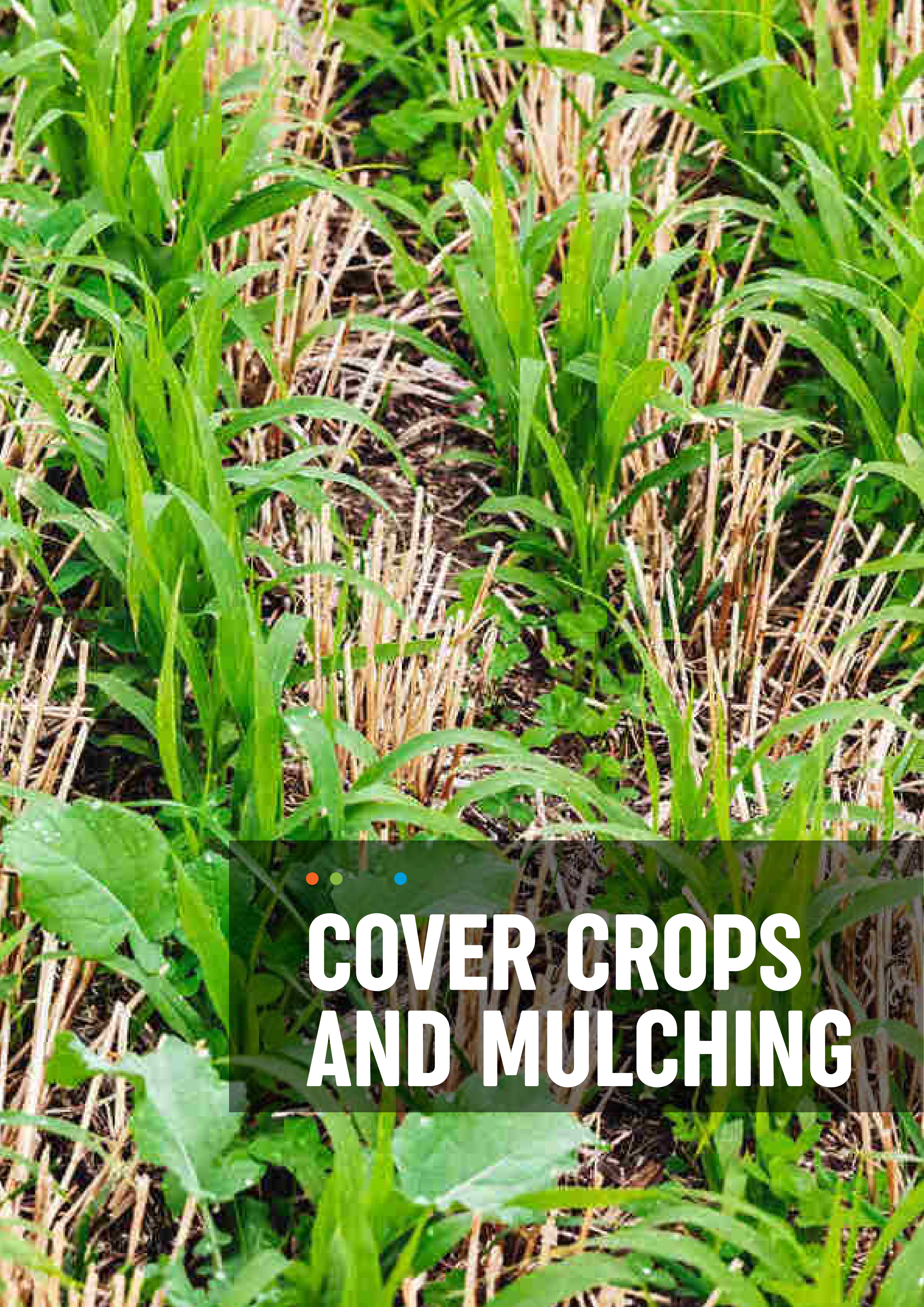
NGOs/CSOs: PRADAN; bioRe Association India; Natural Capital; Centre for Dignity; CARITAS INDIA; Living Farms; Manjari Foundation; BAIF Development Research Foundation; People's Science Institute; Lipok Social Foundation; Foundation For Ecological Security; Vaagdhara; CORD; Organic Foods Pvt Ltd; Ekta Nature Farming Producer Company Limited; Shunya; Indo-Global Social Service Society; SPWD.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on crop rotation and intercropping here: https://www.ceew.in/sites/default/files/crop-rotation-intercropping.pdf

50. Stakeholders consultation.
51. Sravan, Uppu Sai, and Koti Venkata Ramana Murthy. 2018. "Enhancing Productivity in Rice-Based Cropping Systems." In *Plant Competition in Cropping Systems*, 19. InTech. doi:10.5772/intechopen.76904.
52. Beneficial effect of legumes to impact the nitrogen production and fertility in soil.
53. Involves raising morphologically and physiologically different crops that complement each other.
54. Stakeholder consultation.

Image: Unsplash



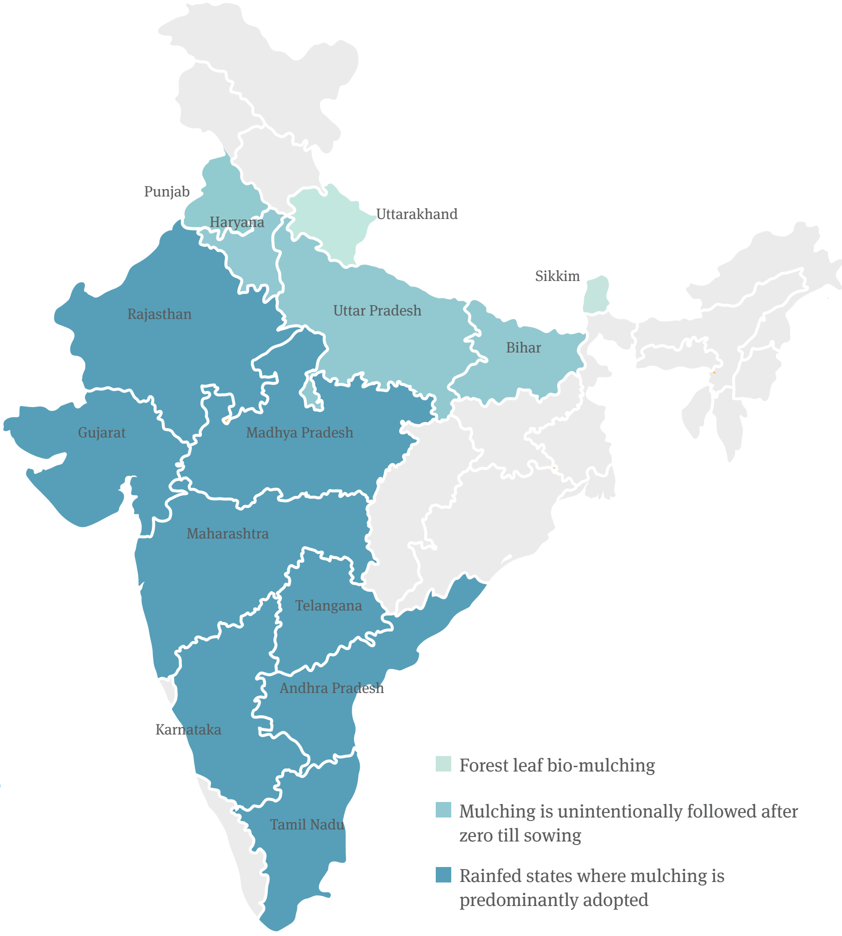
COVER CROPS AND MULCHING

Cover crops are crops planted to cover the soil rather than to be harvested. They can be rotated with other crops or intercropped and also grown in between cultivation seasons to control soil erosion, add organic matter to the soil, supplying nitrogen, controlling weeds, and fighting insects/pests.[55] **Mulching** is the practice of covering the soil surface with organic materials (plant residues, straw, hay, leaf and compost, peat, and animal manure), or synthetic materials (polyethylene, wax-coated papers, aluminium, steel foils, and asphalt spray emulsions). Mulching conserves soil moisture, avoids runoff and increases soil productivity.[56,57,63]

1.9 MILLION ha
under cover crops, which includes plantations having leguminous cover crops[58]

~20 MILLION ha
is estimated under mulching[59]

~1.5 MILLION FARMERS
practise cover crops
<5 MILLION
farmers have adopted mulching[60]



COWPEA, BERSEEM, MUSTARD, PULSES ARE
commonly grown leguminous cover crops[62]

COVER CROPS ARE EQUALLY POPULAR
among different size landholders; large landholding and innovative farmers tend to practise mulching[61]

Source: Authors compilation from stakeholder consultations and literature review

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Synergies | Efficiency | Recycling | Resilience | Human and social values | Diversity | Co-creation and sharing of knowledge | Culture and food traditions

Blue: furthered by cover crops and mulching
Grey: no evidence of being furthered by cover crops and mulching

55. Rana S.S, and M.C Rana. 2011. Cropping System. Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, 80 pages.
56. Stakeholders consultation.
57. Kamei D, Haribhushan A, and Singh Y.K. n.d. *Mulching in vegetable crops.* NICRA KVK-Sylvan, Senapati District. Manipur; Kannan R, Solaimalai A, Anandan P, and Raj T.S. 2020. "Uses of mulching in agriculture: a review". In: Lakhan DR (ed) *Current Research in Soil Fertility.* AkiNik Publications, Delhi, p 186.
58. Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (Modipuram).
59. Ibid.
60. Ibid.
61. Indian Council of agricultural research – National Rice research Institute.
62. Kaur H, Kaur K, Kang J.S, and Singh H. 2017. "Role of cover crops in improving intensively exploited soils in agriculture: A review". *The Pharma Innovation Journal* 2017; 6(12): 457-462.
63. Kamei D, Haribhushan A, and Singh Y.K. n.d. *Mulching in vegetable crops.* NICRA KVK-Sylvan, Senapati District. Manipur; Kannan R, Solaimalai A, Anandan P, and Raj T.S. 2020. "Uses of mulching in agriculture: a review". In: Lakhan DR (ed) *Current Research in Soil Fertility.* AkiNik Publications, Delhi, p 186.

KEY INSIGHTS & RECOMMENDATIONS

01 Cover crops have the potential to reduce the input costs by reducing the need of inorganic fertilisers. Support resource-poor farmers to grow cover crops (like sesbania).[64]

02 Pulses are the most suitable cover crops[65] after the cultivation of nutrient exhausting cereal crops. States with extensive cereal cropping should promote pulses as cover crops to replenish the deteriorating soil health.

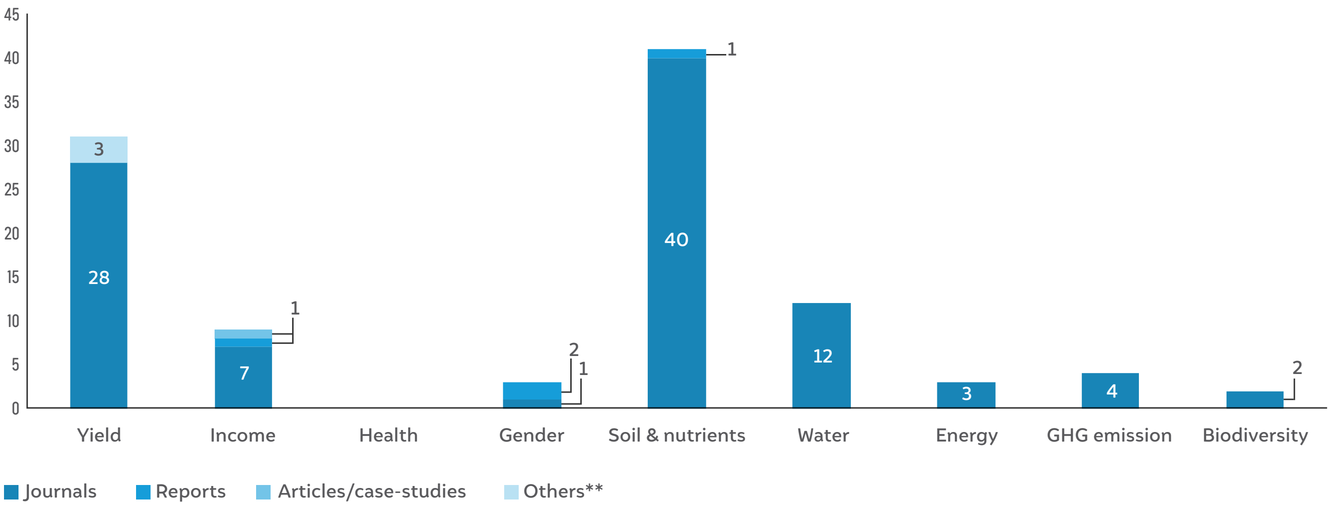
03 The use of plastic film as mulch is increasing due to its water conservation and weed suppression benefits. Appropriate re-use and recycling of polythene or polyvinyl based sheets must be addressed before we scale-up.

04 In India's rainfed areas, mulch-use has increased the yields by 50-60 per cent, depending on the crop.[66] States with high rainfed agriculture should promote mulching among farmers.

05 Both organic mulch and grass mulch reduce the mean maximum soil temperature and evapotranspiration. In the peak summer season, this helps protect the crops in the drought-prone and rainfed areas.

06 No specific policy on cover crops. The *National Mission for Sustainable Agriculture (NMSA)* provides 50 per cent cost assistance, limited to INR 4000/hectare (USD 55/hectare) for in-situ soil conservation bunding, and mulching purposes.

AVAILABLE RESEARCH ON THE IMPACT OF COVER CROPS AND MULCHING



Source: Authors' compilation.
*** Thesis, guidelines, conference papers, etc.*
Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN COVER CROPS AND MULCHING

Government Institutions: Department of Agriculture, Cooperation & Farmers Welfare (DAC&FW); ICAR-Indian Institute of Farming Systems Research (IIFSR), Modipuram; ICAR - ICAR-National Rice Research Institute (NRRI, CRRI); Department of Agriculture, Cooperation & Farmers Welfare (DAC&FW); ICAR-Central Research Institute for Dryland Agriculture (CRIDA); ICAR-Central Arid Zone Research Institute (CAZRI).

NGOs/CSOs: PRADAN; Living farms; BAIF Development Research Foundation; Centre For Dignity; PRADAN; Samaj Pragati Sahayog (SPS); Jamnalal Kaniram Bajaj Trust; Self-Reliant Initiatives Through Joint Action (SRIJAN); Samuhik Vikas Sansthan; Nature Institute for Welfare of Society; Center for Sustainability Policy and Technology Management; Jeevit Mati Kisan Samiti, Kedia.

Note – The stakeholders list is indicative and not exhaustive.

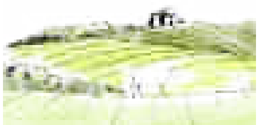
Read more details on cover crops and mulching here: https://www.ceew.in/sites/default/files/cover-crops-mulching.pdf

64.Rao, Srinivasrao, Ashok Kumar Indoria, and Sharma. K. L. 2017. "Effective Management Practices for Improving Soil Organic Matter for Increasing Crop Productivity in Rainfed Agroecology of India." Current Science 112 (7). doi:10.18520/cs/v112/i07/1497-1504.
65.Stakeholder consultation.
66.Shirish P.S, Tushar K.S, and Satish B.A. 2013. "Mulching: a soil and water conservation practice". Res J Agric For Sci 1:26–29.

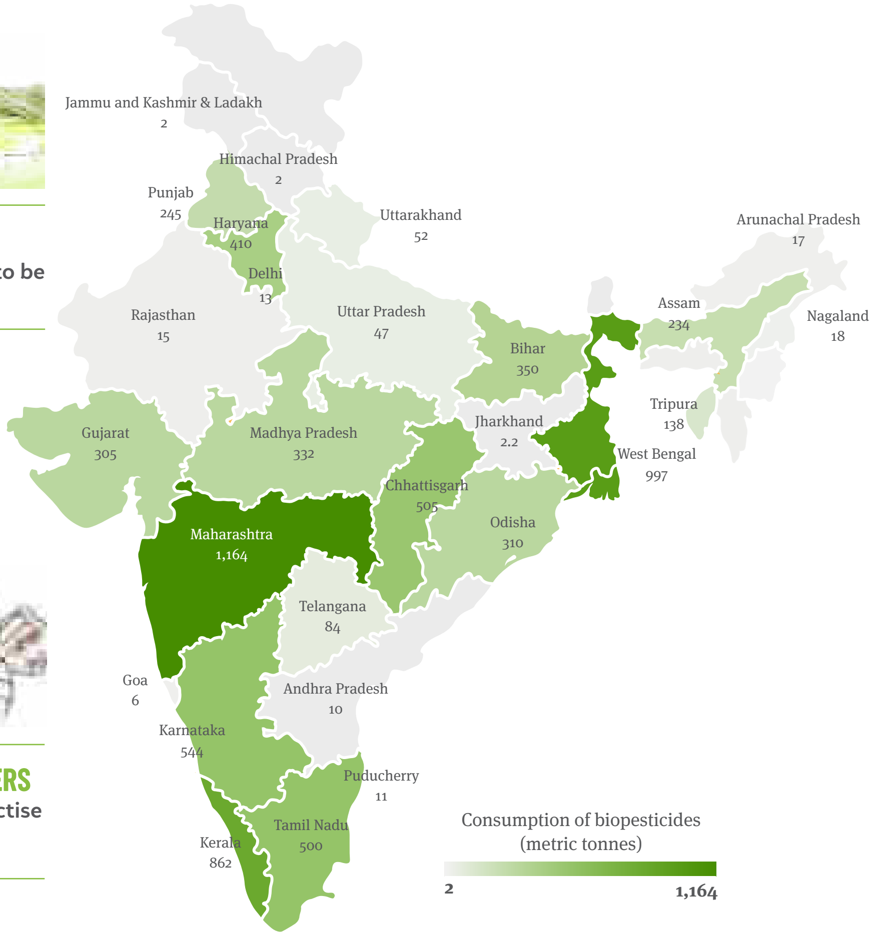
Image: iStock

INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM) system consists of using suitable techniques and methods in a compatible manner to maintain pest populations at levels below those causing economically unacceptable damage or loss.[67] It combines cultural, biological, and chemical measures to provide a cost-effective, environmentally-sound, and socially-acceptable method of controlling diseases, insects, weeds, etc.[68]



5 MILLION ha
of area is estimated to be under IPM in India[69]



ALL LANDHOLDING FARMERS
small, medium, and large practise IPM

~5 MILLION FARMERS
are estimated to practise IPM[70]

RICE, COTTON, PULSES, OILSEEDS, AND HORTICULTURE
crops are commonly cultivated under IPM

Source: Directorate of Plant Protection Quarantine & Storage 2020.

Note - Since biopesticides are one of the chief ingredients used in IPM, its consumption pattern is assumed as a reliable method to understand the relative adoption of IPM in the states.

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Synergies | Efficiency | Recycling | Resilience | Human and social values | Diversity | Co-creation and sharing of knowledge | Culture and food traditions

Green: furthered by Integrated pest management
Grey: no evidence of being furthered by Integrated pest management

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67. Prakash, A., Bentur, J. S., Prasad, M. S., Tanwar, R. K., Sharma, O. P., Bhagat, S., Sehgal, M., Singh, S. P.,Singh, M., Chattopadhyay, C., Sushil, S. N., Sinha, A. K., Asre, R., Kapoor, K. S., Satyagopal, K., and Jeyakumar, P. 2014. *Integrated Pest Management Package for Rice.* Director National Centre for Integrated Pest Management, New Delhi.

68. Directorate of Plant Protection Quarantine & Storage. 2019. *IPM at A Glance*, webpage. DPPQ&S, Ministry of Agriculture and Farmers' Welfare, Faridabad, http://ppqs.gov.in/divisions/integrated-pest-management/ipm-glance. Accessed 6 Jun 2020.

69. Indian Council of Agricultural Research - National Research Centre for Integrated Pest Management.

70. Rao G.V.R, and Rao V.R. 2010. *"Status of IPM in Indian agriculture: a need for better adoption".* Indian J Plant Prot 38:115–121. Directorate of Plant Protection Quarantine & Storage. 2019. "IPM at A Glance", webpage. DPPQ&S, Ministry of Agriculture and Farmers' Welfare, Faridabad, http://ppqs.gov.in/divisions/integrated-pest-management/ipm-glance. Accessed 6 Jun 2020.

KEY INSIGHTS & RECOMMENDATIONS

Evidence from a few States indicate the use of local organic solutions or sprays in IPM management along with various pheromone traps.[71] The availability of location-specific IPM modules will be needed to support large-scale adoption.[72]

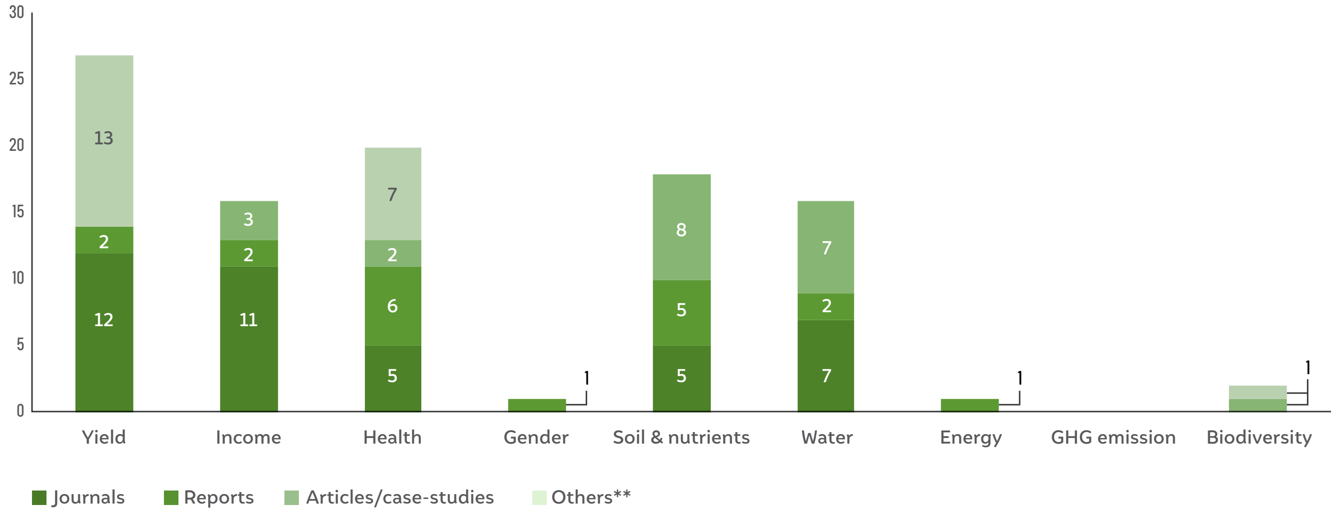
Chemical pesticides use had reduced by 50-100 per cent for rice and 30-50 per cent for cotton under IPM.[73] To scale-up adoption, support awareness generation among farmers about the windfall gains through reduced input costs and improved productivity.

IPM avoids chemical pesticides until the last resort, however its positive impacts on farmers' and consumers' health are not well-established. Support further research to plug the critical evidence gap.

Cost-effective and straightforward certification and labeling systems are needed to boost IPM adoption.[74]

National programmes *Rashtriya Krishi Vikas Yojana* and state programs support IPM *(CROPSAP, HortSAP, OPMAS, RePS)* through pest surveillance activities.

AVAILABLE RESEARCH ON THE IMPACT OF INTEGRATED PEST MANAGEMENT



Source: Authors' compilation.
*** Thesis, guidelines, conference papers, etc.*
Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN INTEGRATED PEST MANAGEMENT

Government Institutions: Directorate of Plant Protection Quarantine & Storage (DPPQ&S); National Institute of Plant Health Management (NIPHM); Indian Institute of Chemical Technology, Hyderabad.

Research Institutions: 35 Central Integrated Pest Management Centres (CIPMCs) established in 28 states and 2 Union Territories; ICAR-National Research Centre for Integrated Pest Management; Central Institute of Cotton Research, Nagpur; BAIF Development Research Foundation; M.S. Swaminathan Research Foundation; Marathwada Agricultural University, Parbhani; Anand Agricultural University, Anand.

NGOs/CSOs: PRADAN; Samaj Pragati Sahayog; Jamnalal Kaniram Bajaj Trust; Centre for World Solidarity (CWS), CARITAS India; Gram Disha Trust; People's Science Institute; Farm2Food Foundation; Ekta Nature Farming Producer Company Limited; Indo-Global Social Service Society; Equality empowerment foundation; BAIF Development Research Foundation.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on integrated pest management here: https://www.ceew.in/sites/default/files/integrated-pest-management.pdf

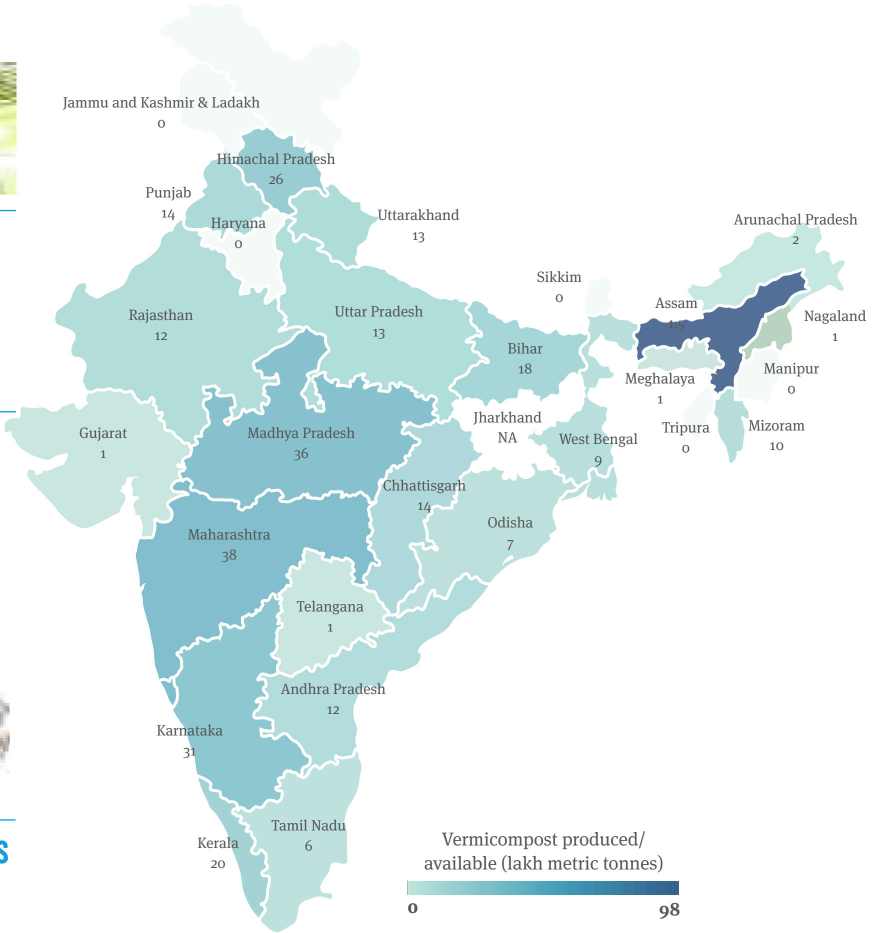
71. Stakeholders consultation.
72. Sehgal, Mukesh, Meenakshi Malik, R V Singh, A K Kanojia, and Avinash Singode. 2018. "Integrated Pest Management in Rice and Its Future Scope." *Int.J.Curr.Microbiol.App.Sci* 7 (6): 2504–11. doi:10.20546/ijcmas.2018.706.297.
73. Directorate of Plant Protection Quarantine & Storage. 2019. "IPM at A Glance", webpage. DPPQ&S, Ministry of Agriculture and Farmers' Welfare, Faridabad, http://ppqs.gov.in/divisions/integrated-pest-management/ipm-glance. Accessed 6 Jun 2020.
74. Sehgal, Mukesh, Meenakshi Malik, R V Singh, A K Kanojia, and Avinash Singode. 2018. "Integrated Pest Management in Rice and Its Future Scope." *Int.J.Curr.Microbiol.App.Sci* 7 (6): 2504–11.
75. Directorate of Plant Protection Quarantine & Storage. 2019. "IPM at A Glance", webpage. DPPQ&S, Ministry of Agriculture and Farmers' Welfare, Faridabad, http://ppqs.gov.in/divisions/integrated-pest-management/ipm-glance. Accessed 6 Jun 2020.

Image: Dr. Girish Chander, ICRISAT

VERMICOMPOSTING

Vermicomposting is a biotechnological composting process that uses certain earthworms to enhance the process of biomass waste conversion to produce good-quality compost. The resultant product is a stabilized, uniformly sized substance with a characteristic earthy appearance known as vermicast/vermicompost. Vermicomposting differs from composting as earthworms accelerate decomposition rates and is considered more superior in quality due to higher nutrient content.[76]

No reliable recent estimates, however, **3.5 MILLION ha** of estimated area covered in 19 states (as of 2010).[77]



More popular among **SMALL AND MARGINAL LAND HOLDING FARMERS**[79]

1.5 MILLION FARMERS are estimated to have adopted vermicomposting[78]

Practised in many crops, but is more **COST-EFFECTIVE IN HIGH VALUE HORTICULTURAL CROPS** (vegetables, fruits, ornamental crops, spices, medicinal).[80]

Source: National Centre of Organic Farming 2018[81]

Note: Data for Jharkhand is omitted due to its unreliability

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Synergies | Efficiency | Recycling | Resilience | Human and social values | Diversity | Co-creation and sharing of knowledge | Culture and food traditions

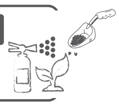
Blue: furthered by vermicomposting
Grey: no evidence of being furthered by vermicomposting

76. Vijayabharathi R, Arumugam S, and Gopalakrishnan S. 2015. "Plant growth-promoting microbes from herbal vermicompost". In: Egamberdieva D., Shrivastava S. VA (eds) Plant-Growth-Promoting Rhizobacteria (PGPR) and Medicinal Plants. Springer, Cham, Patancheru, pp 1–18.
77. National Centre of Organic Farming. 2010. Biofertilizers and Organic Fertilizers Statistics Year 2005-06 to 2009-10. NCOF. Department of Agriculture and Cooperation, Ministry of Agriculture, Govt of India Ghaziabad.
78. International Crops Research Institute for the Semi-Arid Tropics.
79. Stakeholders consultation.
80. Ibid.

KEY INSIGHTS & RECOMMENDATIONS

01 

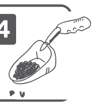
Vermicompost's impact on yield is sensitive to the quality, quantity of compost and the combinations in which it is applied. For instance, few crops gave higher yields when enriched vermicompost[82] was applied rather than standard vermicompost alone or in combination with chemical fertilisers.

02 

Integrating vermicompost with chemical fertilisers (Integrated Nutrient Management) increases the use efficiency of the latter by reducing both use and input cost of chemical fertilisers by 25%.[83]

03 

Additional income by vermicompost sales promotes rural entrepreneurship.[84] Rural skilling and entrepreneurship efforts should consider vermicompost among the vocational opportunities for the youth.

04 

Vermicomposting is labour intensive, constraining its adoption.[85] Training and establishing demonstration units will help in reducing the knowledge gap and promote the practice.

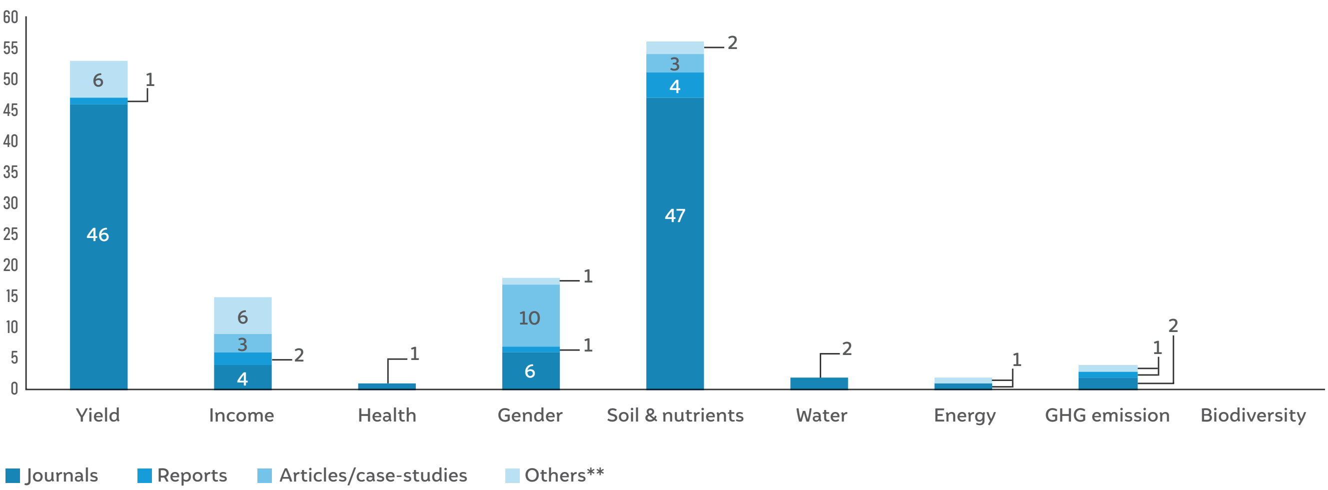
05 

Participatory activities to make vermicompost have benefited rural women tremendously in generating income and livelihoods; through the *National Rural Livelihood Mission/State Rural Livelihoods Mission* and the National Agricultural Innovative Projects.[86]

06 

Vermicomposting received renewed focus in *Godhan Nyay Yojana's* model, launched in 2020 by Chhattisgarh government. More states should incentivise vermicompost production through similar schemes.[87]

AVAILABLE RESEARCH ON THE IMPACT OF VERMICOMPOSTING



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KEY STAKEHOLDERS IN VERMICOMPOSTING

Government Institutions: National Centre of Organic Farming (NCOF); Regional Centres of Organic Farming; ICAR- Central Research Institute for Dryland Agriculture (CRIDA); ICAR-Mountain Livestock Research Institute, Manasbal; National Bank for Agriculture and Rural Development (NABARD).

Research Institutions: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); Tamil Nadu Agricultural University (TNAU); Andhra Pradesh Horticultural University; Kerala Agricultural University; JNAVV Agriculture College, Indore; T.M. Bhagalpur University (Bihar);

NGOs/CSOs: Apna Kheti; M.S. Swaminathan Foundation; PRADAN; CARITAS INDIA; Centre for World Solidarity (CWS); Association for Promotion of Organic Farming (APOF, Bangalore); Bhawalkar Ecological Research Institute (BERI); Manipur Small Farmers Agri Business Consortium (Imphal); BAIF Development Research Foundation; PRADAN; Foundation for Ecological Security; Udyogini; Access Livelihoods Group.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on vermicompost here: https://www.ceew.in/sites/default/files/vermicomposting.pdf

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81. Data for Jharkhand is omitted due to its unreliability.
82. The enrichment of vermicompost with nutrients and microorganisms using different organic and inorganic materials and microbial inoculants.
83. Stakeholder consultations
84. Srinivasarao, Ch., B. Venkateswarlu, R. Veeraiah, S. Rammohan, Vijay S. Jakkula, Sreenath Dixit, B. Shivarudrappa And, and R.V. Rammohan. 2013. "Vermicomposting for Efficient Crop Residue Recycling, Soil Health Improvement and Imparting Climate Resilience: Experiences from Rainfed Tribal Regions." Hyderabad: Central Research Institute for Dryland Agriculture. http://www.aicrpda.in/aicrpda/attachments/555_CRIDA-Vermicopost-bk-ch srinivas.pdf.
85. El-Khawad, Mohamed, and Rajeev Ahal. 2019. "Business Model: Vermicomposting." New Delhi: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. http://www.birdlucknow.in/wp-content/uploads/2020/03/17-Vermicompost-BM.pdf.
86. Srinivasarao, Ch., B. Venkateswarlu, R. Veeraiah, S. Rammohan, Vijay S. Jakkula, Sreenath Dixit, B. Shivarudrappa And, and R.V. Rammohan. 2013. "Vermicomposting for Efficient Crop Residue Recycling, Soil Health Improvement and Imparting Climate Resilience : Experiences from Rainfed Tribal Regions." Hyderabad: Central Research Institute for Dryland Agriculture. http://www.aicrpda.in/aicrpda/attachments/555_CRIDA-Vermicopost-bk-ch srinivas.pdf.
87. Geetha M. 2020. "Towards Organic Farming-Godhan Nyay Yojana in Chhattisgarh Chhattisgarh." https://cdn.cseindia.org/webinar/Godhan-Nyay-Yojana-in-chhattisgarh.pdf.

Image: pixabay

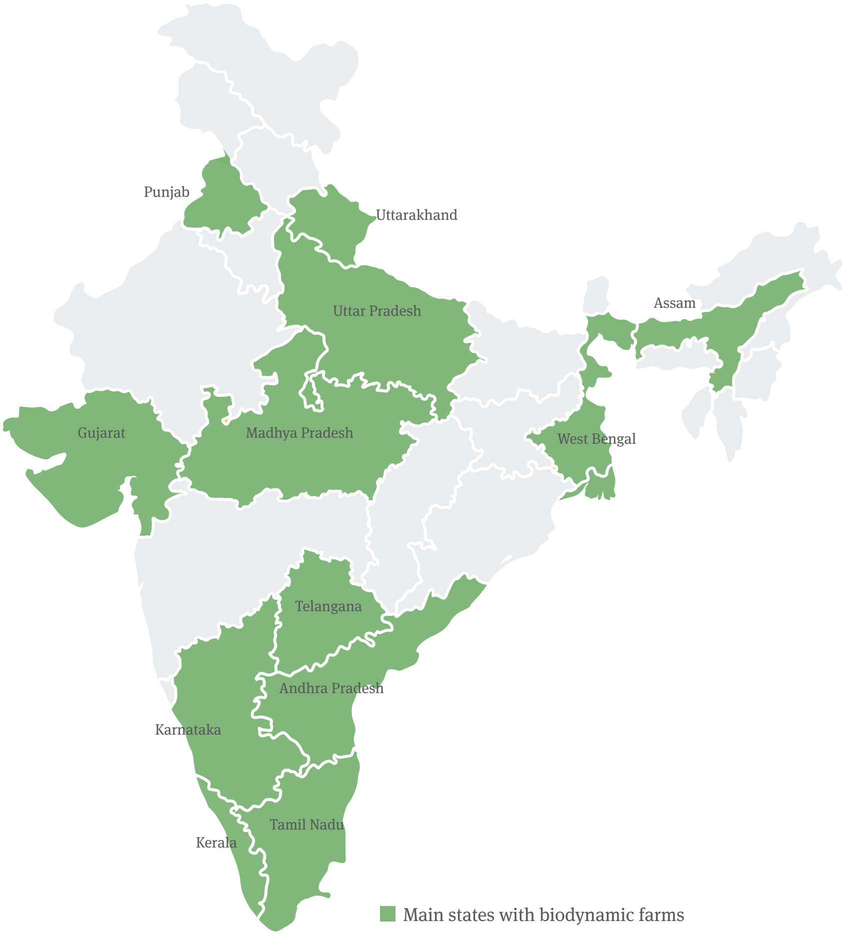
BIODYNAMIC FARMING

Image: Unsplash

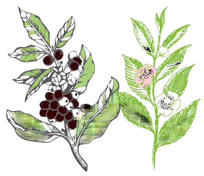
The **biodynamic farming** system mainly works on the relationship between plant growth and cosmic rhythms and emphasises the importance of maintaining sustainable soil fertility[88]. For instance, some biodynamic practices advocate the lunar and cultural calendar synchronisation, the use of preparations (for crops and/or compost) made from medicinal plants, cow dung, quartz, and living animals on the farm[89]. Biodynamic preparations, named BD-500 to BD-700, are the core elements of biodynamic farming. They are biologically active dynamic preparations, which help harvest the potential of astral and ethereal powers to benefit the soil and its different biological cycles.[90]

9,131 ha
of certified biodynamic farms in India[91]

60,000 ha
of uncertified area under biodynamic in India[92]



~1,00,000 FARMERS
practising biodynamic farming, based on sales of biodynamic preparations and self-reports[93]



HERBS, SPICES, TEA, AND COFFEE are the main crops cultivated under India's biodynamic farming

Source: Authors' compilation from Demeter database, and the stakeholder consultations.

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Green: furthered by biodynamic farming
Grey: no evidence of being furthered by biodynamic farming

88. Ramanjaneyulu et al. 2020. Promotion of Organic Farming: Roles of key players. *Biotica Research Today* 2(8): 731-734.
89. Brock C et. al. 2019. "Research in biodynamic food and farming - a review." Open Agric 4:743–757.
90. Ministry of Environment, Forest and Climate Change. 2017. "Report of the Committee on Doubling Farmer's Income - Strategies for Sustainability in Agriculture." Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture & Farmers' Welfare.
91. Demeter International. Available at <Products | Demeter>. Last accessed 02 March 2021.
92. Stakeholders' consultation.
93. Shah A. 2017. "Biodynamic Farming Takes Root in India." Open the magazine, agriculture. Available at < https://openthemagazine.com/features/agriculture/biodynamic-farming-takes-root-in-india/> Last accessed: 02 March 2021.

KEY INSIGHTS & RECOMMENDATIONS

01 There are no definitive conclusions about the comparative agronomic and economic performance. Support longitudinal assessment through primary survey and crop-cutting experiments.

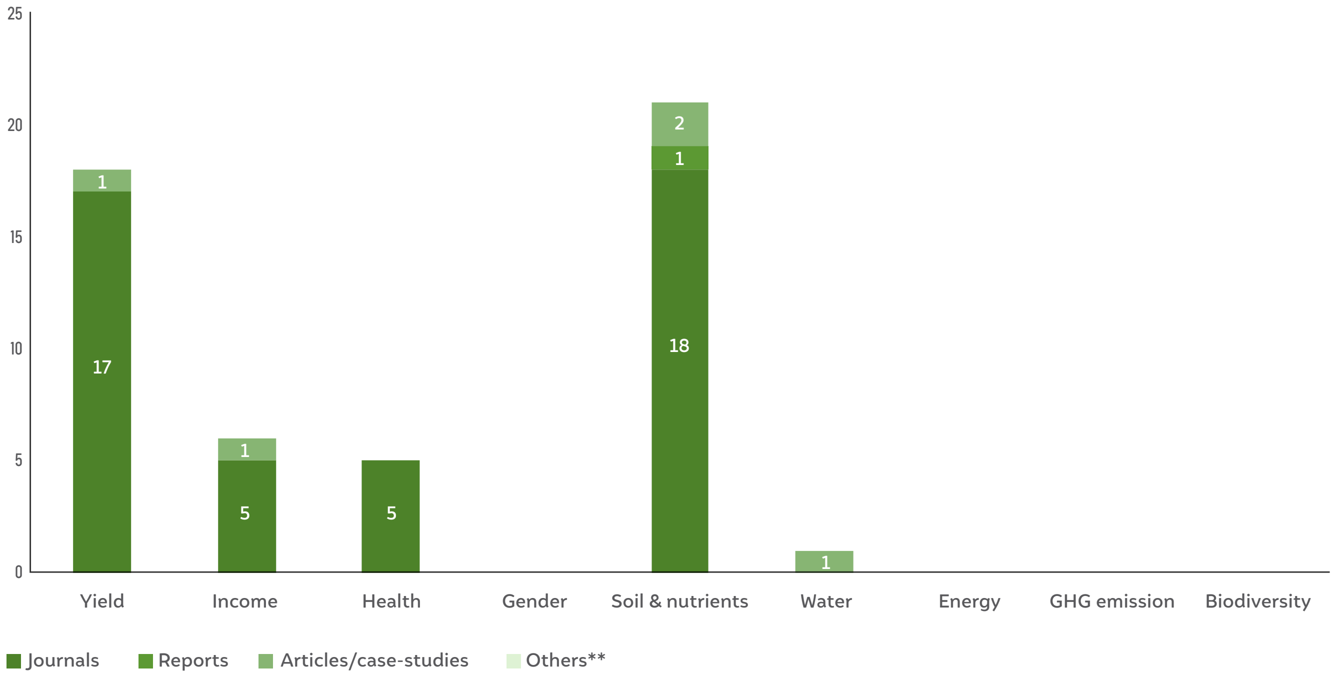
02 The expensive and cumbersome certification process is a significant challenge for small, landless, and uncertified biodynamic farmers. Policy should support farmers in realising the premium prices and in boosting certified products' exports.

03 Biodynamically grown foods are nutritionally superior as they contain higher levels of vitamins, minerals, and amino acids, as per the limited studies. Further research should prioritise assessing its impact on nutrition security.

04 Biodynamic Association of India is the most prominent advocate and promoter of biodynamic farming in India.

05 No explicit support under current policies, but mentioned in a few government documents.

AVAILABLE RESEARCH ON THE IMPACT OF BIODYNAMIC FARMING



Source: Authors' compilation

*** Thesis, guidelines, conference papers, etc.*

Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN BIODYNAMIC FARMING

Government Institutions: ICAR – Central Institute for Subtropical Horticulture.

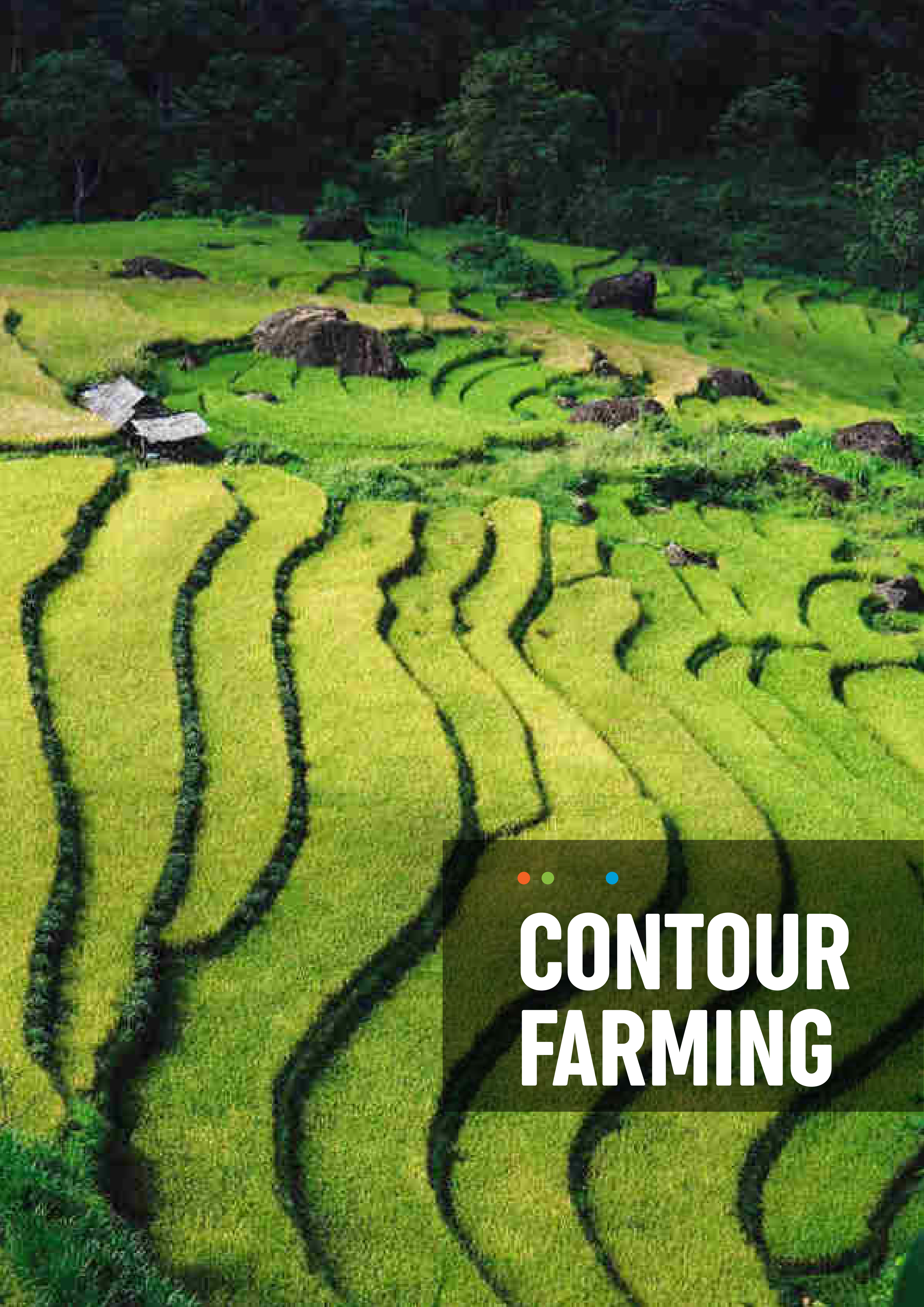
Research Institutions: Biodynamic Association of India.

NGOs/CSOs: SARG Vikas Samiti; Bhaikaka Krishi Kendra; Lipok Social Foundation.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on biodynamic farming here: https://www.ceew.in/sites/default/files/biodynamic-farming.pdf

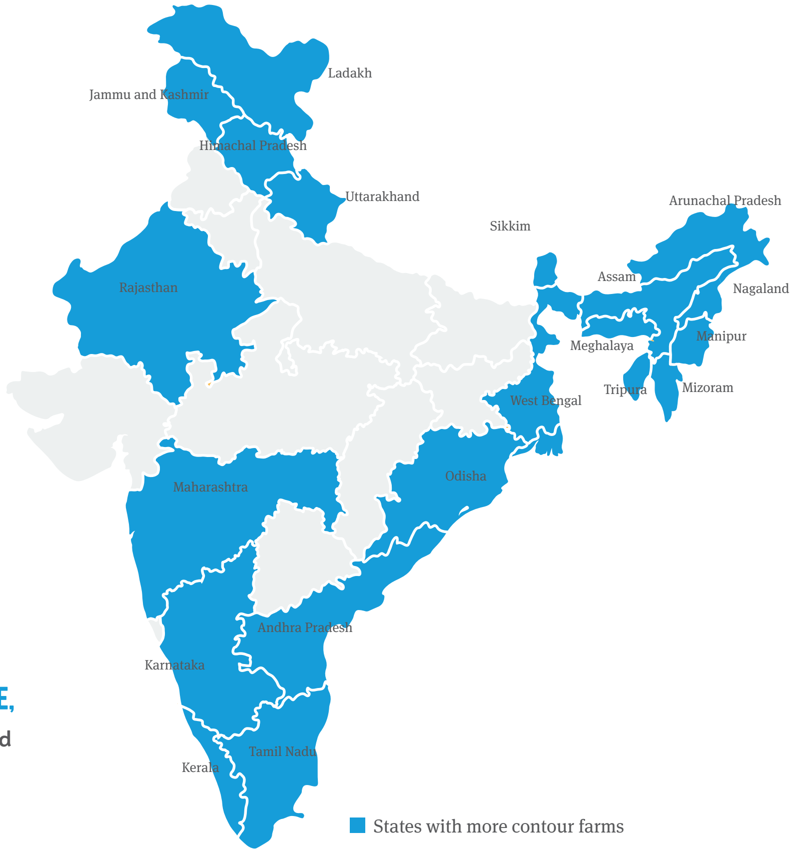

Image: Pixabay



CONTOUR FARMING

Contour farming is ploughing and planting along a contour - across the slope (horizontal) rather than up and down (vertical). Furrows are ploughed perpendicular rather than parallel to the slope. The practice tends to be treated as synonymous with terrace farming; however, contour farming follows the natural shape of the slope without altering it, whereas terrace farming builds walls and alters the shape of the slope to produce flat areas that provide a catchment for water and to check erosion.[94,95,96]

~2 MILLION ha is the estimated area under contour farming, but no official data available



<3 MILLION FARMERS practise contour farming. No official data available[97]

ALL TYPES OF CROPS - CEREALS, HORTICULTURE, SPICES, etc. are cultivated using contours

ALL LANDHOLDING FARMERS small, medium, large — practise contour farming

Source: Authors compilation from literature review and stakeholder consultations.

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Synergies | Efficiency | Recycling | Resilience | Human and social values | Diversity | Co-creation and sharing of knowledge | Culture and food traditions

Blue: furthered by contour farming
Grey: no evidence of being furthered by contour farming

94. Department of Agriculture, Himachal Pradesh.
95. Department of Agriculture, Sikkim.
96. Stakeholder consultations
97. Ibid.

KEY INSIGHTS & RECOMMENDATIONS

01 Many large land holding farmers in the lower altitude plains also practice contour farming, beyond its adoption in hilly to mid-hilly terrains.

02 Research shows more than 10% increase in yields due to improved soil moisture and nutrient preservation in the topsoil from contours.[98]

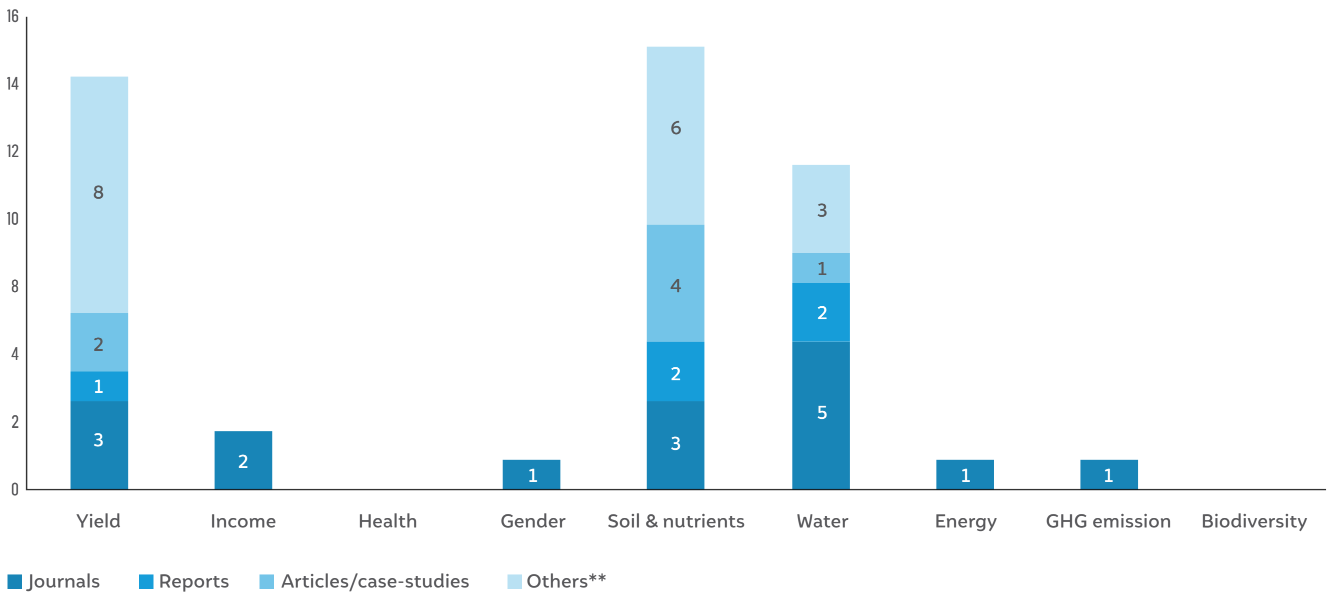
03 We need more studies that cover various agro-ecological zones or regional studies as impact studies are limited to some geographical areas and also recent studies are limited.

04 Contour farming can reduce soil erosion by almost 50% on moderate slopes, however, on slopes steeper than 10%, measures like contour bunding and planting vegetative barriers are required to enhance its impact.[99]

05 It is vital to follow contouring on scientific lines; else, it can erode the fields together with rich soil nutrients.[100] Thus, focus on training and handholding for its proper implementation as we scale-up contour farming.

06 Limited research on the economic and social impacts of practising contour farming. Support further research to enable an informed scale-up.

AVAILABLE RESEARCH ON THE IMPACT OF CONTOUR FARMING



Source: Authors' compilation.
*** Thesis, guidelines, conference papers, etc.*
Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN CONTOUR FARMING

Government Institutions: Department of Agriculture, Cooperation and Farmers' Welfare (DAC&FW); Department of Agriculture, Himachal Pradesh; Agriculture Department, Government of Sikkim.

Research Institutions: ICAR-Research Complex for North Eastern Hill Region; Dryland Agriculture Project, University of Agricultural Sciences, Bangalore; International Crops Research Institute for the Semi-arid Tropics (ICRISAT); College of Agricultural Engineering and Technology, Odisha (CAET).

NGOs/CSOs: Peoples Endeavor for Social Change (PESCH).

Note – The stakeholders list is indicative and not exhaustive.

Read more details on contour farming here: https://www.ceew.in/sites/default/files/contour-farming.pdf

98. Goyal R.K, Khan M.A, and Bhati T.K, et al. 2013. *Watershed Management for Development of Hot Arid Zone of India.* Central Arid Zone Soil Management, Jodhpur. www.cazri.res.in/publications/watershedmanagement.pdf.

99. TNAU agritech portal. 2016. "Agronomic Measures - Contour Farming." *Web Portal.* https://agritech.tnau.ac.in/agriculture/agri_majorareas_dryland_agromeasures_contour_farming.html.

100. Stakeholder consultation.

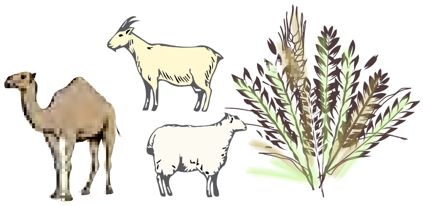
Image: Pexels

INTEGRATED FARMING SYSTEMS

Integrated farming systems (IFS) can be described as a judicious mix and positive interaction between two or more components – such as horticulture crops, livestock, aquaculture, poultry/ducks, apiculture, and mushroom cultivation. It uses the cardinal principles of minimum competition and maximum complementarity with advanced agronomic management tools. It aims to sustain an environmentally-friendly farm income, family nutrition, and ecosystem services.[101]

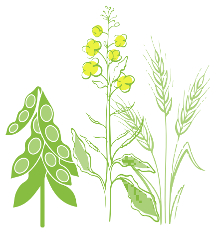
<0.1 MILLION ha
area under IFS in India[102] and 52,079 ha is officially reported as of 2019-20[103]

<0.1 MILLION FARMERS
practising IFS



ANIMAL HUSBANDRY (CAMELS, SHEEP, AND GOAT) WITH MODERATE CROP (PEARL MILLET, PULSES, OILSEEDS, FODDER)
are the most popular IFS models in the arid and desert regions

MOSTLY SMALL AND MARGINAL FARMERS
adopt IFS[103]



45 MODELS FOR CLIMATE-RESILIENT IFS
developed by ICAR

INTEGRATED FARMING SYSTEMS' LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Synergies | Efficiency | Recycling | Resilience | Human and social values | Diversity | Co-creation and sharing of knowledge | Culture and food traditions

Green: furthered by integrated farming systems

101. Panwar A.S, Ravisankar N, Shamim M, and Prusty A. 2018. "Integrated Farming Systems: A Viable Option for Doubling Farm Income of Small and Marginal Farmers." Bull Indian Soc Soil Sci 32:

102. Stakeholders' consultation.

103. Refer: https://nmsa.dac.gov.in/RptActivityAchievement.aspx

KEY INSIGHTS & RECOMMENDATIONS

01 IFS models enhanced the "total production rice equivalent yields (REY) from 9% in Eastern Himalayan Regions to 366% in Western plains and Ghat region."[104] To estimate overall farm productivity[105], we need innovative and integrated evaluation methodologies.

02 IFS promotes diet diversity, improving health and nutrition outcomes. A policy focus on nutrition-security will help scale-up IFS adoption

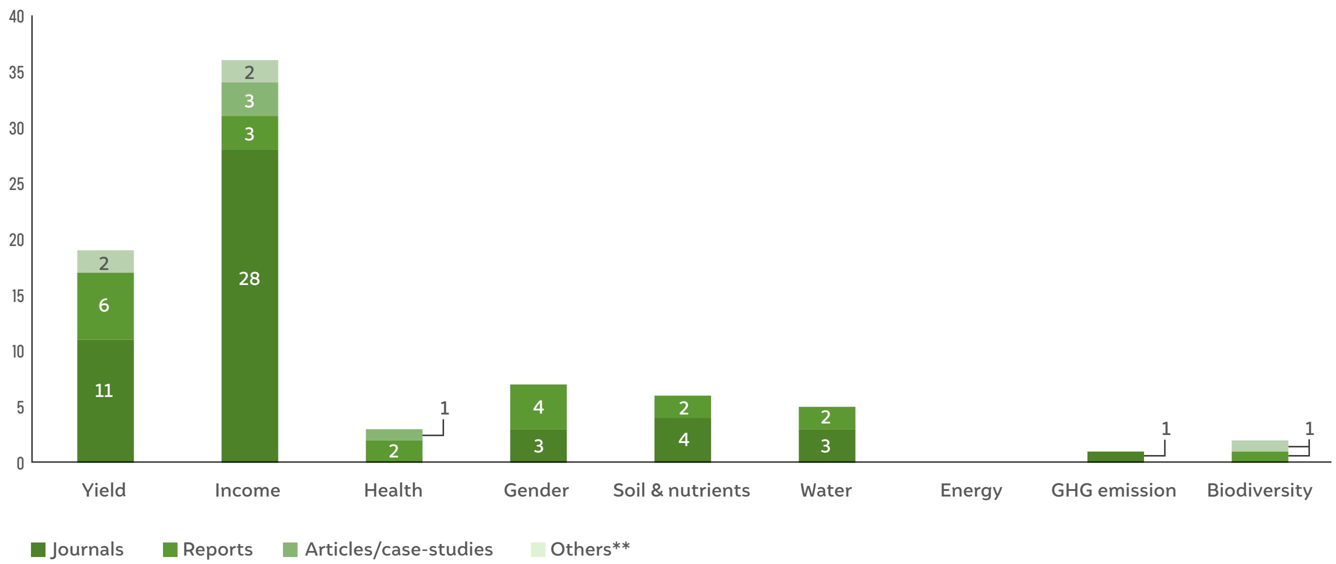
03 Design and adopt IFS models respective to the agro-climatic zones to maximise the outcomes. In regions with 500-700 mm of rainfall, integrate livestock with low-water input crops and trees. In areas with 700-1100 mm of rainfall, promote crops, horticulture, and livestock farming systems. In regions above 1100 mm, promote fisheries with farming.[106]

04 Being labour-intensive, IFS generates additional employment. Leverage IFS to improve farm incomes and limit labour migration in areas with easier availability of labour.

05 Impact of integrated farming models on water use efficiency, energy, and emissions is not well-researched, and should be supported in future research.

06 No explicit policy support for IFS scale-up at national level. Similar to the Kerala government's Jaivagriham project, financial support should be provided for integration of different enterprises.

AVAILABLE RESEARCH ON THE IMPACT OF INTEGRATED FARMING SYSTEMS



Source: Authors' compilation.
*** Thesis, guidelines, conference papers, etc.*
Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN INTEGRATED FARMING SYSTEMS

Government Institutions: Central Research Institute for Dryland Agriculture (CRIDA); Indian Council of Agricultural Research (ICAR) – IIFSR Modipuram Meerut; ICAR-Mahatma Gandhi Integrated Farming Research Institute (MGIFRI); Agriculture Technology Application Research Institutes (ATARI);

Research Institutions: Faculty Centre for Integrated Rural Development and Management - An Off-campus Faculty-Centre of Ramakrishna Mission Vivekananda Educational and Research Institute (RKMVERI); Tamil Nadu Agricultural University (TNAU); Rani Laxmibai Central Agricultural University, Jhansi.

NGOs/CSOs: Welthungerhilfe; Foundation for Ecological Security; Abhivyakti Foundation; Society for Promotion of Wastelands Development (SPWD); Development Research Communication and Services Centre.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on integrated farming systems here: https://www.ceew.in/sites/default/files/integrated-farming-systems.pdf

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104. Kumar S, Kumar U, and Bhatt B.P. 2012. "Integrated farming system for improving agricultural productivity". In *Status of Agricultural Development in Eastern India* (pp.205-230). ICAR Research Complex for Eastern Region.

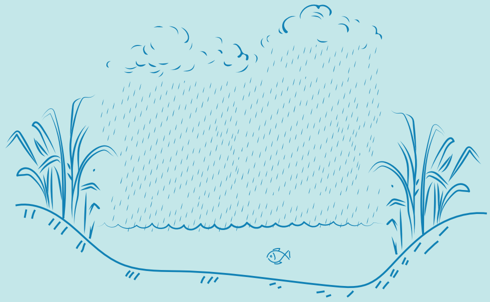
105. such as benefits of straw as fodder/mulching, or edible water/weeds/small fish from the rice field.

106. Stakeholders' consultation.

Image: iStock

RAINWATER HARVESTING -ARTIFICIAL RECHARGE OF GROUNDWATER

Rainwater harvesting (RWH) collects, conveys, and stores the rainfall in an area for beneficial purposes.[107] It is done by storing rainwater on the surface for future use and through recharge to groundwater. It is also known as artificial recharge when rainwater is directed into the ground – either by spreading it on the surface, using recharge wells, or altering natural conditions to increase infiltration – to replenish an aquifer.[108]



>20 MILLION ha
of estimated area under RWH activities in India[109]

<5 MILLION
farmers practise RWH activities in India[110]

MEDIUM AND LARGE-LANDHOLDERS
tend to practise RWH activities more[111]

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Synergies | Efficiency | Recycling | Resilience | Human and social values | Diversity | Co-creation and sharing of knowledge | Culture and food traditions

Blue: furthered by Rainwater harvesting-artificial recharge of groundwater
Grey: no evidence of being furthered by Rainwater harvesting-artificial recharge of groundwater

KEY INSIGHTS & RECOMMENDATIONS

01

Percolation tanks are the most popular rainwater harvesting techniques with high water storage efficiency in semi-arid regions.[112]

02

In some states, RWH structures have improved both on-farm income due to increased crop yields and off-farm income due to diversified activities such as fishing and cattle herding.[113]

03

Less adoption among small-holding farmers due to concerns about the loss of land to RWH structures.[114] More evidence on economic viability will help encourage smaller farmers through appropriate communication strategies.

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107. CPCB ENVIS. 2016. *Rainwater harvesting in India: an appraisal.* CPCB ENVIS CENTRE.http://cpcbenvis.nic.in/envis_newsletter/RWH in India - An Appraisal CPCBENVIS.pdf. Accessed 29 Sep 2020.

108. Bhattacharya Amartya Kumar. 2010. *Artificial ground water recharge with a special reference to India.* Int J Res Rev Appl Sci - IJRRAS 4:214–221.

109. Ministry of Jal Shakti. 2019. "Rainwater Harvesting." *Lok Sabha Unstarred Questions No.4115.* http://mowr.gov.in/sites/default/files/Steps_to_control_water_depletion_Jun2019.pdf; Stakeholder consultation at Central Ground Water Board.

110. No of adopters (farmers) are deduced from the area under RWH divided by the average landholding size for the kind of farmers majorly undertaking the practice.

111. Stakeholder consultations

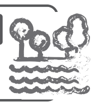
112. Limaye, Daji Shrikant. 2011. "Importance of Percolation Tanks for Water Conservation for Sustainable Development of Ground Water in Hard-Rock Aquifers in India." *Water Conservation.* Pune: UNESCO-IUGS-IGCP Project 523"GROWNET." doi:10.5772/30568.

113. Verma, Shilpa, and Manisha Shah. 2019. "Drought-Proofing through Groundwater Recharge Lessons from Chief Ministers ' Initiatives in Four Indian States" 1: 18. https://openknowledge.worldbank.org/bitstream/handle/10986/33240/Drought-Proofing-through-Groundwater-Recharge-Lessons-from-Chief-Ministers-Initiatives-in-Four-Indian-States.pdf?sequence=1.

114. Nagasree, K, K.S. Reddy, K.V. Rao, M.S. Prasad, M. Osman, Manoranjan Kumar, and G. Venkatesh. 2012. "Rainwater Harvesting and Utilization for Climate Resilient Agriculture in Rainfed Areas." Hyderabad: Central Research Institute for Dryland Agriculture. https://www.cse.iitb.ac.in/~pocra/References/Rainwater Harvesting structures CRIDA.pdf.

04 

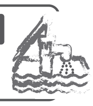
Improvement in quality of life by reduced working hours and empowering women through participatory process in areas where RWH programs were implemented.[115]

05 

RWH structures, in particular, farm ponds, conserve soil and nutrients apart from water and control floods by reducing peak flows in watersheds.[116] Leverage CSOs to ensure rural communities' participation in recharge augmentation.

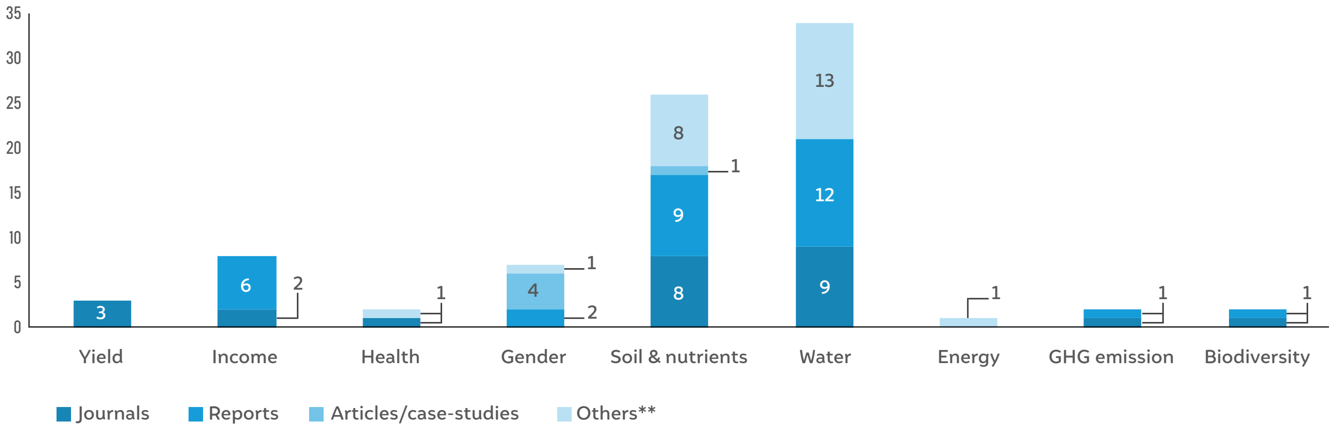
06 

Under the *Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS)*, ~290,000 water conservation, and water harvesting works/structures are completed, as of February 2020.

07 

In various parts of the country (Karnataka, Odisha, Tamil Nadu), rainwater structures and recharged aquifers have improved the groundwater levels.[117] Prioritise districts/ blocks with distressed water levels to scale-up RWH.

AVAILABLE RESEARCH ON THE IMPACT OF RAINWATER HARVESTING-ARTIFICIAL RECHARGE OF GROUNDWATER



Source: Authors' compilation.

*** Thesis, guidelines, conference papers, etc.*

Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN RAINWATER HARVESTING-ARTIFICIAL RECHARGE TO GROUNDWATER

Government Institutions: Central Ground Water Board, Ministry of Water Resources; ICAR-Indian Institute of Water Management; ICAR- Central Research Institute for Dryland Agriculture (CRIDA).

Research Institutions: International Water Management Institute (IWMI); Indian Institute of Management (IIM), Ahmedabad; Institute of Rural Management, Anand (IRMA); Physical Research Laboratory (PRL).

NGOs/CSOs: Centre for Science and Environment (CSE); Watershed Organisation Trust (WOTR); Advanced Center for Water Resources Development and Management (ACWADAM); Arghyam; Samerth Charitable Trust; PRADAN; Kalpavriksh, Environment Action Group; Indo-Global Social Service Society; Gram Vikas; Equality empowerment foundation.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on rainwater harvesting systems-artificial recharge of groundwater here: https://www.ceew.in/sites/default/files/rainwater-harvesting.pdf

115. MoWR. 2016. "Best Practices of Ground Water Harvesting in Different Parts of India (NGO Initiaves)." New Delhi: Ministry of Water Resources. http://mowr.gov.in/sites/default/files/BP_NGO_0.pdf.

116. Nagasree, K, K.S. Reddy, K.V. Rao, M.S. Prasad, M. Osman, Manoranjan Kumar, and G. Venkatesh. 2012. "Rainwater Harvesting and Utilization for Climate Resilient Agriculture in Rainfed Areas." Hyderabad: Central Research Institute for Dryland Agriculture. https://www.cse.iitb.ac.in/~pocra/References/Rainwater Harvesting structures CRIDA.pdf.

117. Biswas, K B, and E Sampath Kumar. 2016. "Project Wise Impact Assessment of Completed Demonstrative Artificial Recharge Projects of XIth Plan." *Interim Report*. New Delhi. http://cgwb.gov.in/AR/Document/Interim_Report-1_20.10..2016.pdf.

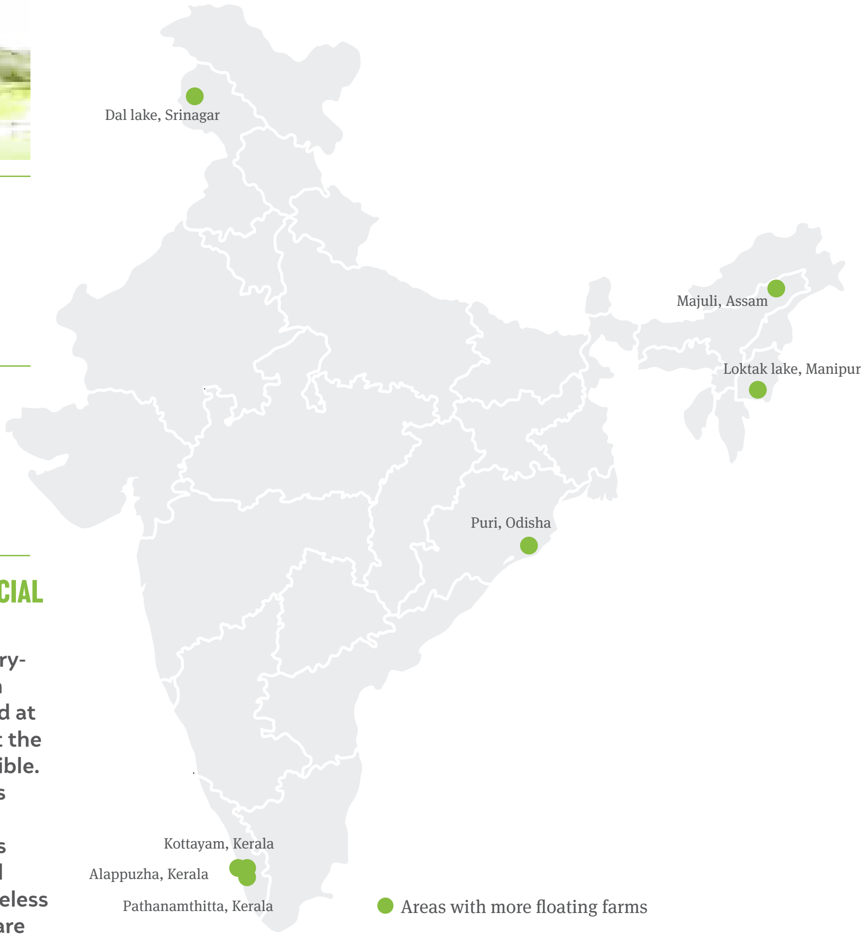
Image: Binapani Mishra, SWAD

FLOATING FARMING

Floating farming is a way of producing food in areas that are waterlogged for long periods. It is mainly aimed at adapting cultivation to increased or prolonged flooding. The system uses floating beds of water hyacinth, mud, and bamboo. The beds can float on the water's surface, thus creating agricultural land areas in a wet area.[118]

VERY NEGLIGIBLE ADOPTION,
a few pilots in select parts of the country

NO OFFICIAL/UNOFFICIAL DATA
available on the country-level adopters, though stakeholders consulted at Odisha mention about the adopters being negligible. In Assam, the numbers are provided in terms of project beneficiaries and not just the actual implementers, nonetheless overall implementers are still insignificant.



145 POOR LANDLESS FAMILIES
were found practising floating farming in Odisha[119]

SHORT-ROOTED AND LEAFY VEGETABLES
are best-suited to floating gardens

Source: Authors compilation from literature review and stakeholder consultations.

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Green: furthered by floating farming
Grey: no evidence of being furthered by floating farming

118. UNEP-DHI. 2018. "Floating agricultural systems". Climate Change Adaptation Technologies for Water. UNEP-DHI. https://www.ctc-n.org/sites/www.ctc-n.org/files/resources/floating_agricultural_systems.pdf.

119. Society for Women Action Development.

KEY INSIGHTS & RECOMMENDATIONS

01 It appeals to vulnerable landless and marginalised households due to its sustainable and low-cost inputs such as bamboo and rope.[120] However, handholding and training are required for long-term sustenance.

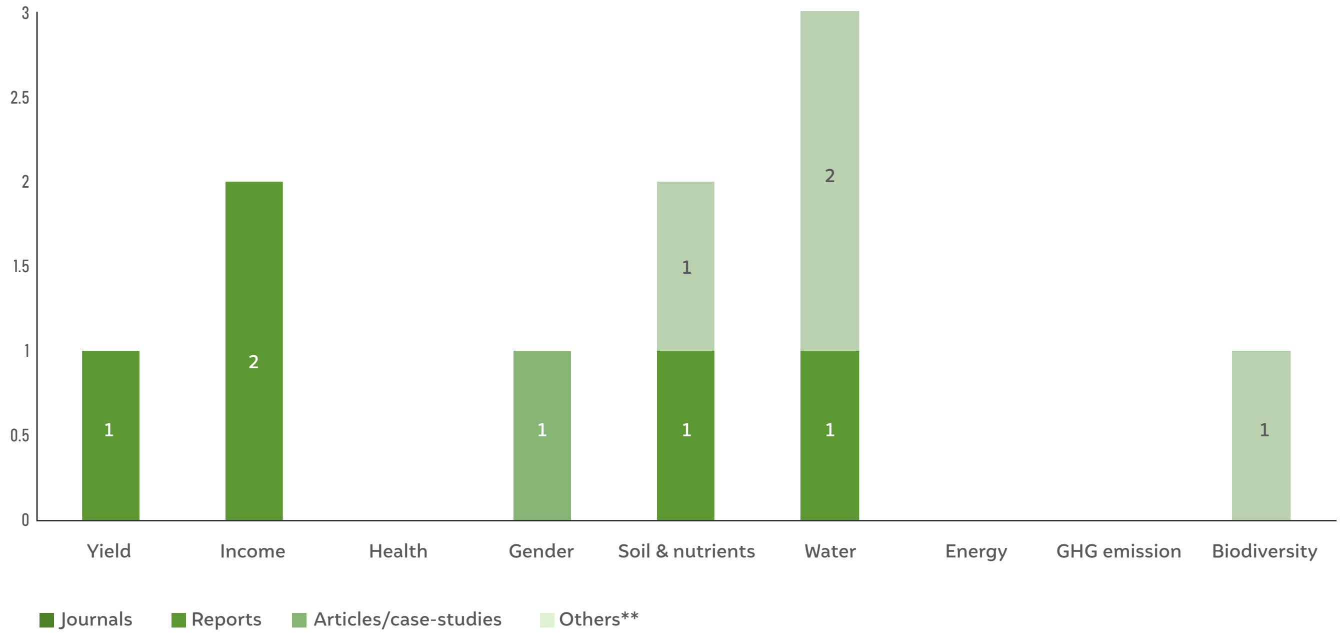
02 In states like Odisha and Assam, farmers and families adopted the practice, especially after the extreme flood events.[121] Its mass adoption has potential to generate surplus vegetables for marketing, making it an attractive proposition for the economically vulnerable.[122]

03 Availability of calm water surface body and raw materials are main necessities for its adoption.[123]

04 Lack of policy support and financial constraints are the main barriers for CSO/NGOs working to promote floating farming.[124]

05 Impact evidence on floating farming in India is missing. As the practice garners further on-ground traction, support evidence research on floating farming.

AVAILABLE RESEARCH ON THE IMPACT OF FLOATING FARMING



Source: Authors' compilation based on the scant publications provided by stakeholders.
*** Thesis, guidelines, conference papers, etc.*
Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

KEY STAKEHOLDERS IN FLOATING FARMING

Government Institutions: No government or research institutions found for the practice.

NGOs/CSOs: Regional Centre for Development Cooperation (RCDC); Society for Women Action Development (SWAD); United National Development Programme (UNDP); South Asian Forum for Environment (SAFE); Welthungerhilfe; AusAID India.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on floating farming here: https://www.ceew.in/sites/default/files/floating-farming.pdf

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120. Ibid.
121. Regional Centre for Development Cooperation; South Asian Forum for Environment. 2018. Floating technology grows hope for a better future. South Asian Forum for Environment, Guwahati.
122. Regional Centre for Development Cooperation.
123. Society for Women Action Development.
124. Regional Centre for Development Cooperation.

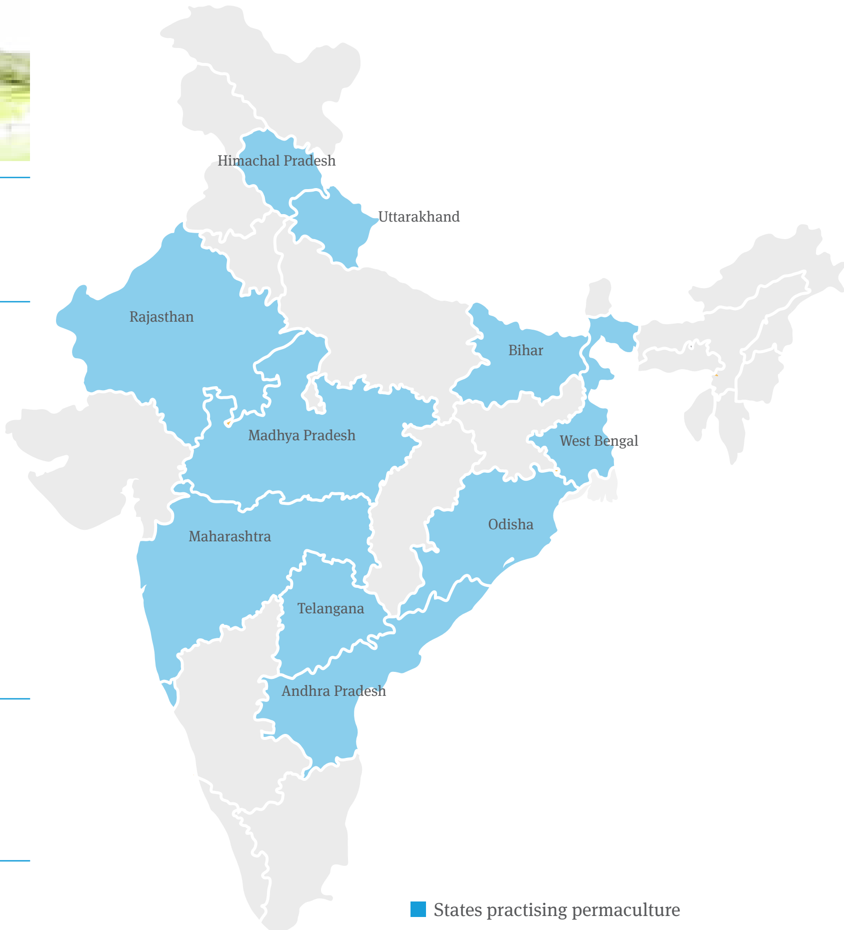
Image: flickr

PERMACULTURE

Image: flickr

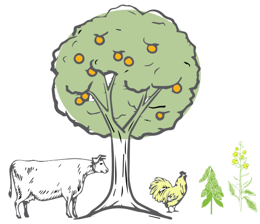
Permaculture is described as "consciously designed landscapes, which mimic the patterns and relationships found in nature while yielding an abundance of food, fiber, and energy for provision of local needs".[125] The three basic ethical norms for permaculture systems are: care for the earth; care for people; and set limits to consumption and reproduction, and redistribute surplus.[126]

<0.05 MILLION ha
of area under permaculture in India



~0.01 MILLION
farmers have adopted permaculture, as per stakeholders consulted

MOSTLY SMALL FARMERS
are practising permaculture



Permaculture includes a diversified and integrated approach for meeting a family's requirement – and includes **HORTICULTURE (FRUIT AND VEGETABLES), FLORICULTURE, PERENNIAL AND ARABLE CROPS, POULTRY, DAIRY,** and related activities

Source: Authors' analysis from the CSO survey and Stakeholder consultations.

LINKAGE WITH FAOs AGROECOLOGICAL ELEMENTS

Blue: furthered by permaculture
Grey: no evidence of being furthered by permaculture

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KEY INSIGHTS & RECOMMENDATIONS

01 No peer-reviewed publications on the permaculture's impact on the economic, social, and environmental outcomes in India specifically.

02 No policy support. Policymakers and donors must support impact studies to assess the permaculture potential for an informed scaling of the practice.

KEY STAKEHOLDERS IN PERMACULTURE

Government Institutions: National Centre of Organic Farming; Regional Centres of Organic Farming.

NGOs/CSOs: Aranya Agricultural Alternatives; Deccan Development Society; The India Permaculture Network; Aananda Permaculture Farms; Bhoomi College.

Note – The stakeholders list is indicative and not exhaustive.

Read more details on permaculture here: https://www.ceew.in/sites/default/files/permaculture.pdf


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

4. Synthesis

In this section, we synthesise the key emerging insight across the 16 SAPSs based on the literature review and stakeholder consultations. Insights that result from the CSO stakeholder survey are also captured along with the existing barriers to adopting the SAPSs.

Sustainable agriculture practices that are relatively easier to adopt and receive explicit national/state policy support fare better in expansion, both area-wise and with implementers

An overview of sustainable agricultural practices in India

India's total net sown area is about 140 million ha, and about half of it (68.4 million ha) is irrigated.[13] It is useful to set the context as we discuss extent of update of various SAPSs. We find that crop rotation, agroforestry, rainwater harvesting, and mulching cover a substantial area (Table 4). **Crop rotation** covers around ~30 million ha as it is practised all over the country, with a significant number of adopters (15 million).[14] **Agroforestry** covers 25 million ha with implementation across the country.[15] This area includes boundary plantations, agri-silviculture, agri-horticulture, block plantations, and scattered trees on farmlands. However, the number of cultivators practising agroforestry is less than 5 million, mostly of medium or large landholding farmers.[16] Traditional practices like **rainwater harvesting**, which is promoted extensively in national programmes, have high coverage (>20 million ha)[17] and many adopters. While **mulching** covers a large area (around 20 million ha), it is primarily medium to large farmers with an average landholding size of 3-5 hectares favouring the practice.[18] **Precision farming** (mostly micro-irrigation) covers 9 million ha,[19] with implementation across the country.

Other practices, such as organic farming, the system of rice intensification, integrated pest management, and vermicomposting, each cover roughly around only 2-3 per cent of India's total net sown area. Despite government policy support, **organic farming** is still around 2 per cent of the country's total net sown area.[20] Sikkim is the only state to have become 100 per cent organic so far. As per stakeholder consultations, India has around 2 million certified organic farmers;[21] however, there is no information on uncertified organic farmers, who could number in the millions. **Biodynamic agriculture**, which is often considered as an advanced form of organic farming, finds a few mentions in policy documents, with an estimated area of 0.1 million ha[22] (where biodynamic inputs are explicitly used along with organic farming practices).

We observed a faster adoption rate of **natural farming** in the last two to three years, both in area and number of farmers. About 0.8 million farmers are practising natural farming, mainly in Andhra Pradesh, Karnataka, Maharashtra, and Himachal Pradesh.[23] The coverage is about 0.7 million ha in terms of area,[24] and the mapping indicates the practice is taken up mostly by small and marginal farmers. There are no official coverage data available for the **system of rice intensification**, but we find that the practice has rapidly increased in the last five years, with an estimated area of around 3 million ha across the country.[25] While it is difficult to estimate the area under science-based **integrated farming systems** models, the practice is looked upon favourably to diversify the income portfolio and generate employment, especially in rainfed regions.

Table 4 Sustainable agriculture practices and systems in India (2021) – key statistics

*Area under the system/practice (million ha)
*Scale of adoption (number of farmers in millions)
**Geographical spread (number of states)

Category	System/Practice	*Area under the system/practice (million ha)	*Scale of adoption (number of farmers in millions)	**Geographical spread (number of states)
SYSTEMS	AGROFORESTRY	25	<5#	ALL
SYSTEMS	PRECISION FARMING	9.2[1]	3#	24
SYSTEMS	INTEGRATED PEST MANAGEMENT	5	~5	22
SYSTEMS	SYSTEM OF RICE INTENSIFICATION	3	>3	25
SYSTEMS	ORGANIC FARMING	2.8	1.9	ALL
SYSTEMS	(PARTIAL) CONSERVATION AGRICULTURE	~2[2]	1#	4-5
SYSTEMS	NATURAL FARMING	0.7	0.8	3-4
SYSTEMS	INTEGRATED FARMING SYSTEMS	<0.1	<0.1	10-15
SYSTEMS	BIODYNAMIC AGRICULTURE	0.1	0.1	~10
SYSTEMS	PERMACULTURE	< 0.05	0.01	3-4
PRACTICES	CROP ROTATION	30[3]	~15	ALL
PRACTICES	RAINWATER HARVESTING-ARTIFICIAL RECHARGE OF GROUNDWATER	>20[4]	<5#	ALL
PRACTICES	MULCHING	~20	<5#	17
PRACTICES	VERMICOMPOSTING	3.5	1.5	ALL
PRACTICES	CONTOUR FARMING	~2	<3	19
PRACTICES	COVER CROPS	1.9[5]	~1.5	ALL
PRACTICES	INTERCROPPING	~1[6]	~0.8	ALL[7]
PRACTICES	FLOATING FARMING	~0	~0	1

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

An overview of impact literature

From the systematic review of literature of last ten years, we find that agroforestry, Conservation agriculture, and SRI were the most popular among researchers assessing the impact of SAPSs on various outcomes (Figure 3). In comparison, the impact evidence of biodynamic agriculture and natural farming is relatively limited currently. Regarding different areas of outcomes, most of the SAPSs have a higher number of publications focusing on environmental indicators followed by economic and social ones. However, organic farming, natural farming, and integrated farming systems have reasonable number of publications focused on economic outcomes.

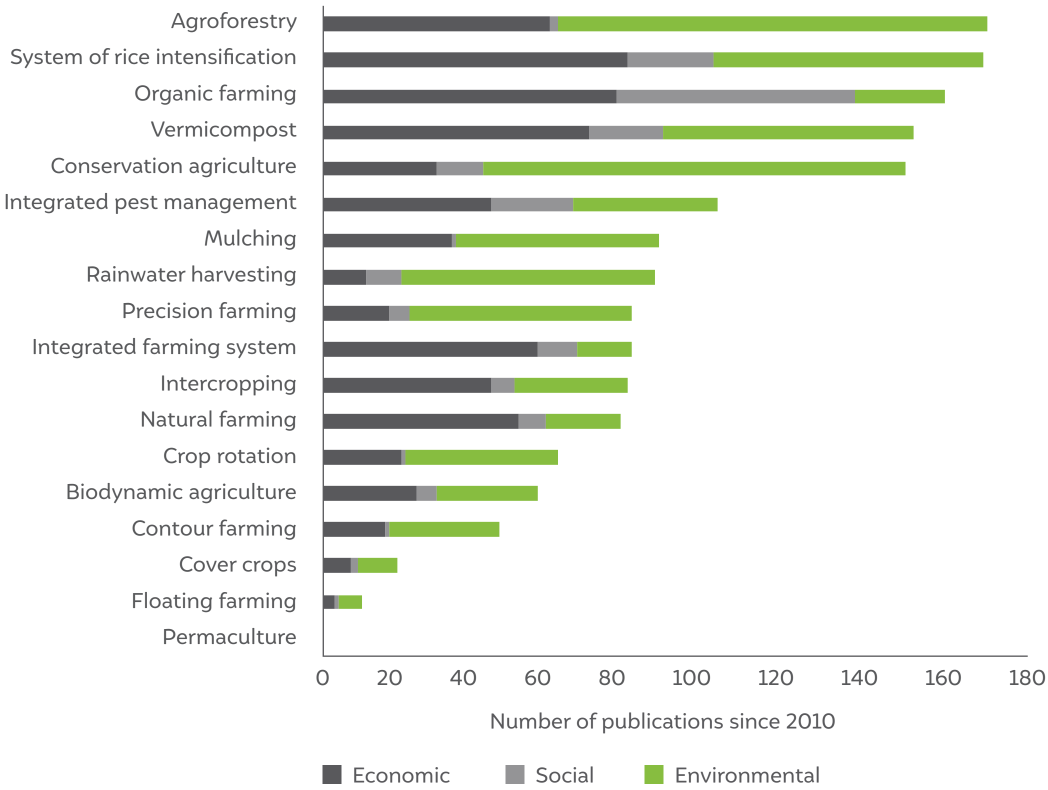

Figure 3
Number of publications for sustainable agriculture practices and systems

Source: Authors' analysis

- **The literature is heavily skewed towards short-term assessments, which do not help understand the long-term impacts of transitions to SAPSs.** We find very limited research involving the long-term (3+ years) impact assessment of SAPSs across all three sustainability dimensions.

- **Most studies are limited to plot-level trials; research at the level of the landscape, region, or agroecological zone is largely missing.** The literature notes that the cost of long-term and more extensive trials and studies is the biggest reason for this research gap.

- **Most publications evaluate the impact on a single dimension of interest instead of focusing on a multi-dimensional analysis.**

- **Farm productivity is measured through conventional measures, which are often not sufficient for SAPSs.** For yields, the studies tend to compare a single crop yield between sustainable and conventional practices. While crop-diversification through inter-cropping, multi-cropping, or crop rotation is frequently advocated across various SAPSs, their outcomes across other crops are rarely accounted for in productivity discussions. Similarly, livestock integration is a common practice promoted in different SAPSs, but there is a

Research gaps that need to be filled: long-term impact assessments, landscape-level studies, multi-dimensional analysis, measuring total farm productivity, and more focus on social and economic outcomes limited understanding of the assessment methods that could capture total productivity under those practices.[26,27]

- **Yields, income, soil health, and water find the most interest among researchers across all the three sustainability dimensions.** We discovered that SAPSs impacts on biodiversity and ecosystem services are the least researched among environmental indicators. We also observed a considerable research gap related to the socially relevant outcomes of SAPSs, such as health and gender.
- New methodologies are needed to capture all the hidden costs in both chemical-based and natural practices to compare both systems' overall productivity.

Several SAPSs can make farmers incomes greater and resilient by diversifying the production, lowering input costs, and fetching premium prices for the produce

Economic, social, and environmental impacts

Changes in net income and resilience

Of the 16 practices reviewed, reductions in input costs (natural farming, SRI, conservation agriculture), extra income from a more diversified portfolio (integrated farming systems, natural farming, agroforestry, intercropping), and premium prices (organic and biodynamic farming) were the most often-cited reasons for an increase in farmers' net income, despite a reduction in yields in a few cases.[28,29,30,31] Besides an increase in income, diversified sources of earnings are another significant incentive across many practices. IFS, organic and natural farming, agroforestry, crop diversification, biodynamic agriculture, and permaculture are all approaches that reduce dependency on one livelihood option and improve the spread of income across the year from different sources, thereby building resilience.[32,33,34,35]

Impact on yields

There are many conceptual limitations in understanding and accurately estimating farm productivity. However, our analysis of the literature indicates that organic farming yields are lower than conventional agriculture in the short term (2-3 years). Beyond this period, some studies show equal and even higher yields for some crops, particularly once the soil changes its form and structure after a few years of applying biological inputs.[36,37] The short-duration studies of natural farming indicate no statistically significant changes in yields for some crops. Still, they suggest increased yields for fruit and gram crops and lower yields for some cereals initially.[38] Yield impacts in SRI are well documented, showcasing a statistically significant increase in yields for various paddy varieties through visibly larger root systems, a higher number of tillers, and longer panicles.[39,40] Resource-conserving practices like vermicomposting, agroforestry and contour farming have also improved crop yields. For vermicomposting, yield gains depend upon the quantity/quality of vermicompost and the combinations applied.[41] Visible yield gains from intercropping occur when crops do not compete and component crops have varying growth periods.[42]

Gender impacts

There are significant research gaps in assessing gender impacts. Women's roles are well-defined in a few practices such as vermicomposting, organic farming, integrated farming systems, and rainwater harvesting. Women have played a critical role in setting up vermicomposting units and micro-enterprises to incentivise the practice among other women farmers at the community level.[43,44]

The stakeholders consulted explained the challenges for women in sustainable agricultural practices. Traditionally, in Indian agriculture, animal husbandry, poultry management, and compost making are women's responsibilities. Most SAPSs include these activities, which increase women's workload as they tend to be more labour-intensive than conventional farming. More evidence is needed for how SAPSs affects women's workloads, income, empowerment, and employment.

We find very limited research focusing on the impact of SAPSs on human health

Health impacts

Anecdotal evidence in the form of case studies and articles mention the positive health impact of SAPSs, mainly through dietary diversity and less exposure to harmful chemicals such as pesticides. However, there is no rigorous or systematic evidence linking sustainable agricultural systems with health outcomes. Several papers mention human health benefits by reducing chemical use in food production from integrated pest management and vermicompost.[45,46,47,48] Conservation agriculture directly benefits human health by lowering residue burning, which reduces local air pollution in nearby cities.[49] Still, no in-depth studies have empirically established these linkages so far.

Impact on soil

From the review of 16 practices, we observed that agronomic practices (e.g., contour farming, cover crops and mulching, crop rotation, intercropping, organic farming, conservation tillage) and agroforestry are successful in conserving soil and water.[50,51,52] However, rainfall intensity, topographic factors, and soil patterns significantly affect their success rate. A few of these practices (e.g., cover crops and mulching, conservation agriculture, organic farming) naturally replenish soil organic matter by incorporating crop residues.[53,54] The leaf litter in agroforestry acts as a protective soil cover and reportedly reduces soil erosion by 10 per cent.[55]

Though natural inputs (organic and green manure, vermicompost, compost, farmyard manure) are healthier for plants and soil, their limited availability means that their ability to replace chemical fertilisers is also limited.[56] Thus, several of the practices evaluated (integrated pest management, precision farming, conservation agriculture) implicitly focus on minimising fertiliser use to achieve nutrient use efficiency.[57,58,59] Site-specific nutrient management techniques (e.g., customised leaf colour chart) have gained considerable adoption and commercial success in Odisha[60] and a few states because of their low cost, easy access, and user-friendly approach. This shows the potential of low-cost precision techniques in the country.

Besides traditional and cultural methods (organic wastes, leguminous rotations, IPM, cover crops, and mulching, no-till), innovative techniques for soil management and assessment (soil quality, soil organic matter, and nutrient availability) with precision farming shows promise. However, farmers must be trained and incentivised to adopt them.

Impact on water

Significant literature exists on water use efficiency gains due to SAPSs, particularly for the SRI, conservation agriculture, and rainwater harvesting.[61,62,63,64] While the first two focus on water use efficiency, rainwater harvesting helps improve groundwater levels, regardless of the scale at which it is practised (watershed, farm, or individual households).[65] SRI is known to consume 50-60 per cent less water than traditional methods.[66] Rainwater harvesting practices and vermicomposting improve the soil's water-holding capacity, facilitate crop productivity, and reduce irrigation requirement.[67,68] They are relevant in dryland areas, though earthworms need to be watered continuously, which can pose a challenge.[69]

Precise micro-irrigation techniques are amply covered in the literature, with several case studies conducted.[70] Various support structures (policies, incentives, training) and a separate mission (*National Mission on Micro-Irrigation*) have promoted its scale-up.

Impact on emissions and energy

Among the SAPSs assessed, agroforestry, SRI, and conservation agriculture have the most evidence for their potential to sequester or mitigate carbon or GHG emissions. Agroforestry is widely known for its carbon-sequestering abilities (above and below ground), and work is initiated by nodal authorities (ICAR-CAFRI, AICRF) on this front with significant progress.[71]

Through its principal component of no-till farming (minimum tillage) practices, conservation agriculture reduces soil disturbance, thereby conserving soil organic carbon.[72,73] Considerable literature is available from several field experiments that estimate quantitatively the emissions saved due to no-tillage practices, especially in the Indo Gangetic Plains.[74,75,76]

A growing body of evidence suggests that the system of rice intensification promotes aerobic soil conditions that reduce methane emissions.[77,78] However, intermittent irrigation, an intrinsic component of SRI, can increase nitrous oxide emissions.[79] There is substantial evidence on the input use efficiency gains from a few practices (organic, natural farming, precision agriculture, IPM) that emphasise farmyard manure and vermicompost, cover crops, crop residue management, all of which build soil organic carbon.[80,81]

India's agricultural sector has a large carbon footprint, contributing around 18 per cent of GHGs emitted.[82] Adopting farming solutions like agroforestry, vermicomposting, precision agriculture and IPM offers great potential to reduce emissions.

Adopting agroforestry, vermicomposting, precision farming and IPM can reduce GHG emissions and contribute to India's climate goals

Impact on biodiversity

Agroforestry, integrated farming systems, permaculture, crop diversification strategies (rotation, intercropping, mixed), and natural and organic farming all tend to increase the spatial, vertical, and temporal diversity species on a farm (and landscape) level.[83,84,85,86,87] These integrated systems involve multiple components and levels – tree, crop, and animal species – and support more biodiversity. Though their impact on biodiversity is mentioned in literature, there is a lack of more in-depth investigations or experimental studies.

One exception is agroforestry, where the research is more substantial. Considerable work has gone into collecting and evaluating the germplasm of 184 promising tree species in India, out of which potential tree species under various agro-climatic zones are identified.[88] However, there is an absence of research on faunal diversity under these systems.

A few articles mention how rainwater harvesting initiatives improve biodiversity through enhanced soil moisture and vegetation growth.[89] Similarly, vermicompost and some conservation farming management practices (contour, cover crops, mulching)[90] affect soil biodiversity by enhancing soil microbial activities, enriching them with microbial populations.[91,92]

Though the mutually beneficial impact of biodiversity in most SAPSs is well established (i.e., they both promote and are enhanced by biodiversity), there is a dearth of long-term, in-depth studies on this topic. A few papers merely mention general nuances on biodiversity impacts rather than offering substantively empirical findings.

Emerging themes

Our extensive analysis has revealed several common themes across SAPSs. These are discussed below.

Knowledge and skill-intensiveness

An emerging theme for all the reviewed practices is their knowledge and management intensiveness. Given that they often directly leverage symbioses and interactions across various natural elements and phenomena, to realise the full potential of multiple SAPSs, a practitioner needs sound knowledge and skills. This might include preparing organic inputs, managing nutrient cycles, controlling pest and disease organisms, choosing synergistic combinations of crops and trees, mechanical weed control, and livestock integration. Stakeholder interviews highlighted that the lack of qualified practitioners and workforce is a significant constraint to the large-scale adoption of various SAPSs.

Beyond technical knowledge and skills, social skills to enable collective action are also important to successfully scale up many SAPSs

Precision agriculture is a highly skilled farming approach – one which tends to attract young people. We also observe that effective natural resource management — such as IPM, waste recycling, water conservation approaches, or crop-livestock integration — requires collective action beyond individual practitioners or farmers. Thus, in addition to technical knowledge and skills, social skills to enable collective action are also important to successfully scale up SAPSs. A lack of social cohesion or community engagement could delay or deter some of the SAPSs adoptions. However, if community action is present or cultivated over time, it ensures the long-term sustenance of such SAPSs.[93]

Labour-intensiveness

Another common insight across the practices is that sustainable agriculture is labour-intensive. Organic, natural, biodynamic, mulching, integrated farming systems, intercropping and vermicomposting require more labour to prepare the inputs,[94,95,96] and manage the different enterprises throughout the cropping season.

The extra labour required for managing a range of activities all year round in integrated farming or agroforestry is reported both as an opportunity and a challenge.[97,98,99] On the one hand, this means more employment generation in terms of more days of on-farm employment.[100] On the other hand, in areas where labour availability is a challenge, it could be a constraint, especially in the absence of family labour.

Potential for rainfed areas

In India, rainfed dry/humid/sub-humid areas constitute over 60 per cent of the cultivated area. They are mostly characterised by poor soil quality, water erosion, prolonged dry periods and a short growing season, a large population of ruminant livestock, and small fragmented landholdings. Yields are stagnant, and due to biophysical and socioeconomic constraints, low levels of inputs are used. The literature and stakeholder consultations suggest that rainfed areas should become the priority area to scale up many of the SAPSs. A shift towards sustainable practices such as integrated farming, conservation agriculture, natural and organic farming can significantly support resource-constrained farmers in strengthening their net incomes and creating jobs. The integration of livestock supports off-farm income generation, provides inputs such as manure, and enhances nutritional security.[101,102] These practices improve soil quality, reduce the water-runoff and erosion. Thus, in rainfed areas, SAPSs can not only improve farm incomes and productivity, but can also contribute positively to the soil, water and other scarce natural resources to ensure long-term resilience for the community.

In rainfed areas, SAPSs can improve farm incomes, farm productivity, and can positively impact soil and water resources ensuring long-term resilience for the community

Nutritional security and diversity

While food security is essential, diverse diets are equally crucial for India, which has large gaps in nutrition security. Most SAPSs promote diversification of crops and agricultural systems on a farm. For instance, integrated farming systems can increase food availability beyond the primary crops;[103] agroforestry diversifies food availability through shrubs, trees, and livestock integration.[104] Natural and organic farming promotes crop rotation and intercropping, which increase temporal and spatial diversity.[105,106] This focus on enhancing the farm's overall productivity and diversification could significantly enhance the overall nutrition security for farmers, their communities, and the nation. Furthermore, by increasing and diversifying incomes, SAPSs can also indirectly lead to better nutritional outcomes for marginal and subsistence farmers.

However, no research methods or studies focus on total farm productivity or the link between total farm output under SAPSs and nutritional security. These evidence gaps need to be bridged to understand how the large-scale adoption of various SAPSs could impact food and nutrition security at large.

Policy ecosystem for sustainable agriculture in India

Since 2014-15, India has had a *National Mission for Sustainable Agriculture (NMSA)* to promote sustainable agriculture, an amalgamation of several programmes focusing on agroforestry, rainfed areas, water and soil health management, climate impacts, and adaptation.[107] 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, the budget allocation to NMSA is minuscule (0.8 per cent) compared to the overall budget of the Ministry of Agriculture and Farmers Welfare (MoAFW). 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.[108] So, while the Indian government recognises the importance of promoting sustainable agriculture, the focus remains skewed towards green revolution-led farming.

While the Indian government recognises the importance of promoting sustainable agriculture, the focus in budgetary allocation remains skewed towards green revolution-led farming

Under the NMSA, various sub-programs receive the following for the year 2021-22: *National Project on Organic Farming* – INR 12 crore (USD 1.6 million); *Mission Organic Value Chain Development for North East Regions* – INR 200 crore (USD 27.5 million); Rainfed area development – INR 180 crore (USD 25 million); *National Project on Agro-Forestry* – INR 34 crore (USD 4.7 million); *Paramparagat Krishi Vikas Yojana (PKVY)* - INR 450 crore (62 million). Beyond NMSA, the Central allotted INR 2,340 crore (USD 321 million) to the *Pradhan Mantri Krishi Sinchayee Yojana* schemes aim to adopt precision-irrigation water-saving technologies.[109]

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

- We surveyed about 180 on-ground civil society organisations involved in the promotion of various SAPSs in India. We find that, similar to the policy side, organic farming gets the most interest among CSOs. Almost two-thirds of them are active in organic agriculture, followed by natural farming (59 per cent), vermicompost (48 per cent), and IPM (43 per cent). Almost a third of them are active in conservation agriculture, mulching, cover crops, intercropping and agroforestry. About a fifth of them are involved in SRI. Very few CSOs are dealing with precision farming, integrated farming systems, and biodynamic agriculture (Figure 4).
- Across states, Maharashtra is the most popular among the CSOs. A third of them are active in the state. Rajasthan, Madhya Pradesh, and Odisha are the next in order. We find very few CSOs active in states like Punjab and Haryana (Figure 5).
- 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.

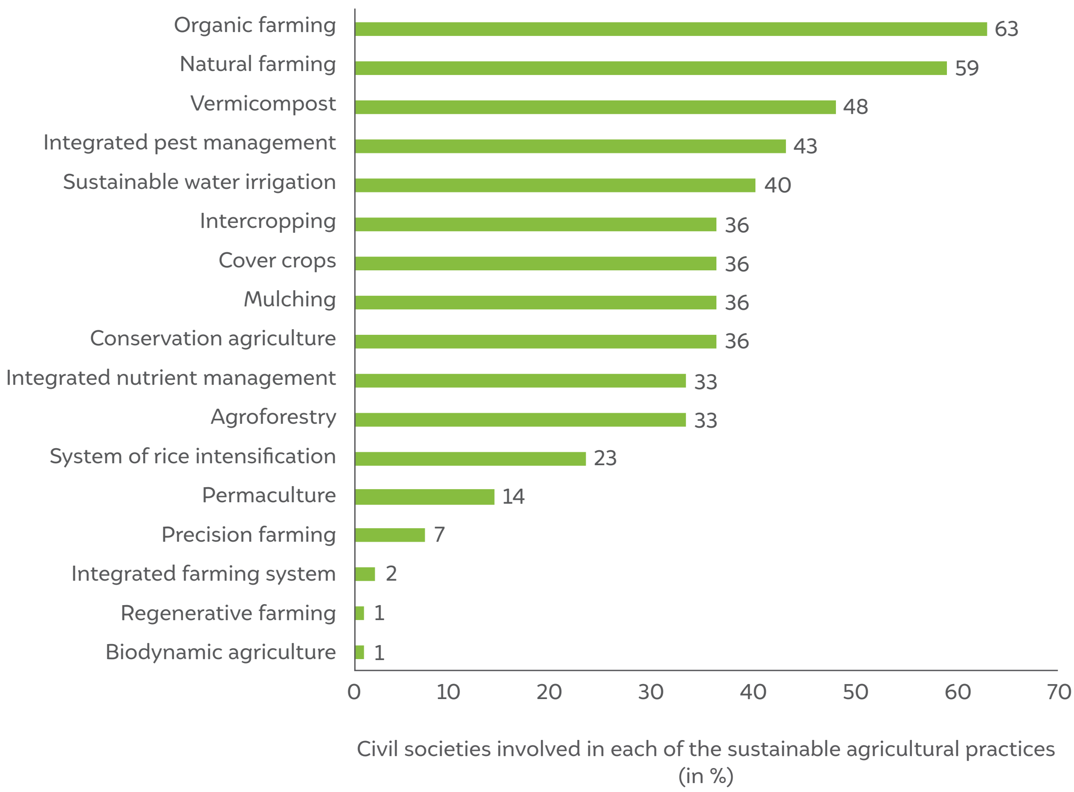

Figure 4

Most CSOs surveyed were found promoting organic and natural farming

Source: Authors' analysis based on CSO survey

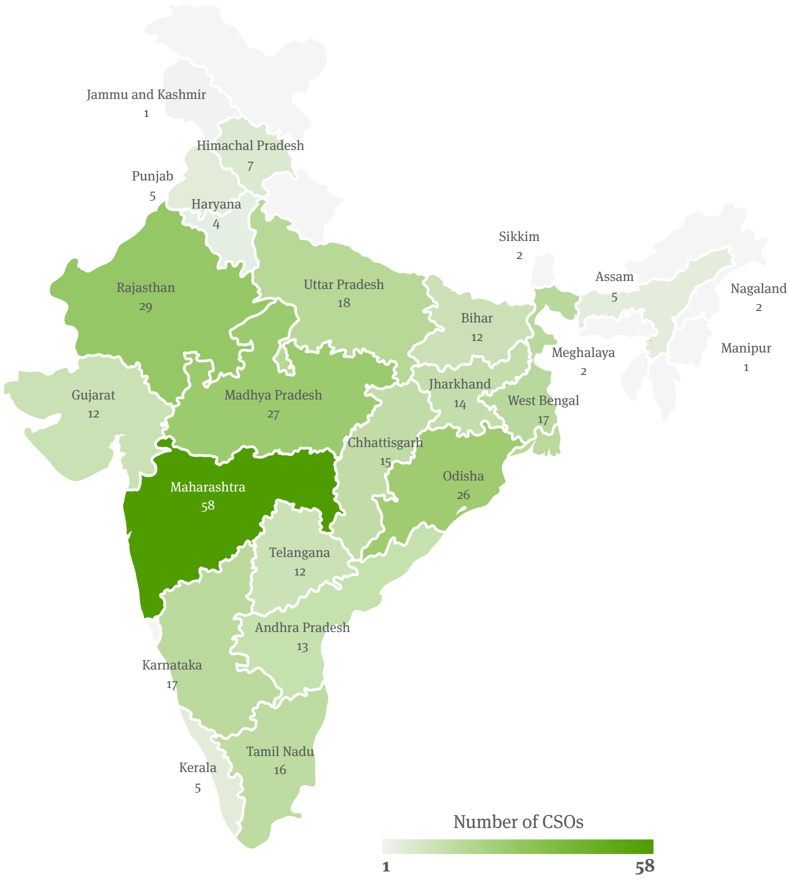

Figure 5
Most CSOs surveyed were active in Maharashtra, Rajasthan and Madhya Pradesh

Source: Authors' analysis based on CSO survey

Barriers to adoption and scaling up

We have identified four main challenges and barriers to the more widespread adoption of sustainable agriculture.

Lack of knowledge and hand-holding

As discussed above, SAPSs are knowledge-intensive. The most prominent challenge farmers face in their adoption is the lack of knowledge and training on these practices adapted to their climatic zones and their available resources.[110] For instance, while scientists may have developed several models of integrated farming systems, the agroclimatic zone, available resources, landholding size, distance and access to markets, and local infrastructure are critical elements determining a farmer's decision to adopt a model and to implement it successfully.[111] Farmers need advice and technical support to translate the scientific models or literature into practical knowledge on the field.

While many civil society organisations, champion or leader farmers, and a few extension services are working with farmers to fill these gaps, they remain insignificant. We need to scale-up such support services at least one or two orders of magnitude to impart change at the desired scale. At the same time, farmers' innovations and experiments and their traditional indigenous knowledge also need to be recognised and valued by scientists and extension workers. Often farmers themselves have the best solutions, and these solutions are best suited to their contexts. Thus, information flow needs to be both top-down and bottom-up.

For their large-scale adoption, the knowledge intensiveness of SAPSs warrants a radical scale up of hand-holding and knowledge sharing support to farmers

Lack of safety nets and incentives

It appears that the transition from chemical-intensive to reduced or no-chemical approaches can lead to lower yields, at least initially. This potential loss of yield is a significant barrier, especially for small farmers and tenant farmers, who depend upon the harvest from one season to the next.[112] Lack of a safety-net in the initial years makes many farmers hesitant to adopt SAPSs at scale. Farmers who are aware of the ecological benefits of SAPSs are more likely to adopt them over the long term, despite the reduced yields in the first few years, but only if they have enough resources and can afford the transition.[113] Lastly, agricultural subsidies and incentives for fertiliser, seeds, and irrigation predominantly focus on conventional agriculture. Apart from irrigation, farmers adopting SAPSs at present do not benefit from these subsidies.[114] The need to give up such benefits is another critical barrier to making the transition.

Lack of safety-nets in the initial years makes many farmers hesitant to adopt SAPSs at scale

Lack of markets for sustainable agriculture products

The lack of well-functioning markets for both SAPSs inputs and final products is another constraint highlighted across most practices.

Most SAPSs promote on-farm locally-made inputs, such as compost, vermicompost, bio inoculants, biopesticides, BDA preparations, green manure, etc. The preparation of most of these inputs is time and labour intensive.[115] While the inputs required for organic and biodynamic farming are becoming more readily available from input shops, the market is not as developed as chemical inputs. The products are expensive due to limited demand and the niche nature of the market. In fact, for many other SAPSs, inputs are simply not available commercially. Lack of readily available organic inputs is a key constraint for farmers, particularly those with large landholdings.

Much like inputs, there is a lack of consistent market linkages to support fair prices for SAPSs products. These products could fetch premium pricing given their chemical-free nature. However, as observed in many SAPSs, limited market access means that farmers end up selling their produce through the usual channels, including local *mandis*, where they rarely realise higher prices.[116] Even in organic farming, where a certification process somewhat ensures that the farmer realises better prices, we observed similar constraints. Despite the certification process (which is often expensive and cumbersome), farmers do not necessarily fetch the premium prices due to a lack of consumer demand for these products (partly due to lack of awareness).[117]

Limited market access means that farmers end up selling their produce through the usual channels, including local mandis, where they rarely realise higher prices

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.

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Annexure

Table A1

Methodology for area and adoption estimates for the SAPSs

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

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

Practices	*Area covered	*Range of farmers
Organic farming	27,80,000 hectares + 14,90,000 million (wild harvest that is uncertified). Out of this, the total area considered for organic farming is 27,80,000 hectares as the wild harvest is not considered. Thus, 2.8 million ha is considered under the practice.	19,00,000 farmers (Certified); no information for uncertified and hence 1.9 million adopters is estimated for the practice.
Natural farming	No information available at the country level. Hence the area estimate calculated is 652,000 hectares in Andhra Pradesh + 6377 hectares in Himachal Pradesh is about 658,377 hectares or 0.65 million hectares. Hence the area under the practice is broadly estimated to be 0.7 million ha.	No reliable info at the country level, thus implementers at the state level are 600,000 (Andhra Pradesh) + 1,16,700 (Himachal Pradesh) + 80,000 (Karnataka) = 796,700 or 0.8 million. Hence the cumulative number of farmers are estimated to be about 0.8 million.
System of rice intensification	Stakeholders consulted have estimated the area under the SRI as around 3-4 Mha. Hence, we take the area as 3 Mha.	The number of farmers who are adopting SRI is estimated to be more than 3 million of them.
Biodynamic agriculture	About 9,131.89 hectares consist of the certified area under BDA and around 60,702.84 hectares is the area provided from stakeholders consulted. Thus, the final area is estimated considering both certified and uncertified area, which is about 69,834.73. Almost 70,000 hectares/0.07 million ha of the area is considered under biodynamic farms which is broadly estimated as 0.1 million.	Based on the sales of biodynamic preparations and self-reports, at least around 1 lakh farmers or 0.1 million farmers are estimated to practise them.
Conservation agriculture	The area for CA is estimated based on the recent methods developed and accepted by CA proponents/experts. Partial CA (where at least one crop has no-till, with or without residue retention), is estimated to be around 2.5 million ha in South Asia. Stakeholders consulted affirmed that around 80-90 per cent of this cited area constitutes the portion under CA in India, which is approximately 2 million ha (considering 80 per cent of the area). Hence, roughly 2 million ha in partial CA is estimated and there is no data on complete CA area, as CA with all the 3 principles hardly tend to be followed in India. **Area of partial CA in South Asia referred from:** Jat et al. (2020).	If the area under CA-based systems is around 2 million ha as estimated, then dividing this with the average landholding size, i.e., for Punjab (3.62 hectares) and Haryana (2.20 hectares) where CA is mostly practised can give rough estimates of the farmers practising CA in the country. As farmers practising CA are mostly medium to large farmers, thus we assume the landholding size of Punjab/Haryana to be a more appropriate measure than the national average landholding size of 1.08 hectares which is small. Hence: Average landholding size of Punjab/ Haryana: (3.62 hectares+2.20 hectares) =5.82 hectares 5.82 hectares/2=2.91 hectares Hence the number of adopters: Area (2000000 million ha)/Average landholding size (2.91 hectares) = 6,87,285 number of farmers, which is broadly ~700000 of them (0.7 million or close to 1 million).
Integrated farming systems	Reliable estimates are not available for the country, however, around 52,078.94 hectares/0.05 million ha was achieved under different IFS activities as per the NMSA. Stakeholders consulted have estimated the area as less than 0.1 million ha.	The number of adopters is broadly estimated as tens of thousands, around 0.1 million of them.

Table A1 contd

Practices	*Area covered	*Range of farmers
Permaculture	This farming type covers very little area, of less than 0.05 million ha.	The stakeholders consulted estimated the range to be around 0.01 million farmers.
Precision farming	The area under precision farming is considered by taking the area under micro-irrigation techniques as it is the most widely used PF methods in the country with an area of around 9205473 ha/9.2 million ha spread over 29 states as per DAF&FW estimates as on 31.03.2017. Out of this drip irrigation accounts for 4.2 million ha and sprinkler irrigation covers 4.9 Mha. Other PF techniques cover insignificant area, such as farmers in the North have adopted the Laser land levelling PF technology in more than 10,000 acres (4046.856 ha) in western Uttar Pradesh and Haryana. Area source: (DAC&FW 2017, refer pg 61)	If the area under PF systems is 9.2 million ha as estimated, then the range of farmers who are adopting PF is calculated by dividing the area with the landholding size of the implementers. Since the practice is mostly popular among semi-medium to medium landholders and large land-holding farmers, which ranges from 3 ha and above. For our analysis we assume 3 ha as a safer estimate to calculate the adopters. By this methods we broadly estimate around 3 million implementers to practise PF, especially micro-irrigation activities. Area: 9.2 million ha Landholding size: 3 hectares No of adopters: 9.2 million ha/3 hectares = 3.06 million farmers
Agroforestry	As per the literature and stakeholders consulted from ICAR-CAFRI, estimate the current area under agroforestry as 25 million ha which covers the 15 agroecological zones of the country.	From the ICAR-CAFRI stakeholder consulted, it was found that a small amount of the area is under industrial plantations (nearly 1 million ha). Thus, we assess the number of farmers by taking the area of 24 million ha under agroforestry farming systems. Assuming that most of the adopters are medium to large holder farmers, who generally have landholdings that range from 4 hectares and above. Thus, we consider around 5 hectares as the best approximate to calculate the adopters. By such methods we get around 5 million of farmers adopting agroforestry. Area: 25 million ha Landholding size: 5 hectares No of farmers: 25 million ha/5 hectares = 5 million farmers
Integrated pest management	As per stakeholders consulted at ICAR-NCIPM, an estimated area of around 3-5 per cent of the cultivated area is under IPM. Hence, 3-5 per cent of the net sown area of the country (140 million ha) is around 4.2-7.0 million ha and broadly the area under IPM is assumed to be around 5 million ha.	From the data that was available, we found at least 3.2 per cent of the farmers around the country practised IPM in 2010. According to an estimate done by the population census 2011, the number of cultivators in India is around 11.8 crore (118 million). Thus, we determine that the 3.2 per cent of the IPM farmers out of the total cultivators to be around 3.7 million, broadly 4 million of them. (3.2*118/100) = 3.7 million farmers. Post 2010, we find that farmers are increasingly employing evolving technologies and farm practices to enhance efficiency and reduce costs, thus we expect the adopters as of present to stand at around 4-5 million of them.
Crop rotation	The area under crop rotation is estimated to be around 15.11 million ha (excluding rice-wheat, rice-rice, sugarcane-ratoon) as communicated by the stakeholders consulted at ICAR- IIFSR, Modipuram. While the stakeholders at NRRI, Odisha allocate around 16 million ha under rice-based cropping systems. Hence, the total area estimated under crop rotation is around 30 million ha, which includes cereal-cereal based rotation.	According to the stakeholders consulted at ICAR – IIFSR, Modipuram, around 12-15 million farmers are implementing crop rotation practices in the country.

Table A1 contd

Practices	*Area covered	*Range of farmers
Intercropping	Stakeholders consulted at ICAR-IIFSR, estimate the area under intercropping to be around 1 million ha in the country, however, this excludes intercropping in horticultural crops.	As per stakeholders consulted at the ICAR – IIFSR, about 0.70 to 0.90 million farmers are practising intercropping in the country.
Cover crops	Cover cropping is mostly done in plantation crops like arecanut, coconut, which spreads in about 3.88 million ha in India, while still less than 50 per cent of this figure constitutes the area under cover crops which is around 1.94 million ha. These are the estimates provided by the stakeholders consulted at the ICAR-IIFSR, Modipuram.	From the stakeholders consulted at the ICAR – IIFSR, at least around 1-2 million farmers have adopted cover crop practises in their farms.
Mulching	Stakeholders consulted at ICAR-IIFSR, estimate the area under mulching to be around 20 million ha. This estimate is based on the assumption that the total crop residue available is 634 Mt/year, and the majority of this crop residue is used for, (but not necessarily limited to) as fodder for cattle feeding, bio-manure, thatching for rural homes and fuel for domestic and industrial use. Despite these uses, there is a surplus of about 178 Mt of crop residues around the country that is available for incorporation into the soil. Out of which 92 Mt/year is burnt leaving a balance of 86 Mt available for mulching. Hence: Total Crop residue availability = 634 mt/year Net sown area = 140 million ha Therefore, the crop residue available per hectare is (634/140) = 4.5 t/yr/ha As the balance available for mulching = 86 mt/year therefore, The total area of mulching is (86/4.5) = 19.11 million ha (~20 million ha).	As per stakeholders consulted at the ICAR–IIFSR, mulching practices are more popular among medium to large scale farmers with landholdings size of 4 hectares and above. Thus, we consider 4 hectares as the best (safer) approximate to calculate the adopters. Considering the area of ~20 million ha and land-holding size of around 4 hectares, we broadly estimate around 5 million farmers who practise mulching in the country. (20/4) = 5 million farmers.
Contour farming	There is a lack of reliable national estimates for contour farming as it is mostly done in hilly terrain and no national level studies are undertaken till date. However, stakeholders consulted from few states provide the numbers as around 50,000 ha in Sikkim, covering the whole state and about 0.50-1.0 million ha is under contour farming in Karnataka. As the practice is carried out in several states (atleast 19), we assume a formidable estimate of 1-3 million ha across the country.	Again, State level sources have given around 35,000 of them practising contour farming in Sikkim. While in Karnataka, about less than 30 per cent of large-scale farmers and 5-10 per cent of small and marginal farmers follow the practice in the state. However, as the practice expands across several states, the scale of adoption is assumed as less than 3 million of farmers who have adopted the practice.
Rainwater harvesting-artificial recharge to groundwater	A lack of reliable countrywide dataset is lacking on area estimating for RWH activities, as assessed from the literature and validated by stakeholders at CGWB, WoTR. Thus, the area is estimated from the area allocated under the Integrated Watershed Management Programme (2009-10 to 2014-15), which is about 39.07 million ha. Water conservation is an inherent aspect of these watershed programs, as communicated by a CGWB stakeholder, it is safe to presume about 50-70 per cent of the area would have taken care of harvesting water or water conservation in the area of 39.07 million ha. This leads to a rough estimate of around 20-27 million ha under water harvesting activities in the country.	No reliable information available, but it is usually medium to large farmers who see the benefits of undertaking these water harvesting practices, while smallholder farmers are wary of devoting their small farms to ponds with not enough land available for cultivation purposes. Thus, we assume the area of around 25 million ha from the earlier estimate of 20-27 million ha and the practise being popular mostly among medium to large farmers. Medium to large scale farmers mostly have a farm size of 4 hectares and above and we reckon 5 hectares as a reasonable estimate to calculate adopters which gives around 5 million farmers practising water conservation activities in the rural areas.

Table A1 contd

Practices	*Area covered	*Range of farmers
Floating farming	No information available on a national scale, as the practice has a negligible presence in area and adoption. Though the RCDC stakeholders mention a floating pond can consist of 1 hectare, the area seems to be inconsistent (varies from pond to pond) and negligible (as not all of the ponds in the projects were constructed). According to them, at least 4 ponds were constructed in Odisha hence (1*4= 4 hectares) only around 4 ha of coverage in Odisha, which is insignificant.	According to the SWAD stakeholders, about 145 poor landless families in Odisha are involved in floating farming activities and they seem negligible while in Assam, the numbers are given in terms of project beneficiaries and hence no sense of the actual implementers, though, the overall figures are still insignificant.
Vermicompost	As per the NCOF estimates, 3.5 million ha of area covered under vermicomposting for 19 states in the country (NCOF 2010). However, it was challenging to find reliable estimates of recent data under the practice.	Stakeholders consulted at ICRISAT, have roughly estimated the numbers of farmers who have adopted vermicompost in the country to be around 1-1.5 million.

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

Image: iStock

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