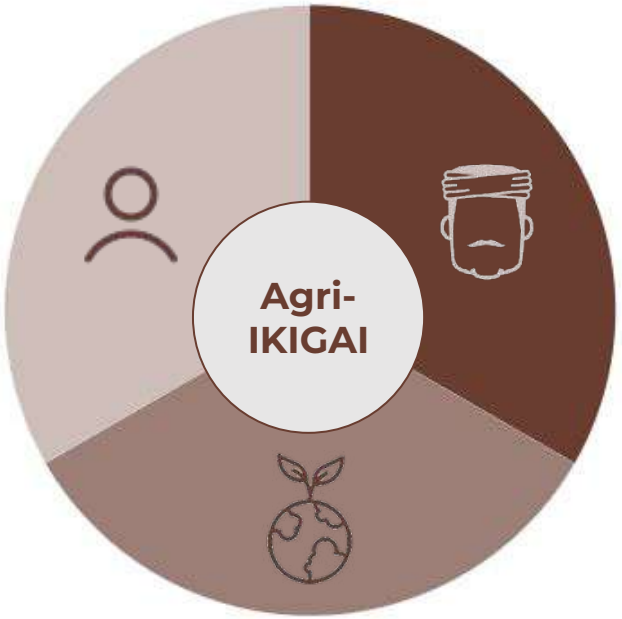
Agri-IKIGAI Solutions

THE/NUDGE INSTITUTE

This work is licensed under a Creative Commons Attribution - No Derivatives 4.0 Unported License

Agri-IKIGAI Concept

Agricultural solutions which are financially beneficial to the **farmer** and good for the **environment** and the **consumer**

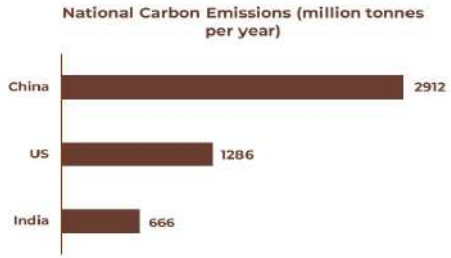


Preface 1/3

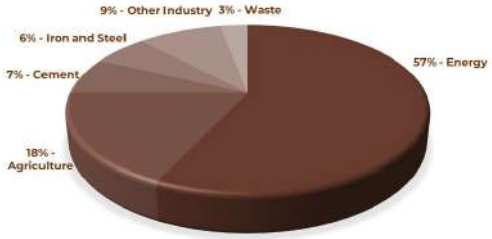
The Nudge Institute (T/NI) seeks to alleviate poverty within our lifetime. The Transforming Agriculture for Smallholder Farmers (TASF) program within T/NI aims to double income and reduce income variability for 10 million smallholder farmers[1] in a financially and environmentally sustainable manner. It aspires to do this by identifying and/or developing innovative interventions and business models and using the vibrant agricultural private sector to scale these solutions.

Smallholder farmers (who account for 27% of the farming population and cultivate 25% of our land) face a host of barriers to increasing their incomes which includes use of non-scientific practices, the presence of high input and labor costs, lack of good market access, etc. But a major consideration is climate – in our earlier research[2], 63% of smallholder farmers cited climate as their top concern and 70% of them experienced crop loss due to variations in weather. Agriculture is also a major contributor to climate change. It accounts for 18%[3] of greenhouse gas emissions, and this is only going to increase as our population increases, consumption increases and other sources of emissions decrease. It is therefore critical to address the impact of agriculture on climate. Given the financial situation of the smallholder farmer, it is difficult to expect them to change to agricultural practices that may be better for the environment but will reduce their income or have them take more risk.

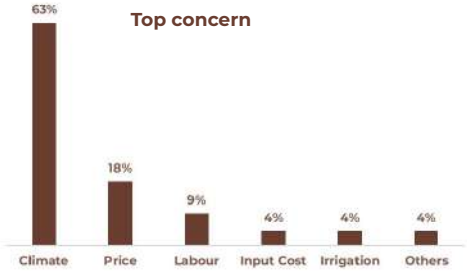
India is the 3rd largest emitter of GHG



18% of these emissions come from Agriculture including Livestock



Farmers state Climate Change as their top concern



1 - Smallholder farmers are defined as farmers who owned 1-3 acres of irrigated land or 3-7 acres of rainfed land and typically earned a sizeable proportion of household income from farming.
2 - Small Farmers Big Opportunities. (2022). Published by The Nudge Institute.
3 - Sapkota T.B. et al. (2019). Cost-effective opportunities for climate change mitigation in Indian agriculture.

Preface 2/3

TASF's "Agri-IKIGAI" initiative is working on both sides of the climate challenge: i.e. understand the impact of climate change on smallholder farmers as well as identify solutions to alleviate the impact of farming on climate.

To understand the impact of climate change on smallholder farmers, it has conducted primary research to bring out the voices and experiences of smallholder farmers. It will use its network to share findings among relevant stakeholders (e.g., think tanks, government, civil society and academia) to bring the voice of the smallholder farmer to the forefront. We hope that these stakeholders will incorporate the farmer perspective in their work - including intervention and practice development, propagation, and policy recommendations.

To alleviate the impact of climate on farming, it has identified 13 **"Agri-IKIGAI Solutions"** that are good for the environment and the consumer and financially beneficial for the farmer. It will use its networks to disseminate these practices to stakeholders including think tanks, philanthropies, academia, governments, NGOs, formal private sector companies involved in agriculture, Agri-tech startups, etc. It will also work on scaling these practices by doing pilots in partnership with commercial partners, getting them to start spreading these practices to their networks of farmers and becoming role models for other private sector players to emulate.

This report (published in August 2023) highlights the 13 Agri-IKIGAI solutions identified by the TASF team through a six-month research effort including interactions with 70+ experts and organizations, secondary research and field visits.

Preface 3/3

This report will be directly relevant to stakeholders working at the intersection of agriculture and climate change. We hope it will also stimulate thinking and interest from other stakeholders in agriculture to consider the environmental impact of agriculture and ways to minimize the same. We are sharing examples of how stakeholders could use this report.

Philanthropies

Philanthropies working in the environment and climate space can fund organizations that can help farmers adopt these practices. Adoption of these practices will be easier as they make economic sense for the farmer.

Private Sector Organizations

Private Sector organizations who are connected with procurement and are interested in sustainability goals or work with minimum residue products can help in the adoption of these practices by creating a demand for products that use Agri-IKIGAI farming methods. E.g. Chilli buyers can help in the adoption of IPM which will decrease pesticide residue in the end produce.

NGOs

NGOs can work on the adoption of these practices. One of the common barriers to the adoption of different practices by farmers is economic viability. Since Agri-IKIGAI practices make economic sense to the farmer, it should be comparatively easier to help in their adoption.

Government

Government can help with enabling more research on the effectiveness of upcoming and promising Agri-IKIGAI practices like Biostimulants/ PROM fertilizers and can bring in policies/schemes which can help in the adoption of Agri-IKIGAI practices. For e.g., there is an opportunity to improve access to subsidies for Drip Irrigation.

About this Report

Our goal in the report is to highlight a **range** of “good” solutions that would get players thinking about these types of solutions i.e. “good for the environment, consumer and **financially beneficial for the smallholder farmer**”. This list is not exhaustive nor the “best” set of solutions. We look forward to other players finding more and better solutions.

Most of the Agri-IKIGAI solutions are well known and the focus of this report, in addition to highlighting the environmental impact, is understanding the economic benefit to the farmer and observations from the ground.

Acknowledgements

Partners

This report has been written after speaking to 70+ organizations and experts. The organizational profile is spread across ~30 private sector companies, ~30 civil society organizations and ~11 research and scientific entities. We have had multiple conversations with many of these organizations/experts and are sincerely grateful to them for their inputs. We have acknowledged them in the upcoming section.

We would also like to acknowledge the ongoing strategic support of KPMG Global Services.

Finally, and most importantly, we would like to express our deepest gratitude to Rituj Sahu and Deepali Khanna of The Rockefeller Foundation. In addition to financially supporting the research, they have been true thought partners throughout the journey.

Team

Our team comprised of Shruti Soumya, Ashish Karamchandani, Medha Ojha, Shalini Gupta, Prem Prasad, Ankur Sanghai, and Rupal Saxena.

Organization/Expert Connects

Organization/Expert Connects



Other Expert Connects:

Kapil Ingle B.B. Singh A. Daniel Anand Raj K. Gangadhar

Scope of Work

- We have not restricted the impact to a component of the environment i.e. soil, air or water etc. We have kept the scope broad and have considered solutions that have a net positive impact, e.g., in DSR, there is large reduction in GHG emissions though there is some increase of weedicides.

- We have not specifically quantified the impact on the environment in terms of a metric like reduction in GHG emissions or reduction in water usage. We look forward to collaborating with players interested in this work to take this ahead.

- Agri-IKIGAI Solutions should be good for the environment and the consumer. As we started our project, we realized that in general, solutions that are good for the environment are inherently good for consumers too. But the relative and specific impact of each practice from a consumer lens could not be included in the scope of the work. We look forward to other players doing more work on this aspect of the Agri-IKIGAI concept and shall be happy to collaborate with them.

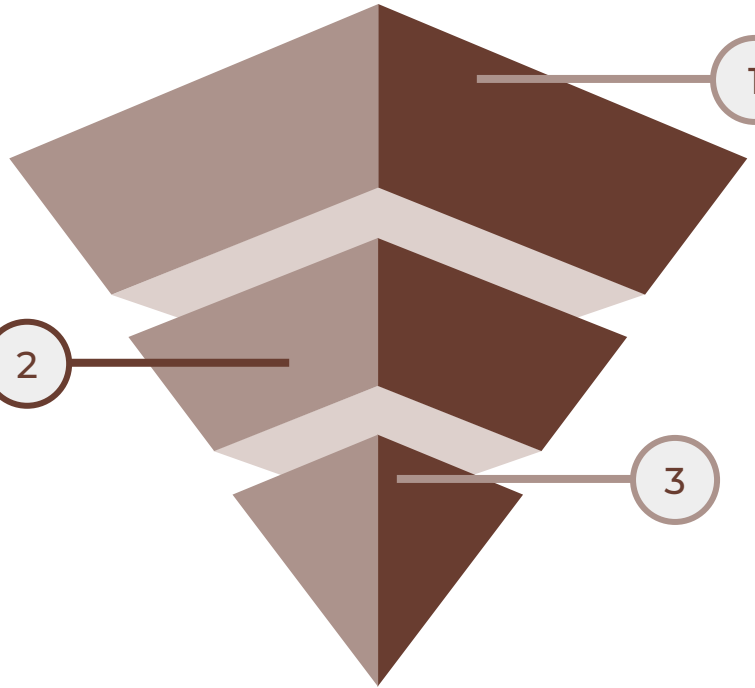
- We have focussed on finding impactful solutions that impact a significant number of smallholder farmers and have not restricted ourselves to a geography or a crop. So some solutions work across crops and geographies (e.g., PDM and PROM), while others are crop specific (e.g., DSR), but all solutions impact a significant number of farmers.

- The scope of our work is limited till the harvest stage of cultivation and we have not considered solutions post harvest.

- Agri-IKIGAI solutions could be either individual practices (e.g., Seed treatment) or overall systems (e.g., Integrated Pest Management). We have not limited ourselves to a single level as we felt that it's important to highlight solutions that we feel work best.

Methodology

We followed a funnel approach:



1

Initial List of 47 Solutions

We came across a pool of potential solutions through secondary research and conversations with experts.

2

Intermediate 19 Solutions

Additional primary research supported by secondary research findings led to narrowing down the pool to 19 intermediate solutions.

3

Final 13 Solutions

For the shortlisted 19 solutions, we invested in further conversations with experts and conducted field visits to arrive at the final 13 Agri-IKIGAI solutions.

Criteria For Shortlisting Solutions

Application to Smallholder Farmers' Context	We have only considered solutions that are suitable for smallholders farmer's context.
Economic Feasibility	Solutions should make economic sense for the farmer in both short term (1 year) and long term.
Environmental Impact	The solutions have a net positive environmental impact.
Scale	The solutions should have the potential to impact a large number of farmers.
Maturity of Solution	We chose mature solutions where there has been significant experience in using them.

Step 1 - Initial List of Agri-IKIGAI Solutions

- Agroforestry
- Alternate Wetting and Drying
- Biodynamic Agriculture
- Biofertilizer
- Biostimulants
- Border and Trap Crops
- Canopy Management in fruit crops
- Conservation Agriculture
- Contour Cultivation
- Crop Diversification
- Crop Rotation
- Cultivation by Broad Bed Furrow method
- Cultivation of citrus crops on broad ridges
- Direct Seeded Rice
- Floating Farming
- Foliar Spray
- Furrow Opening
- Improved Seeds
- Incorporation of Biomass
- Integrated Farming System
- Integrated Nutrient Management
- Integrated Pest Management
- Integrated Weed Management
- Intensifying Fallow Land
- Intercropping
- Large Farm Ponds (Non-Plastic Lining)
- Mechanization of Farming
- Micro Irrigation
- Natural Farming
- New Variety of Fodder Crops
- Non Puddled Transplanting Rice
- Organic Farming
- Organic Mulching
- PDM and PROM Fertilizers
- Permaculture
- Precision Farming
- Rainwater Harvesting
- Residue Management
- Rice Crop Management
- Seed Treatment
- Soil Testing & Remediation
- Solar Power
- Sprinkler Irrigation
- System of Crop Intensification adopted in Finger Millet
- System of Rice intensification
- Urea Deep Placement Machinery
- Vermicomposting
- Zero Tillage Machinery

Note: We sourced these practices from various organizations and experts and have listed the names here verbatim. There are some overlaps which we have accounted for as we moved forward.

Step 2 - Intermediate Solutions

We chose practices at this stage basis additional secondary and primary research. Each of these practices was recommended by multiple experts.

- Alternate Wetting and Drying
- Biofertilizers
- Biostimulants
- Crop Diversification
- Direct Seeded Rice
- Improved Seeds
- Integrated Nutrient Management
- Integrated Pest Management
- Integrated Weed Management
- Large Farm Ponds (Non-Plastic Lining)
- Micro Irrigation
- Organic Mulching
- PDM and PROM Fertilizers
- Seed Treatment
- Soil Testing and Remediation
- Solar Power
- Urea Deep Placement Machinery
- Vermicomposting
- Zero Tillage Machinery

Step 3 - Final Agri-IKIGAI Solutions

We identified solutions that are either methods of farming or are at different stages of farming.

Farming Approach/Method:

1. **Direct Seeded Rice**
2. **Crop Diversification**

Stages of Farming:

Land Preparation

3. Soil Testing and Remediation
4. Zero Tillage Machinery

Seeds

5. Seed Treatment
6. Improved Seeds

Crop Nutrition & Application

7. Biofertilizers
8. Biostimulants
9. Urea Deep Placement Machinery
10. PDM and PROM Fertilizers

Irrigation

11. Large Farm Ponds (Non -Plastic Lining)
12. Micro Irrigation

Crop Protection

13. Integrated Pest Management

Highlights of the Final 13 Agri-IKIGAI Practices

Direct Seeded Rice:

Current method of rice cultivation with transplanting and flooding is the second largest cause of agricultural GHG emissions. DSR, an alternate method to transplanting, is a well-proven approach which with appropriate weed control can significantly reduce emissions, address labor availability issues and increase incomes for farmers in rice-growing areas like Punjab and Haryana. Given that there are already farmers practicing DSR in these areas, machines are available for laser leveling and sowing seeds along with access to subsidies, there is an opportunity to accelerate adoption by players who are interested in outsize climate impact (CSR and Philanthropy) and buyers who are interested in achieving their sustainability goals or interested in procuring sustainable produce.

Crop Diversification:

Mono-cropping, practiced in many parts of the country, leads to an increased prevalence of pests and diseases and depletion of soil nutrients. Even crop rotation when practiced is often suboptimal. Appropriate crop rotation and intercropping is a simple approach to improving incomes and the environment.

KVKs and agricultural universities can help identify effective local cropping patterns (keeping in mind access to markets) and NGOs can help with the dissemination of these crop patterns. Private companies like buyers with access to farmers can also help in adoption through advisory and procurement.

Soil Testing and Remediation:

Many farmers tend to use chemical fertilizers sub optimally, damaging the environment and also spending more than they need to. A soil test recommends optimal macro fertilizer dosage with some additional secondary/micro-nutrients resulting in better yields and often lower costs. This also reduces environmental damage and, in the long term, can lead to potential savings in government subsidies. New agri-tech start-ups and digital public infrastructure will make it easier to get accurate soil data and help in the adoption.

There is an increasing reach of players engaging/trusted by farmers (e.g., NGOs, direct procurers) and it is in their self-interest to increase farmers incomes/sustainability, so they can promote soil testing and remediation.

Highlights of the Final 13 Agri-IKIGAI Practices

Zero Tillage Machinery:

Tilling as practiced currently, can sometimes be excessive, leading to unnecessary soil erosion and loss of important nutrients and organic matter present in the soil. Zero tillage machinery, which causes minimal soil disturbance and places seeds and fertilizer in the soil can address these issues and can be effective for some crops and agro climatic situations.

There is an interesting and large opportunity to use Zero tillage machinery in rice-wheat growing regions like UP, Punjab, and Haryana where it will reduce plowing costs and allow for earlier planting (with potentially less loss due to climate issues). It will require getting tractor owners who currently provide plowing and related services to buy these machines and provide zero tillage services to smallholder farmers. Given the economic benefit to farmers, it could be possible to get CSR and philanthropies working on climate change to seed this practice and let it scale on its own.

Seed Treatment:

Seed treatment with fungicides, insecticides, and biofertilizers is a low cost solution that leads to improved germination, more robust seedlings, uniform crops, and less pest and disease attacks. Commercial seeds are typically treated with fungicides and some farmers treat non-commercial seeds with fungicides. There is therefore an interesting opportunity for farmers who are not treating non-commercial seeds to use fungicides and for all farmers to do seed treatment with biofertilizers and appropriate insecticides.

Given the increasing number of players interacting with farmers (e.g., input providers, advisory organizations, and buyers) they can be effective in securing and disseminating information about these practices and promoting their adoption.

Highlights of the Final 13 Agri-IKIGAI Practices

Improved Seeds:

Farmers are looking for ways to increase yields and deal with increasing challenges due to changing climatic conditions and pest and disease attacks. Improved seeds can be a convenient way to deal with some of these issues.

There can be good improved seeds that are not available to farmers, including open-pollinated varieties produced by agricultural universities and scientific institutions. Input companies can source these seeds from commercial providers or partner with agricultural universities and scientific institutions to make these available to farmers.

Also, often farmers may not know about the most suitable seed for their crop and context, therefore, KVKs, NGOs and private players like buyers who engage with farmers can spread awareness about appropriate seed varieties.

Biofertilizers:

Farmers are using chemical fertilizers to meet the nutrient requirements of the plants. However, only a limited amount of nutrients from these chemical fertilizers (30–40%) is absorbed by the plants, and the rest gets bound to soil or is lost as runoff to nearby water bodies or escapes to the atmosphere.

Biofertilizers make the already available nutrients in the soil or atmosphere accessible to the plants thereby reducing requirements for chemical fertilizers. They are available in the market at reasonable prices, hence, do not significantly increase the input cost.

There is an opportunity for scientific institutions to research the extent to which biofertilizers can replace chemical fertilizers and lower costs. As they are low-cost and good for the environment, NGOs and KVKs can promote their adoption. The lower cost will also lead agri advisory companies to include biofertilizers as part of their fertilizer recommendation and give a lever for manufacturers to promote usage.

Highlights of the Final 13 Agri-IKIGAI Practices

Biostimulants:

Farmers are encountering challenges like climate change resulting in crop losses, a rise in pest and disease attacks, and low fertilizer use efficiency.

Biostimulants are a category of product that works on crops' physiological processes to help plants increase immunity against pests and disease, gain stress tolerance against climatic changes and improve nutrient use efficiency.

There is an economic opportunity for agri-input companies to include biostimulants in their portfolios and invest in raising awareness around its benefits amongst farmers. Also, since this category of products is new to the market, there is a need to conduct more research to understand the effectiveness of these products including the extent they can reduce the use of chemical fertilizers.

Urea Deep Placement Machinery:

Urea is the most commonly used, and often overused, fertilizer. It is typically broadcast and a large amount of it is lost to the atmosphere and leaches into the soil/water causing significant environmental damage.

UDP machinery places easily made urea briquettes in the root zone. The briquette format allows for slow release of Urea and the deep placement allows for efficient nutrient uptake by plants, which reduces fertilizer required, reduces GHG emissions and leaching, and increases yields resulting in increased income for farmers.

While still new, it has tremendous potential as urea is one of the largest causes of environmental damage. Buyers that have close relationships with farmers (e.g. Sugarcane industry where the technology is proven to increase productivity) can promote the adoption of this practice among their farmers including supporting the initial introductions of the machines.

Highlights of the Final 13 Agri-IKIGAI Practices

PDM and PROM Fertilizers:

Science-based approaches to agriculture recognize that plants need nutrients. The conventional approach uses chemical fertilizers, sometimes overused, that meet these nutrient needs but cause damage to the environment including the soil.

PROM and PDM provide plants with two core nutrients (Phosphate and Potassium respectively) without the harmful effects of chemical fertilizers and in fact, improve the soil through the introduction of microorganisms. The cost is similar to chemical fertilizers but current production has variable quality. There is an economic opportunity for scale players like fertilizer companies or input providers to manage quality control and promote this product.

Large Farm Ponds (Non-Plastic Lining):

51% of net agricultural land in India is rainfed. The lack of irrigation reduces the amount of crop that can be grown in a piece of land coupled with the inability of farmers to handle unpredictable rains (which is becoming an increasing issue with climate change).

Large farm ponds with low-permeability soil lining are a relatively low-cost and effective way to address the irrigation issue for smallholder farmers in low-permeability soils. Unlike the typical government small farm ponds, the volume of water in large farm ponds is enough to address their irrigation needs. Also since they do not have a plastic lining, the cost is significantly lower and maintenance is easy.

The Deshpande Foundation has developed an effective model where a 100x100x12’ pond costs Rs 80-100,000. With about 75% financing from SBI using a JLG structure, the farmer can see a positive income increase from the first year. The Deshpande Foundation has constructed 6000 such ponds and is now actively working to scale the model through NGOs. Given it is one of the few solutions to address the irrigation issue, other stakeholders like CSR and philanthropy can support scaling and the government can also include this model in their programs.

Highlights of the Final 13 Agri-IKIGAI Practices

Micro Irrigation:

Water scarcity and groundwater depletion are major challenges for farmers in India. Conventional flood irrigation has a very poor water use efficiency of only ~30%. Drip and Sprinkler Irrigation are two alternatives to flood irrigation that ensure high water use efficiency. Drip irrigation places the water or fertilizers (a process known as fertigation) in the root zone of the plant leading to yield improvement and reduced fertilizer requirements. Sprinkler irrigation sprinkles water over the plants (like natural rainfall) across the field resulting in yield improvement and making the plant resilient to heat.

Despite the subsidies provided by the government, its adoption still remains low among smallholder farmers because of the high upfront costs and issues in getting the subsidies. Agri-finance companies can help adoption by providing credit to farmers to adopt micro irrigation. There are also new low-cost solutions that fit the requirements of smallholder farmers.

Integrated Pest Management:

Farmers can face huge crop losses due to pest & disease attacks and these have been increasing in the last few years. Chemical pesticides have been the mainstream way to deal with this issue.

Integrated pest management can be a cost-effective and environment-friendly way to tackle the issue of pests. It involves biological, mechanical, cultural, and chemical methods that farmers can implement in different combinations. However, it is a knowledge-intensive practice and requires advisory & training.

There is an opportunity for buyers who procure low-pesticide produce to provide farmers a premium for the IPM produce and also support with advisory. These companies can also collaborate with input companies that provide tools like pheromone traps, light traps, sticky pads, etc. to support the practice.

Final Agri-IKIGAI Solutions

The following section contains details on the final solutions:

Farming Approach/Method

Direct Seeded Rice

Paddy is traditionally grown using transplantation and flood irrigation techniques. This technique requires the field to be continuously flooded with water, and this constant presence of standing water in the field releases methane gas into the environment. Rice is one of the largest sources of agricultural GHG emissions.

Direct Seeded Rice (DSR) is a well-researched practice in which rice seeds are sown directly into the field instead of first growing the seedling in a nursery and then transplanting. DSR does not require standing water as well; instead, the only requirement is for the farmland to remain moist. One of the challenges with DSR is weed germination. In transplanting, standing water naturally suppresses weed growth. However, we observed that by following the right package of practices and applying the appropriate weedicides at the right stages, weeds no longer seem to be a problem.

Direct Seeded Rice

DSR requires less labor & less water. The increasing difficulty of getting labor at the right time and the cost of labor make DSR attractive. Some farmers also have limited access to water and this makes DSR (at least on some of their land) a go-to alternative. Lastly, in large paddy-growing areas like Punjab and Haryana, the government provides grants to farmers who practice DSR.

Our conversations with practitioners and players on the ground indicate that there seem to be some farmers (maybe a few percent) who have started using DSR on an ongoing basis in areas such as Punjab and Haryana. There also seems to be the availability of the machinery required for DSR (seed drills, happy seeders, etc).

DSR seems to be a practice that has a high positive environmental impact potential and core factors that could drive adoption seem to be in place in high-priority areas like Haryana and Punjab.

Direct Seeded Rice

Benefits to the Environment

- Methane emissions are one of the biggest contributors to global warming and DSR leads to a reduction in these emissions.[1]
- DSR saves up to 25% of water because flooding of fields is not required.[1]
- Up to 27% of energy (diesel) is saved in DSR because pumping requirements for field preparation, nursery raising, puddling, and continuous irrigation are avoided.[1]
- Lesser fertilizer usage in DSR improves soil health. DAP usage drops because DAP is applied directly with the seed using machines like a zero till machine or seed drill (instead of broadcasting) which ensures more efficient absorption.[1]

Benefits to the Farmer

- DSR when compared to transplanting, leads to a net cost saving of ~INR 6500 per acre (35% reduced cost from transplanting) in Punjab & Haryana. This includes a reduction in labor cost in puddling & transplanting of INR 2600 per acre, and also a subsidy of INR 4000 per acre.[4]
- Early maturity of crops by 7-10 days in DSR reduces the risk of lodging (bending of crops) and helps in the timely sowing of succeeding crops.[1]

1 - Sharma, S et al. (2019). A compendium of technologies, practices, services and policies for scaling climate smart agriculture in Odisha (India).
2 - Lather, V.S. (2022). TAR VATTAR DSR: An eco-friendly weed-control and water-conservation technology for direct-seeded rice.
3 - Conversations with experts
4 - TASF field visit in Haryana

Direct Seeded Rice

Observations from the Ground

TASF team did field visits to UP and Haryana. We observed:

- In Prayagraj, UP with Sehgal Foundation
  - DAP usage drop by ~20%
  - Farmers happy with line sowing & observed improved grain health
- In Kaithal & Karnal, Haryana with WRMS
  - Yield similar or slightly less
  - DAP usage is almost similar

In both the locations, we saw that weeds, which are usually mentioned as a challenge in DSR, were easily handled by the farmers using weedicides. In Haryana, farmers were also able to avail subsidies from the government to practice DSR.

Challenges in Adoption

- DSR may not be adopted by farmers who don't have any irrigation source because water is essential at specific times after sowing.
- Farmers are resistant to changing their conventional ways of growing rice. Farmers tend to get anxious when visual appearances of DSR are inferior to transplanted rice for the initial few days.[1]
- DSR practice has higher weed infestation as compared to the transplanting method. However, even though the weeds can be managed by using weedicides, farmers aren't confident. There is also a risk of using the wrong weedicide which might also lead to a higher cost of production.[1]
- The unavailability of equipment such as seed drills & laser levelers in some regions leads to lesser adoption of DSR.[1]

1 - Conversations with experts

Direct Seeded Rice

Potential Opportunity

We find the practice powerful from two perspectives - increasing incomes for farmers and reducing the high negative environmental impact of growing rice. In places like Haryana and Punjab where the practice is known, some farmers are already using it on an ongoing basis. Equipments like seed drills and laser levelers are available, subsidies are relatively easy to get, so the core enablers seem to be in place. There is, therefore, an opportunity to help adoption at a wider scale. CSRs and philanthropies working on climate change who see the benefit of DSR in reducing emissions and saving water could fund NGOs to spread awareness about DSR and promote adoption.

DSR can help private procurers interested in sustainably grown rice and/or who have internal sustainability goals meet these needs. These players can therefore incentivize farmers to grow rice using the DSR method. This would lead to an increased market demand for DSR produce which can help solve the key issue of adoption.

Farmers who are practicing DSR are able to manage the increased incidence of weeds by timely usage of weedicides.

“I started doing DSR because of water and labor scarcity in my village. I have been doing it for a few years, and I have been able to manage the weeds through the use of the weedicides.”

Crop Diversification

Monocropping is practiced in many parts of India. This can lead to an increased prevalence of pests and diseases which along with risks due to climate variability can lead to damage of the entire crop and resulting in devastating financial losses. Moreover, continuous cultivation of the same crop also depletes soil nutrients, requiring farmers to use more synthetic fertilizers in addition to using more pesticides to manage the potential increased pest and disease prevalence. This raises production costs and contributes to environmental degradation.

Crop diversification is a practice that includes intercropping (i.e. planting multiple crops at the same time) and crop rotation (i.e. changing the crops every few years to preserve and augment soil nutrients). As per our observation, while many farmers do crop rotation (refer to our report), there are many key food production areas like Punjab, Haryana, and Western UP that do monocropping. Even those who are using crop diversification often rely on historical knowledge or word of mouth.

Crop Diversification

Hence, there seems to be a big opportunity to improve the practice. Crop diversification helps to improve soil health and fertility by rotating the right set of crops, thus reducing the need for chemical inputs. In case of unfavorable weather conditions, disease or pest outbreaks, and/or market price fluctuations, the presence of diverse crops (inter-cropping) ensures that farmers have alternate sources of income.

Crop Diversification also helps in managing pests and weeds better because eggs of prominent pests and weeds die when they don't get the usual nutrition due to the introduction of a new crop.

Governments and agriculture institutes continuously research and recommend good crop combinations for a particular area. Access to markets for new crops being introduced in an area would be crucial for adoption. Partnerships with private sector companies and food processors can help address this.

Crop Diversification - Crop Rotation & Intercropping

Benefits to the Environment

Crop Rotation:

- A well-planned crop rotation strategy helps improve soil fertility by either restoring depleted nutrients or using excess nutrients, thus balancing the soil's nutrient levels.
  - For example, in Maharashtra, deep-rooted cotton absorbs fertilizer from deep layers of soil and is then followed by shallow-rooted groundnut.[1]
- Crop Rotation helps in balancing water requirements when it involves less water-intensive successive crops. For example, cotton is followed by soybean as it requires lesser water.[3]

Benefits to the Farmer

Crop Rotation:

- Crop rotation helps in breaking cycles of pests & diseases, hence ensuring lesser crop loss and better yields.[3]
- Soil health improvement due to crop rotation leads to more productivity & lesser usage of fertilizers, hence lesser cost.[3]
- Rice & maize rotated together in 13 locations in India showed a 30% yield increase over production of only rice every year.[4]

1 - Gupta, Niti et al. (2021). Sustainable Agriculture in India 2021.
2 - Singh, KK et al. (2009). Pulses in Cropping Systems.
3 - Conversations with experts
4 - Deep, Mangal et al. (2018). Rice-based cropping systems for enhancing productivity of food grains in India: decadal experience of AICRP.

Crop Diversification - Crop Rotation & Intercropping

Benefits to the Environment

Intercropping:

- Intercropping with legumes helps in fixing atmospheric nitrogen. Example, In Telangana, intercropping of cotton & pigeon pea in ratios 6:1, 8:2. In Maharashtra, cotton and soybean are grown in 1:1 ratio. Here, cotton is a long duration crop, whereas soybean is a short duration crop.[2]
- Intercropping is energy efficient & sustainable in rainfed regions.[1]
- Soil runoff is controlled and better soil structure is the outcome.[1]

Benefits to the Farmer

Intercropping:

- It gives extra income from the extra crops with marginal additional cost because ploughing, sowing, etc. are done for the main crop.[2]
- If the main crop fails or the yield from it reduces, intercropping ensures additional income.[2]
- In North West India, a yield increase of 24% was observed in intercropping of maize & cowpea (4:1) over the monocropping of both crops.[3]

1 - Gupta, Niti et al. (2021). Sustainable Agriculture in India 2021.
2 - Conversations with experts
3 - Khokhar, Anil et al. (2021). Impact of Land Configuration and Strip-Intercropping on Runoff, Soil Loss and Crop Yields under Rainfed Conditions in the Shivalik Foothills of North-West, India

Crop Diversification - Crop Rotation & Intercropping

Observations from the Ground

- In Bidar, Karnataka & Nanded, Maharashtra, many farmers are doing intercropping of soybean & tur (6:1 is the most common) and crop rotation between soybean & cotton (some also rotate urad, moong, etc. with soybean).
- Most of them mentioned higher yields by ~15-20% due to crop rotation, and additional incomes (& lesser risk of income loss) due to intercropping.
- A few farmers also saw improvement in soil health due to both practices.

Challenges in Adoption

- Intercropping is labor intensive as it requires separate efforts for weeding and harvesting, hence it might lead to additional costs.[1]
- Additionally, access to information on the right crop combination that is good for the soil and financially beneficial for the farmer is very important to make the initiative successful.

1 - Gupta, Niti et al. (2021). Sustainable Agriculture in India 2021.

Crop Diversification - Crop Rotation & Intercropping

Potential Opportunity

Crop diversification is a very simple practice to improve soil health, productivity and safeguard against risks. Still, many farmers, e.g., in regions like Punjab, Haryana, and Western UP, are doing monocropping. And even those doing crop diversification may be doing it sub-optimally. There is an opportunity to help farmers with contextual knowledge on the right crop combinations which are good for the soil & financially beneficial for the farmers. KVKs and universities who are active in crop research and soil management can identify appropriate cropping patterns & NGOs can help in dissemination & implementation. Private companies like buyers active in an area can promote better cropping patterns through advisory and can additionally procure crops that are grown as a part of crop diversification.

Farmers practice crop rotation as they believe that if they grow the same crop every season, it would lead to more pests & diseases, and hence, lesser yields.

"I practice crop rotation on my 5-acre farmland. I have planted cotton on 2 acres and chili on the remaining 3 acres. Continuous chili cultivation without rotation will lead to the domination of chili wilt disease on my farm which will impact the yields substantially."

Land Preparation

Soil Testing and Remediation

India has a variety of agro-climatic zones and diversity in crops grown. Given that different crops need different types of nutrients, soil testing, and remediation help in identifying and supplying the soil nutrients based on current soil nutrient content, the soil type, and the crop.

We have observed that farmers tend to follow agricultural practices based on word of mouth, personal experiences, or what is commonly used in the community. For example, the amount of seeds used or the choice of fertilizer varies significantly amongst farmers growing the same crop in adjacent fields, with what seems similar soil types.

In our conversations with experts, numerous experts have consistently stated the need for scientific practices in agriculture. Soil testing is one of the most fundamental practices to start with. It is a rapid chemical analysis that assess soil and typically includes interpretation, evaluation, and fertilizer recommendation based on the result of chemical analysis and other factors such as crop to be grown, agro-climatic zone, etc.

Soil Testing and Remediation

Given the suboptimal use (and likely overuse) of macronutrients (NPK), soil testing often leads to recommending less usage of these fertilizers and targeted addition of secondary and micronutrients. This typically leads to cost savings, increased yields, and environmental benefits due to lower overall usage of fertilizers. The government has also been trying to make it a mainstream practice but the adoption is still low among the farmers.

During our research with smallholder farmers, we observed 96% of farmers interviewed did not get soil testing done. The main reason for this was that they felt that their systems are working and that there is no need for soil testing.

In addition, based on our observations on the ground and interactions with practitioners, there are operational issues like effective soil collection, sample transportation, delayed results, accuracy of results, etc. There seem to be new innovations that can solve these operational challenges which can also support adoption.

Soil Testing and Remediation

Benefits to the Environment

- Soil testing leads to improved soil quality and structure as the right nutrition including micro nutrition and organic matter is provided and in the right amount.[1]
- It reduces GHG emissions because generally, soil testing recommends less usage of fertilizers, especially urea/nitrogenous fertilizers against what farmers tend to use today.[1]
- It also reduces environmental pollution as there is less runoff of fertilizers which pollutes soil and waterways.[1]

Benefits to the Farmer

- Soil testing increases the productivity of crops. For example, in Andhra Pradesh, cotton productivity increased by 14–62%, groundnut productivity increased by 11–12% and rice productivity increased by 5%.[2,3]
- It leads to a 20-30% reduction in costs by using the right amount of fertilizer and no wastage of excesses.[1]
- It ensures improved resilience of crops, as the right amount of nutrients is given to them.[1]
- Through soil testing, farmers can produce higher-quality crops that are more attractive to buyers. This can help increase marketability and profitability.[1]

1 - Conversations with experts
2 - Chander, Girish et al. (2013). Soil test-based nutrient balancing improved crop productivity and rural livelihoods: case study from rainfed semi-arid tropics in Andhra Pradesh, India.
3 - Jayalakshmi, M. et al. (2021). Impact of Soil Test Based Fertilizer Application on Yield, Soil Health and Economics in Rice.

Soil Testing and Remediation

Observations from the Ground

The TASF team interacted with farmers to understand their experience with soil testing:

- In Satara, Maharashtra, farmers (growing maize, sugarcane, pomegranate) mentioned reduced usage of DAP and Urea. This led to an average decline of 40% in fertilizer costs.
- Farmers in Amravati, Maharashtra who got soil testing results mentioned yield increase and drop in fertilizer costs due to doing remediation as per soil testing results (they mentioned that they started to add Sulphur & Potash, and reduced Urea & DAP).
- Many of them also reported that soil testing was done, but they didn't receive any results.

Challenges in Adoption

- The whole process of soil testing is suboptimal and the turnaround time is also high - collection of soil sample, sending the sample to the lab for testing, and delivering the results back to the farmer are major issues.[1]
- Farmers' experience with some government labs has not been good in the past.
- Behavior change is an issue as farmers feel that the more fertilizer the better, hence they tend to apply more fertilizer even if soil tests recommend a lower dosage.[1]

1 - Conversations with experts

Soil Testing and Remediation

Potential Opportunity

Soil testing is one of the most impactful interventions that can help farmers as well as the environment. The biggest challenges for adoption have been both operational difficulties and behavior change for the farmers. Technical innovations which are solving operational challenges can be a big breakthrough as they will ease behavior changes too. Also, with more and more private sector players interacting with farmers, there is an opportunity where they could encourage this practice. Some of these private players who sell fertilizers & inputs can also include micronutrients in their portfolio & encourage farmers to use the same.

Farmers who get soil testing done and follow the advisory given by the reports tend to get higher yields with better quality produce.

"I got soil testing done for my tomato farm, and then applied boron as suggested by the soil testing reports. It helped me to get rid of cracks in tomatoes and hence got 30% higher prices for them."

Zero Tillage Machinery

Tilling is an agricultural practice that involves mechanically preparing the soil for cultivation. It is typically carried out by using various tools (harrows, plows, etc.) or machinery to break up the soil, loosen it, and create a favorable environment for the growth of crops. Tilling is commonly performed before planting seeds or seedlings to enhance soil conditions and maximize crop yields.

In addition to breaking up compacted soil and loosening it, tilling helps disrupt and uproot weeds, reducing competition for resources such as water, light, and nutrients. It also helps to manage crop residues from the previous season.

However, there are many disadvantages of tilling. Intensive or improper tilling practices can lead to soil erosion. Exposing the soil to wind and water erosion can result in the loss of valuable topsoil, which contains essential nutrients and organic matter. This erosion can negatively impact soil fertility and productivity over time. Tilling can accelerate the decomposition of organic matter in the soil, resulting in a loss of soil organic carbon.

Zero Tillage Machinery

Instead of traditional tilling which causes significant disturbance to the soil, the usage of a zero till machine with a tractor creates a thin furrow in which the seed and fertilizer are placed by the machine. This causes minimal disturbance to the soil structure around and ensures less fertilizer use as the fertilizer is applied at the root zone. It is also effective in soil water conservation and increases water use efficiency of the crops and prevents erosion. It also does minimum disturbance to soil microorganisms.

Farmers who do harvesting which clears the crop close to the ground can directly use the zero till machine. But farmers who use machines like combines that leave significant portions of stalks standing need to clear the stalks before using a zero till machine.

It can be used in many situations, but one very high potential opportunity is for sowing wheat in the context of rice-wheat cropping which is a major cropping system practiced in 13.5 million ha in the Indo-Gangetic Plains.

Zero Tillage Machinery

Benefits to the Environment

- Compared to traditional tilling methods, Zero Tillage (wherever applicable) can be done to enhance soil health. This method results in higher soil organic carbon content and helps reduce erosion, minimizing runoff that often carries residual agrochemicals and soil sediments.[1,2]
- Zero till leads to a decrease in carbon dioxide and other greenhouse gas emissions.[1]
- In water-limited environments, it increases soil water storage efficiency by increasing the soil water holding capacity, which allows for cropping system intensification and diversification.[3]

Benefits to the Farmer

- The amount of seeds required for sowing also reduces to half. Seeds are sown in line instead of broadcasting wherein seeds are randomly thrown around.[4]
- In addition to fewer seeds, it also leads to less ploughing and use of DAP and a total saving of ~INR 2600 per acre in UP.[4]
- In UP, zero till machine helped increase the yield by 20% according to the farmers (as compared to broadcasting) as line sowing and fertilizer placement helps the plant get appropriate nourishment leading to stronger crops and better quality of produce.[4]
- In Karnal, a higher net return by ~14% was observed in rice due to a reduction in operational costs (labor, machine & irrigation costs); in wheat, higher yield by ~5.5% and a higher net returns by ~24.7% were observed.[5]

1 – Gupta, Niti et al. (2021). Sustainable Agriculture in India 2021.
2 - Busari, M.A. et al. (2015) Conservation tillage impacts on soil, crop and the environment.
3 - Lyon, Drew et al. ((2004). Achievements and Future Challenges in Conservation Tillage.
4 - TASF Field Research done in UP on No Till Wheat Crop
5 - Raju, R et al. (2012). Economics of zero tillage and conventional methods of rice and wheat production in Haryana.

Zero Tillage Machinery

Observations from the Ground

- TASF team witnessed the use of zero till machinery for sowing wheat in Prayagraj and Sultanpur in UP.
- Local tractor owner who was providing ploughing and other such services, purchased this machine and provided zero till services to farmers at INR 1000/acre.
- The machine helped to sow wheat within a week of paddy harvesting and saved on costs of ploughing as well.
- Farmers were very positive about the 20% increase in yield and quality improvement of wheat after using a zero till machine.

Challenges in Adoption

- Some farmers who have access to this machine end up doing tilling and use this machine just as a seed drill as they are used to their usual methods of farming and psychologically feel that tilling is important. There is a need to increase the awareness about right usage of this machine.[2]
- In zero till, the inability to control weeds (because tilling exposes weed seeds to sunlight and hence doesn't let them grow) and other pests leads to an increased usage of pesticides & weedicides.[1]

1 - Lyon, Drew et al. ((2004). Achievements and Future Challenges in Conservation Tillage.
2 - Conversations with experts

Zero Tillage Machinery

Potential Opportunity

Zero tillage machinery can be very useful in the rice-wheat growing regions as smallholder farmers can directly save on the costs of plowing before sowing wheat and lead to faster sowing resulting in potentially less damage from weather issues. This will help increase farmers' income as well as be beneficial for the environment. Adoption of this practice will require involving tractor owners who currently provide ploughing and related services to buy these machines and provide zero tillage services to smallholder farmers.

Some farmers who have access to this machine end up tilling and using this machine just as a seed drill as they are used to their usual methods of farming. NGOs and grassroot organizations working with farmers to improve their incomes as well as who have an environmental mandate can create awareness and help use these machines in the right way.

The usage of zero till machines for sowing wheat after harvesting paddy has been very beneficial for farmers.

"I saw another farmer using a zero till machine and after observing its benefits I also started using it to sow wheat after paddy harvesting. I got a 30% yield improvement, and the crop was stronger and shinier."

Seeds

Seed Treatment

Traditionally, farmers have faced challenges like lower seed germination, less robust seedlings, non-uniform plants, and pests & disease attacks. Seed treatment is an effective method to mitigate these issues. It involves treating seeds with the following:

- Fungicides to protect from fungal attacks
- Insecticides, to protect from diseases, sucking pests & insects in soil like termites
- Biofertilizers fix atmospheric nitrogen into the soil and improve availability of nutrients to plants

Fungicides and pesticides are available in biological forms as well. These are cheaper and equally effective as chemical forms, but in some cases may require more effort like maintaining the timing of application etc. Hence, chemical treatments are more widely used.

Treated seeds have improved germination rates and more robust seedlings leading to higher crop establishment and uniformity.

Seed Treatment

They may also require lesser amounts of pesticide spraying. This, in turn, translates to improved profitability for farmers.

Some examples of seed treatments:

- Sugarcane: Carbendazim (fungicide), Trichoderma (bio fungicide)
- Rice: Trichoderma (bio fungicide), Chloropyriphos (pesticide)

Most commercial seeds come pre-treated with fungicides or with packets that can be used for fungicide seed treatment. When seeds are not pre-treated, or when the farmers are using their own seeds, even if they do treat them, they tend to treat them only with fungicides.

There is an opportunity to also treat seeds with insecticides and biofertilizers, when they have already been treated with fungicides. When they haven't been treated at all, there is an opportunity to treat them with all three.

Seed Treatment

Benefits to the Environment

- The use of insecticide seed treatment helps against diseases and sucking pests and hence reduces pesticide usage.[4]
- Biofertilizers seed treatment leads to a reduction in fertilizer usage as it fixes atmospheric nitrogen and makes soil nutrients available to the plant.[1]

Benefits to the Farmer

- Seed treatment leads to the prevention of diseases - for example, chances of wilt disease decreased in chickpea in Maharashtra.[1]
- By using seed treatment, the cost for the farmers goes down because:
  - The quantity of pesticides used is reduced
  - Fertilizer cost reduces.[1]
- Biofertilizers like Azotobacter, Rhizobium and PSB in combination with NPK and FYM lead to higher yield and economic returns.[3]
- Biological treatments improve disease control by 55% & crop yield by 21%.[4]
- Chemical seed treatment of Carbendazim + Mancozeb in green gram led to an increase in yield by ~51%.[5]

1 – Conversations with experts
2 - Sharma, KK. (2015). Seed treatments for sustainable agriculture-A review.
3 - Kalita, Nilim. et al. (2019). Effect of Biofertilizer Seed Treatment on Growth, Yield and Economics of Toria (Brassica Campestris L.) under Rainfed Condition in Hill Zone of Assam.
4 - Lamichhane, JR et al. (2022). Biological seed treatments promote crop establishment and yield: a global meta-analysis.
5 - Deshmukh, Amol et al. (2020). Efficacy of Fungicidal Seed Treatments on Growth and Yield Parameters of Green Gram.

Seed Treatment

Observations from the Ground

TASF did field visit in Nanded, Maharashtra and Bidar, Karnataka and spoke to farmers who are doing seed treatment:

- We observed adoption of seed treatment in this area because of interventions by KVK & Syngenta Foundation India (SFI).
- Most farmers were using chemical treatments, and some of them were also using bio fertilizers for last 3-4 years.
- All those who have done seed treatment have seen an increase in yield and therefore plan to continue doing it in the future. They also mentioned getting rid of fungal root disease that was earlier causing lot of crop loss.
- Some of them also mentioned lesser pesticide usage due to lesser pest attacks.

Challenges in Adoption

- There are significant gaps in the information available about seed treatments specific to a region, crop, agro-climatic zone to the farmer.[1]
- Farmers have some knowledge about fungicides but mostly lack knowledge on insecticides and biofertilizers treatments leading to very low adoption of both these.[2]

1 - Sharma, KK. (2015). Seed treatments for sustainable agriculture-A review.
2 - Conversations with experts

Seed Treatment

Potential Opportunity

Seed treatment can help farmers deal with pest attacks and crop damage in addition to improving germination. This is a very simple practice yet not practiced by many farmers optimally. There is scope to standardize and contextualize the information for the farmers at a local level and enhance its adoption. KVKs and universities can help provide local contextual advisory to farmers and NGOs can also help in adoption.

Private players (like input providers, advisory organizations, buyers) can provide advisory to include seed treatments as a part of a package of practices. Seed companies can sell treatments along with the seeds, which is currently done for fungicide, but can be done for other treatments too.

Improved Seeds

With changing climatic conditions, increasing pest pressures, and the need for higher crop yields, farmers are recognizing the need of adopting improved seeds. There are a lot of options available in the market and farmers have been trying the same. But due to the availability of so many options farmers may find it difficult to choose the right seeds for their context.

These improved seeds can be open pollinated variety or hybrids. Open pollinated seeds are developed over a long period through open pollination, where pollen is transferred within the same plant species or variety by wind, insects, birds, or other natural means. These have genetic diversity and genetic stability (plants produced are consistent across generations). These seeds can be saved and replanted year to year, thus allowing farmers to maintain a continuous supply of seeds without purchasing them.

Hybrid seeds are the result of controlled cross-pollination between two genetically distinct parent plants to create offspring with desired traits such as disease resistance, high yield, etc.

Improved Seeds

Their offsprings don't resemble parent plants and hence increase farmers' dependence on buying these in every season.

By improved seeds, we are referring to either of these seeds that give higher yields, and/or are climate smart, and/or are pest & disease resistant.

Recognizing the potential of improved seeds, both the government and private sector are actively involved in research and development (R&D) efforts. In 2021, the government launched 35 new seed varieties. For example: Rice - Pusa Basmati 1979 has higher herbicide tolerance than older variety of Pusa Basmati 1121. In Soyabean, NRC 138 variety has early maturing amenable to mechanical harvesting.

The demand for open pollinated improved variety is high among the farmers and there seems to be an opportunity to increase access to these seeds. There also seems to be an opportunity for private players, KVKs, and NGOs to make contextual advisory on the right seed varieties available to the farmers.

Improved Seeds

Benefits to the Environment

- Better disease-resistant seeds also reduce pesticide usage and thus reduce environmental impact.[1]

Benefits to the Farmer

- Swarna-sub is a climate-resilient rice variety:[2]
  - that has submergence tolerance and performs better under flood situations apart from being high yielding with good grain quality
  - that has a yield advantage of 3.4% in normal years whereas in flood years it had a more than 90% yield advantage
  - whose production cost was reduced by Rs.1175 per hectare due to reduced pesticide spraying.
- In wheat, higher yields by 25% are shown by WH 1270 as compared to WH 1105, and is also resistant to yellow and brown rusts, flag smut, leaf blight, and powdery mildew diseases.[4]

1 – Conversations with experts
2 - Sharma, S et al. (2019). A compendium of technologies, practices, services and policies for scaling climate smart agriculture in Odisha (India).
3 - TASF field visit in Nanded, Maharashtra
4 - Jindal, Y et al. (2021). Varieties of CCS HAU Continued Efforts Towards Food Security.

Improved Seeds

Observations from the Ground

- In Nanded, Maharashtra, and Bidar, Karnataka, farmers are using newer varieties of soybean like KDS 726, KDS 992, and JS 335.
- They mentioned higher yields due to these varieties; most farmers had started using these in the hope of higher yields.
- These are also pest & disease resistant. For example, KDS 726 is resistant to rust disease & tolerant to major pests. JS 335 is resistant against girdle beetle and stem fly and has a high tolerance to moisture stress conditions.
- Interventions by Syngenta Foundation India (SFI) and awareness creation through KVK have led to the adoption of these varieties in these villages.

Challenges in Adoption

- Awareness among farmers about the most appropriate seed is still very low.[1]
- The seed delivery agents or dealers are not incentivized to promote the most appropriate seeds. They are likely to sell seeds that have the most margins and are marketed heavily.

1 - Conversations with experts

Improved Seeds

Potential Opportunity

Many improved seed varieties and hybrids have been developed to help farmers deal with pests and disease attacks and also increased yields. With the availability of so many different types of seeds, farmers may not be clear about the most appropriate for them. Hence, private players, including buyers of the produce can provide contextual advisory and recommend the right seeds to the farmers as the right seed helps in better yields and reduces crop damage (due to less impact of pests and diseases). There is also scope for KVKs and NGOs to spread awareness about the appropriate seeds which can help the farmers get improved yields as well as climate & pest-resistant crops.

Hybrids give a better yield but farmers need to buy them every year. Hence, there is more demand for open pollinated varieties where farmers can reuse the seeds, but this demand is not being met currently. To address this demand gap, input providers beyond just seed companies can help in the commercial production of these seeds.

Crop Nutrition & Application

Biofertilizers

When a farmer uses chemical fertilizer, only a limited amount of nutrient (30–40%) is absorbed by the plants and the rest gets bound to soil in unavailable forms or is lost as runoff to nearby water bodies, leaches into groundwater or escapes to the atmosphere.

Biofertilizers make the already-available nutrients in the soil and atmosphere accessible to the plants. They contain living microorganisms like bacteria, fungi, or algae, which act on the nutrients in the soil and make them available for the plant to absorb. An exception to this is the nitrogen fixing biofertilizers that can fix atmospheric nitrogen into a form that plants can utilize.

Biofertilizers may also maintain the soil pH so that the nutrients are absorbed effectively by the plants and also work in increasing the organic matter content of the soil.

Biofertilizers

It collectively leads to improved soil health and reduced need for chemical fertilizers, therefore, leading to environmental benefits. Biofertilizers are available at reasonable prices in the market. General applications of biofertilizers are for seed treatment, soil treatment or seedling root dip. Common examples of Biofertilizers are Nitrogen fixing bacteria (eg. *Rhizobium, Acetobacter, etc.),* Phosphorus Solubilizing Bacteria (PSB), Potassium Mobilizing Biofertilizer (KMB), Zinc Solubilizing Biofertilizer (ZSB) and PGPR (plant growth promoting rhizobacteria).

Agri advisory companies can make use of soil testing results, which provide insights into the current nutrient levels in the soil. By using this information, there is an opportunity to include biofertilizers as part of their fertilizer recommendation hence reducing the dependency on chemical fertilizers in agricultural practices.

Biofertilizers

Benefits to the Environment

- Biofertilizers reduce the requirement of chemical fertilizers, improve soil health, reduce runoff into water bodies and leaching of groundwater.[3]
- For eg., *Azotobacter,* a nitrogen-fixing biofertilizer, makes atmospheric nitrogen available to the plants thus reducing the requirement of urea to be applied. Reduced urea usage can help lower GHG emissions, protect the soil from becoming hard and avoid the leaching of groundwater.[2]

Benefits to the Farmer

- Biofertilizers use already available nutrients in the soil and atmosphere, potentially reducing in fertilizer usage and costs.
  - In a field trial on the Chrysanthemum plant in Indore (MP), usage of PSB and azotobacter led to 20% reduction in phosphoric and nitrogenous fertilizer.[1]
  - It has been observed that applying a nitrogen-fixing biofertilizer in wheat led to a 16.3% increase in grain yield.[3]
- Soil microbes present in biofertilizers maintain the optimum concentration of soil nutrients, hence providing better plant growth and crop yield.[3]

1 - Mishra D.K. et. al. (2018). Impact of Bio-Fertilizers on the Yield and Economics of Chrysanthemum Under Real Farming Situation.
2 - Conversations with Experts
3 - Kumar S. et. al. (2022). Biofertilizers: An ecofriendly technology for nutrient recycling and environmental sustainability.

Biofertilizers

Observations from the Ground

TASF spoke to farmers from Satara, Maharashtra who are applying biofertilizers in their crops-

- We observed adoption of biofertilizers in this area was because of interventions by Mann Deshi Foundation.
- Farmers were applying common biofertilizers like Azotobacter, PSB, KSB, etc. in fruits and vegetable crops.
- Farmers reported that the crop quality became better (more green and heavier grains) because of using biofertilizers.
- Most of the farmers observed a yield increase after using biofertilizers .

Challenges in Adoption

- No immediate results of using biofertilizers are seen in the crop health hence farmers aren't able to assess its value.[1,2]
- Farmers are used to applying chemical fertilizers in large quantities and might not feel the need to apply bio fertilizers.[1]
- Retailers are unwilling to keep stock of biofertilizers since the profit margins are not significant.[1]
- Biofertilizers with a short shelf life carry the risk to be recycled if they are not used or sold before expiry, resulting in a net monetary loss to the marketing agency.[2]
- It's been observed that there is a supply of low or spurious quality biofertilizers in the market due to unavailability of robust quality checks.[2]

1 - Conversations with experts
2 - Basu A. et. l. (2021). Plant Growth Promoting Rhizobacteria (PGPR) as Green Bioinoculants: Recent Developments, Constraints, and Prospects.

Biofertilizers

Potential Opportunity

Biofertilizers are a promising solution to utilize nutrients present in the soil or atmosphere but unavailable to plants, thereby reducing the need of additional chemical fertilizers. Additional research by scientific institutions is required to encourage manufacturers to invest in biofertilizers and bridge the evidence gap regarding their effectiveness. This research would focus on areas such as the extent to which biofertilizers can reduce the need for chemical fertilizers and their impact on soil health, among other aspects. Since biofertilizers are a low-cost, high-potential solution, NGOs can work on its awareness and adoption amongst the associated farmers. Although there is already some interest among agri-input companies in this segment, there is potential for further growth if more companies choose to include it in their product portfolios and recommend the same.

Farmers using biofertilizers saw positive impact on their crop growth as well as soil health.

“I used PSB and KMB for my Sugarcane crop and observed that the crop growth was better this season and the soil health also improved.”

Biostimulants

Farmers are facing increasing challenges: climate change leading to crop losses, increasing incidence of pests & diseases and low nutrient-use efficiency of fertilizers. The agri ecosystem is working towards solving these problems by developing products like drought-resistant seed varieties, integrated pest management solutions, etc.

Biostimulants are another segment that addresses the above-mentioned challenges by regulating and enhancing a crops' physiological processes to improve input use efficiency, growth, yield or stress tolerance. They are classified mainly as:

Immunity booster: Biostimulants in this category help the plants to activate their innate or acquired immunity using particular biomolecules that protect them from diseases and pest attacks or reduce their severity.

Stress tolerance builder: Biostimulants in this category help plants mitigate abiotic stress (like drought or flooding, high temperature, high humidity & other climatic factors) by making them structurally robust or activating biochemical processes.

Biostimulants

Nutrient use efficiency enhancer: Biostimulants in this category do not provide nutrients directly to the plants but facilitate the absorption and assimilation of already-available nutrients in the soil by supporting metabolic processes in the plants.

In addition to the above outcomes, they also benefit the crop by improving the plant health, soil health and yield improvement.

Most commonly manufactured biostimulants are made from seaweed extracts and humic acid that improve the plants' stress resistance. Some companies like BioPrime are manufacturing biostimulants across all categories; for example: Fortisea for yield improvement and increased stress tolerance, Verdant for immunity development, etc.

Biostimulants

Benefits to the Environment

- Since biostimulants increase the nutrient use efficiency of the crop, they help reduce chemical fertilizer doses by upto 25%.[1]
- Biostimulants change microclimatic conditions in the soil i.e., help with good bacteria and improving microflora.[1]
- Biostimulants inherently make the plant stronger, leading to reduced incidence and severity of pest attacks, thus reducing the need for pesticides.[1]
- Biostimulants that target stress tolerance work on climate adaptation by making them resilient to abiotic stresses.[1]

Benefits to the Farmer

- Biostimulants improve plant resilience against abiotic stresses like water, high temperature, humidity & other factors, thus helping improve survival and reduce losses.[1]
- Biostimulants have shown the capacity to increase the yield by 15-18%.[1]
- Applying a combination of three biostimulants (at different crop stages) resulted in the grape treatment yield to be 14% higher than control yield and wheat yield higher upto 20%.[3]
- Biostimulants that target nutrient use efficiency are known to reduce fertilizer usage.[1,2]
- Biostimulants make the appearance of the produce better in terms of color, size, shape and weight, hence more appealing to buyers.[1]

1 - Conversations with experts
2 - Ricardo O. Russo. and Graeme P. Berlyn. (2008). The Use of Organic Biostimulants to Help Low Input Sustainable Agriculture.
3 - BioPrime's case study on Grapes (Nasik) and Wheat (Lucknow)

Biostimulants

Observations from the Ground

- The team interviewed some farmers who were using BioPrime's biostimulants:
  - Crops covered: Tomato, Chilli, Onion, Cauliflower and Pomegranate.
  - All farmers said that despite the increased input costs associated with biostimulants, the advantages in terms of improved yield and crop quality outweighed the expenses.
  - Impact of biostimulants on:
    - **Yield:** Reported increase in the range of 10-25%
    - **Crop quality:** Produce was shinier, greener and the size of fruit/vegetable was bigger
    - **Other benefits:** Better root development, no loss at the flowering stage, better branching
    - **Fertilizer application:** No reduction in fertilizer application reported
  - All farmers said they will use biostimulants again in the next season.

Challenges in Adoption

- Awareness of their usage and impact is limited.[1]
- Bioproducts usually take time to show results regarding yield impact and climate management. Farmers generally tend to focus on short-term gains.[1]
- Biostimulants are expensive and farmers might feel hesitant to invest additional money apart from fertilizers.[1]
- Variability in results due to the lack of science-backed products in the market has resulted in low trust amongst the farmers impacting the adoption.[1]
- For row crops, farmers tend to attribute the yield increase to seeds, climate or cultivation practices instead of biostimulants.[1]

1 - Conversation with experts

Biostimulants

Potential Opportunity

Biostimulants help plants increase immunity against pest and disease, gain stress tolerance against climatic changes and promote nutrient use efficiency by modifying a crop's internal physiological process unlike most other solutions that are external (e.g. applying pesticides or fertilizers). Since this category of products is new to the market, there is a need to conduct more research to understand the effectiveness of the available products in context of different crops and geographies. It is gaining popularity amongst the fertilizer and input companies, and there could be a business opportunity for them to include biostimulants in their portfolios, which would also lead to educating the farmers on their usage and benefits.

Urea Deep Placement Machinery

Traditional fertilizer broadcasting method leads to significant nutrient losses (due to inefficient uptake by the plant), water pollution, soil degradation and GHG emissions. Nowadays, usage of seed drills has grown which deep places the fertilizer (usually DAP) along with the seeds. Urea Deep Placement (UDP) is a promising agricultural practice that addresses the challenges of broadcasting of urea which leads to high GHG emissions. The practice has been used in Bangladesh where urea briquettes were deep placed manually. UDP machine, a substitute to the manual method, places the urea briquettes in the root zone (about 7-10 cm below the soil surface) of crops. The machine can be used to deep place other fertilizers in granular format.

The environmental benefits of UDP is its effectiveness in reducing nitrogen losses that occur due to volatilization of ammonia or surface runoff. UDP machinery places easily made urea briquettes in the root zone. The briquette format allows for slow release and the deep placement allows for efficient nutrient uptake by plants, which reduces fertilizer required, reduces GHG emissions & leaching, & increases yields resulting in increased income for farmers.

Urea Deep Placement Machinery

Manually performing UDP is labor-intensive, expensive and time-consuming. There is an existing ecosystem of service providers that are providing seed drill, cultivator and similar services to farmers for a fee. There is a business opportunity for these village-level entrepreneurs to provide UDP services to farmers in their area. As per our conversation with District Horizon (a UDP machine manufacturer in India), the rental costs of these machines are currently between INR 800-2000/acre for Sugarcane and INR 800-1000/acre for Paddy.

There is an opportunity for UDP machines to be promoted in the sugar industry where the buyers have close relationships with farmers. DCM Shriram has recognized the value of UDP and is raising awareness about it with its farmers. It is also providing a 25% subsidy on the machine cost to its affiliated service providers to buy these machines and provide services. Two years post trial, DCM Shriram now has 80 UDP machines and 5 briquette manufacturing machines in 2 districts providing UDP facilities to ~2 lakh farmers.

Urea Deep Placement Machinery

Benefits to the Environment

- A study in Bangladesh on deep placement of urea in rice showed a reduction in direct N20 emissions by 0.07 tCO2e/ha/yr.[3]
- According to District Horizon, in Jabalpur, deep placement of urea in Paddy helped reduce GHG emissions by an average of 0.3 tons CO2 eq/hectare.[4]
- UDP leads to a significant reduction of excess chemicals as there is much lower runoff into water bodies and leaching into groundwater.[1]
- In the case of Sugarcane, the UDP machine also performs weeding which reduces the requirement for weedicide application.[1]

Benefits to the Farmer

- In Jabalpur (MP), a 25% increase in Paddy crop yield and a 30% reduction in urea consumption was observed due to urea deep placement.[4]
- In a study conducted in Bangladesh on Paddy, deep placement of urea saved urea by 33%.[2]
- In the case of sugarcane, the UDP machine also performs weeding while placing urea; hence, there is saving on weedicide input and labor costs.[1]
- There is an opportunity for local service providers to buy and rent UDP machines to farmers as these machines are expensive (~1.68 lakhs for sugarcane). Entrepreneurs connected with District Horizon achieved breakeven in 2 months for Sugarcane and in 1.2 years for Paddy.

1 - Conversations with experts
2 - Md. Miah A. M. et. al. (2016). Fertilizer Deep Placement Increases Rice Production: Evidence from Farmers' Fields in Southern Bangladesh.
3 - Nash J. et. al. (2016). Accelerating Agriculture Productivity Improvement in Bangladesh: Mitigation co-benefits of nutrient and water use efficiency.
4 - Fertilizer Briquette Deep Placement Project Report 2022 by District Horizon.

Urea Deep Placement Machinery

Observations from the Ground

TASF team visited Shahbad, UP, to witness the usage of UDP machines provided by Distinct Horizon to Sugarcane growing farmers:

- Yield for sugarcane increased by 35%, and usage of Urea decreased from 3 to 2 bags per acre. Though there is an increase in the cost of urea application (because of the machine rental costs), it is offset by the yield increase.
- The local service provider model was being leveraged to promote the adoption of UDP machines and for manufacturing Urea briquettes.

Challenges in Adoption

- Lack of farmer awareness on the benefits of deep placing fertilizers.[1]
- UDP machines are new to the Indian markets and are expensive. Their availability at the village-level (on a fee-for-service model) will take some time to pick up, thus impacting its current adoption levels amongst farmers.
- The availability of government subsidies on urea relieves farmers from concerns about reducing its usage, resulting in a low acceptance of UDP practices.
- There is a lack of government focus on promoting UDP technology in India.

1 - Conversations with experts

Urea Deep Placement Machinery

Potential Opportunity

UDP is an impactful intervention to reduce GHG emissions occurring due to Urea broadcasting. The practice has been practiced manually for rice in Bangladesh for many years but seems to have challenges due to the labor required for urea application. In India, a UDP machine has been developed that replaces manual placement. Given it's environmental impact in areas like rice, philanthropies working in the climate space can invest in creating awareness amongst farmers about its economic benefits and subsidize the initial machine costs to stimulate a practice that will scale on its own. For crops where buyers have close relationships with farmers (e.g. Sugarcane where the technology is proven to increase productivity), buyers can promote the adoption of this practice among their farmers including supporting the initial introductions of the machines.

Farmers doing urea deep placement have seen increase in yields and decrease in weedicide costs.

"I applied urea using the UDP machine and my yield increased by approximately 12q/bigha. When the machine was used between the crop rows, it also did weeding which reduced my investment in buying weedicide from Rs. 700/bigha to Rs. 100/bigha."

PDM and PROM Fertilizers

In conventional agricultural practices, chemical fertilizers are commonly used to provide nutrients to crops. Excessive use of these chemical fertilizers can lead to high GHG emissions, soil degradation, water pollution, and health risks. Recognizing these challenges, there is an opportunity for using organic fertilizers that provide the same nutrients to the crop with no detrimental effects of chemical fertilizers.

PDM & PROM fertilizers are two such examples of organic fertilizers that are made from materials like rock phosphate, microorganisms, ash, molasses, compost or crop residues. These are the environment friendly substitutes of traditionally used chemical fertilizers e.g. MOP (Muriate of Potash) and DAP (Di-ammonium Phosphate) respectively.

While the chemical fertilizers provides nutrients, a significant amount of this is not used by the plants. For eg, In the case of SSP (Single Super Phosphate) or DAP, only ~30% of the phosphorus is utilized by plants and rest get accumulated in the soil leading to increased soil hardness and degraded soil quality.

PDM and PROM Fertilizers

PDM and PROM also contain nitrogen and other micronutrients essential for crop health.

PDM - Potash Derived from Molasses
PDM is a cost effective organic substitute for MOP and provides potassium(K). It is prepared by processing potash rich spent wash (a byproduct of sugar factories) into ash which is further granulated for ease of application.

PROM - Phosphorus Rich Organic Manure
PROM is an organic substitute for Phosphorous (P) based chemical fertilizers. It is manufactured by composting rock phosphate with organic manure, farm residue and Phosphate Solubilizing Bacteria (PSB).

PDM and PROM Fertilizers

Benefits to the Environment

- PDM and PROM production has lower GHG emissions when compared to DAP and MOP.[1] Also, PROM's production requires lesser energy than DAP since there is no requirement for high temperature, pressure or chemical catalyst.[2,3]
- PDM and PROM lead to reduced waterway pollution and improved soil health due to high bioavailability of nutrients compared to their chemical substitutes.[1]

Benefits to the Farmer

- PDM and PROM's bag to bag is cheaper as compared to chemical Potash and DAP however it is required in double the quantity leading to the net cost being the same as DAP and MOP. Hence without paying extra the farmer is able to improve soil quality and potential yield increase.[1]
- Using PROM as a substitute of DAP in rice increased the yield by 12%.[2]
- Microorganisms present in PROM fertilizer enhances soil health which may lead to lower pesticide/insecticide costs.[1]

1 - Conversations with experts
2 - Khatik G. et. al. (2022). Phosphate Rich Organic Manure (PROM).
3 - Sekhar DMR. (2013). PROM Technology – Progress Review 2011.

PDM and PROM Fertilizers

Observations from the Ground

Our team visited farmers in Bhilwara (Rajasthan) and Sabarkantha (Gujarat) who are using PROM as an organic substitute to DAP/SSP.

- All farmers reported a decrease in inputs cost by an average of 54% because farmers who were using PROM stopped using cow dung in that particular farm area.
- All farmers observed that using PROM has improved their soil quality (making it softer) and some farmers reported that the produce is shinier and heavier.
- The interviewed farmers have been using PROM from a couple of years and majority of them reported they will use PROM again in the next season.

Challenges in Adoption

- Subsidized and adequate availability of DAP and MOP gives no incentive to the farmer to switch to organic alternatives. The soil and environmental benefits are secondary to the majority of farmers. Currently, PDM and PROM are mainly used when there is a shortage of MoP and DAP/SSP in the market.
- Lack of adherence to good practices by many small PDM and PROM producers has led to quality issues making it challenging to gain farmers' trust.[1]
- In the case of PROM, production at scale is a challenge due to the low availability of raw materials.[1]
- Results may take longer to show as compared to DAP or MOP; farmers might come to an early conclusion of its ineffectiveness.[1]
- Chemical fertilizers currently dominate the market, and there is a lack of significant investment from companies in promoting PDM and PROM.[1]

1 - Conversations with experts

PDM and PROM Fertilizers

Potential Opportunity

PDM and PROM are the environmental friendly alternatives to chemical fertilizers (of K and P respectively). Despite being regulated by the Fertilizer Control Order, one of the major gaps present in this segment is the lack of quality products available in the market. Commercial players like fertilizer companies and large input providers may have a business opportunity to enter this segment, maintain the quality as per guidelines as well as invest in promoting the same. There is also a need to do scientific research on their quantity substitution against chemical fertilizers, impact on productivity of crops and potential substitution of Farm Yard Manure (FYM).

Farmers using PROM have seen reduction in costs leading to overall income increase.

“After using PROM, I am able to save huge costs of cow dung that I used to put with DAP earlier. My crop is also shinier, heavier and tastier. The soil has also become smoother.”

Irrigation

Large Farm Ponds (Non-Plastic Lining)

51% of agriculture land in India is rainfed and Deshpande Foundation (DF) recognized the critical need to combat water scarcity and initiated the Farm Pond program in 2014. This program focuses on providing farmers with farm ponds as a source of irrigation, particularly in drought-prone and semi-arid regions with low-permeability soils.

Farm ponds help farmers with protective irrigation in Kharif and sometimes additional irrigation in Rabi as well. This improves their income as well as reduces the risk of climate variability in terms of rainfall.

This Farm Pond is different from the typical MNREGA scheme farm ponds promoted by the GOI. These farm ponds are big in size, typically 100*100*12 feet which provides significant irrigation, do not have a plastic liner and the cost of construction is low. Most government farm ponds are smaller in size and the large ones typically have PVC lining making them significantly more expensive to build.

Large Farm Ponds (Non-Plastic Lining)

DF constructs farm ponds of various sizes based on the specific requirements of farmers. DF utilizes a scientific approach to locating farm ponds for maximum effectiveness using satellite imagery and geospatial information. They are constructed in locations with low permeability soil and this soil is used as the lining for the pond instead of a plastic material. This lowers the cost as well as does not have maintenance and replacement issues.

The program has witnessed remarkable success and has constructed 6000 farm ponds which have irrigated 15750 acres of land and positively impacted the lives of more than 24,000 people in the states of Karnataka and Telangana.

Deshpande Foundation wants to scale this to 100,000 farmers in the near future but financing is one of the major barriers in this journey.

Currently, JLG groups have been formed which can take a loan of up to Rs 60000 at a discounted 8% interest from SBI, but implementing this model also has several challenges.

Large Farm Ponds (Non-Plastic Lining)

Benefits to the Environment

- Farm ponds have led to improved biodiversity by increasing greenery, rich flora and fauna in the vicinity of the farm ponds.[1]
- In an area where the program is being run, by virtue of a number of farm ponds, the groundwater level improves. Even though the farm ponds have been designed to primarily store water, a collective farm pond effort in an area increases the groundwater level because of water percolation.[1]

Benefits to the Farmer

- Construction of farm ponds has increased the water availability for the farmers which helps them improve their productivity or go for an additional crop during Rabi. The intervention saw an overall increase of 20% in income (from INR 2,93,683 to INR 3,51,347).[1]
- The typical cost of a 100*100*12 feet farm pond construction ranges between INR 80000 to 1.2 Lacs. Farmers typically can take a loan up to 75% of the amount and can pay back the loan in 3-4 years. This way they are able to make money from this investment from year one itself.[2]
- More than 55% of targeted farmers are able to diversify and grow multiple crops.[1]

1 -Yasmin S. et al. (2021) Evaluation of Deshpande Foundation's Farm Pond Program. Published by LEAD, Krea University.
2 - Conversation with experts

Large Farm Ponds (Non-Plastic Lining)

Observations from the Ground

TASF team spoke to farmers who constructed farm ponds with Deshpande Foundation's support:

- Farmers mentioned they opted for farm ponds because of water unavailability and unpredictable rains.
- Farmers observed an increase in income as water availability increased for the current as well as 2nd crop.
- Most farmers we spoke to added a new crop after the farm pond. Common crops added were fruits, chilli and paddy.
- Some farmers also added cash crops like Sugarcane which helped them increase their income significantly higher.
- The investment for 100*100*12 feet farm ponds ranged from 80000 to 1.2 Lakhs and some farmers availed a loan of 60000 and some opted to invest the amount themselves.

Challenges in Adoption

- While most of the farmers feel there are no challenges to the adoption of farm ponds, 30% of them feel the cost of maintenance (like maintenance of bunds etc) is high.[1]
- Scaling up may require loans to be taken up by farmers.[2] 71% of farmers who approached DF after seeing the benefits of FPs sought financial assistance.[1]
- Perceived loss of cultivable land.
- Water losses due to percolation and evaporation.[1]

1 - Yasmin, Jain, Tannirkulam, & Satish. (n.d.). Evaluation of Deshpande Foundation's Farm Pond Program-Project Report. LEAD, Krea University.
2 - Conversations with experts

Large Farm Ponds (Non-Plastic Lining)

Potential Opportunity

Deshpande Foundation has proven a model of creating farm ponds which have helped farmers increase their income due to additional sources of irrigation in water-scarce areas. There have been many elements like the scientific location of ponds, absence of plastic liner, cost-effective construction, creation of JLGs to access credit, etc. which have contributed to the success. They are working on scaling their model, e.g., through the use of non-profits, philanthropy and CSR could support their efforts.

Since GOI has also been working on the farm ponds, there is an opportunity to more actively include the low-cost large farm pond models and use some of Deshpande Foundation approaches (e.g., using satellite imagery for the location of the ponds) in the government model.

Micro Irrigation

Water scarcity and depletion of groundwater resources are major challenges for farmers in India. Conventional flood irrigation has a very poor water use efficiency of only ~30%. More than 70% of the water used is wasted due to run offs, leaching, evaporation and weed growth. Micro irrigation (MI), which includes sprinkler and drip irrigation, is one of the solutions to address the water crisis in agriculture.

MI helps in enhancing crop productivity and overall farm profitability. Better water usage efficiency gives the farmers an option to bring more of their agri land under irrigation. While there is an upfront investment in installing drip or sprinkler systems, the cost savings from reduced water usage, reduced labor costs coupled with higher productivity often outweigh the upfront costs.

Micro Irrigation

MI is principally of two types, sprinkler and drip:

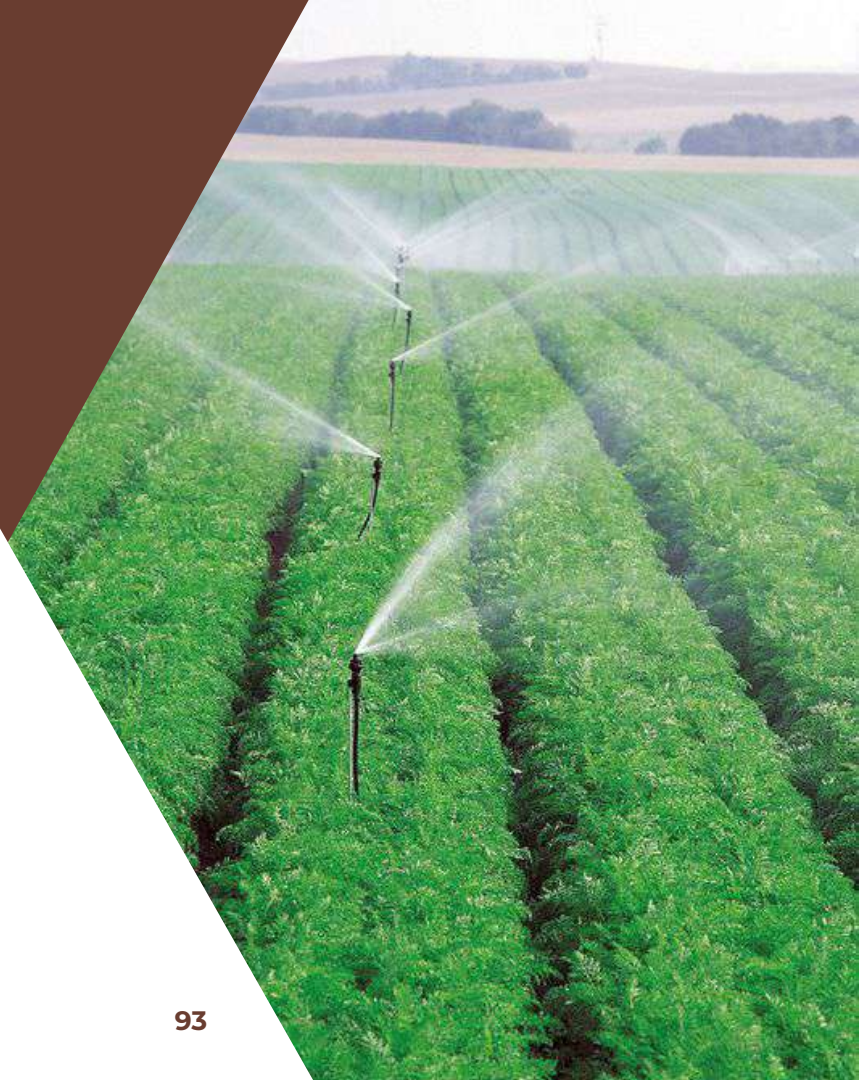
(i) Drip irrigation uses pipes and tubes ending with micro-tubes with pores/drippers near the roots zone of plants to deliver the water drop by drop. This minimizes water loss through evaporation and runoff and ensures that plants receive the right amount of moisture. By ensuring supply of nutrients directly to the root zone and in the right amount, plants can grow optimally, resulting in increased yields and improved crop quality. Additionally, the precise application of water helps in preventing weed growth, reducing competition for resources and minimizing the need for herbicides.

Drip irrigation is largely adopted in states like Maharashtra, Andhra Pradesh and Tamil Nadu. According to FAO, drip irrigation is suitable for all types of soils and row crops, vegetables, fruits, tree and vine crops where one or more emitters can be provided for each plant.

Micro Irrigation

(ii) Sprinkler refers to a technology that sprinkles water over the plants (like natural rainfall) across the field. The impact of water droplets hitting the ground can help break up compacted soil, promoting better infiltration and drainage. It is largely adopted in states like Haryana, Rajasthan and Madhya Pradesh. According to FAO, sprinkler irrigation is suited for most row, field and tree crops. Water can be sprayed over or under the crop canopy using sprinklers.

Several government schemes, subsidies and organizational support are available to support farmers in adopting micro irrigation systems, further incentivizing their implementation. However, it is worth noting that the government subsidies have had a patchy success rate in India. Key issues include (i) non-alignment of plans and priorities between Central & State governments (ii) challenges at farmer level in availing these subsidies



Micro Irrigation - Sprinkler Irrigation

Benefits to the Environment

- Sprinklers have water-use efficiency of up to 70%, compared with 35-40 % efficiency in surface method of irrigation.[3]
- Sprinklers eliminate the loss of water occurring as seepage in earthen channels and through run off.[1]

Benefits to the Farmer

- Using sprinklers makes the available water last longer as compared to flood irrigation.[1]
- Light and frequent irrigation using sprinklers avoids yield loss from terminal heat.[1]
- Sprinklers can be used in lands with undulating topography, therefore, saving levelling costs.[1]
- Sprinkler irrigation leads to savings on labour hired for irrigation.[1]
- Sprinklers are easily portable and can be used in different crops based on need.[1]
- A study by ICAR on pulses production in Hamirpur (UP) showed that sprinkler irrigation saved upto 40% of water and increased the yield by 35%.[2]
- Using sprinkler irrigation, Groundnuts (in Gujarat) showed a 24% average increase in productivity.[4]

1 - Sprinkler manual by Jain Irrigation, India
2 - Successful Demonstration of Sprinkler Irrigation System in Pulses Production in Hamirpur District of Bundelkhand Region.
3 - Narayanamoorthy, A. (2009). Drip and sprinkler irrigation in India: Benefits, potential and future directions. India's water future: Scenarios and issues. Strategic Analyses of National River Linking Project of India.
4 - IIE Initiative. IIM Ahmedabad-Gujarat. Report on Socio-Economic Impact Survey of the Micro Irrigation (MI) Scheme Implemented by GGRC in Gujarat.

Micro Irrigation - Drip Irrigation

Benefits to the Environment

- The on-farm irrigation efficiency of drip irrigation systems can be as high as 90% compared with 35 to 40 % efficiency in surface method of irrigation.[4]
- In drip systems with fertigation, fertilizer usage is reduced (upto ~50%) as it is targeted directly at the plant roots, benefits the soil health and controls groundwater contamination as appropriate quantities of fertilizer reduce leaching.[2]
- The use of drip irrigation in wheat and rice resulted in a 50% energy savings for water pumping.[5]
- The precise application of water helps prevent weed growth resulting in less weedicide application.

Benefits to the Farmer

- A study conducted by IIM-A in Gujarat (with 2774 farmers adopting drip systems) showed a mean increase in productivity in the range of 25% to 30% for crops like cotton, banana, castor, vegetable and orchard crops.[6]
- According to Rivulis Irrigation, a representative potato farmer had 19% higher yield as compared to flood-irrigated land while a sugarcane farmer had a 47% higher yield.[3]
- Fertigation leads to savings in labour hired for irrigation and weedicide costs (as it applies fertilizer directly to plant roots leading to a limited scope of weed growth).[1]
- Drip irrigation has shown uniformity in grain size and early maturity of crops.[5]

1 - Conversations with experts
2 - Patel Neelam. (2017). Precision Farming Development Centres Research Findings on Fertigation Techniques.
3 - Success Stories from Rivulis. Official website- https://www.rivulis.com/
4 - Narayanamoorthy, A. (2009). Drip and sprinkler irrigation in India: Benefits, potential and future directions. India's water future: Scenarios and issues. Strategic Analyses of National River Linking Project of India.
5 - Wheat and Rice manual as shared by Jain Irrigation
6 - CIIE Initiative. IIM Ahmedabad-Gujarat. Report on Socio-Economic Impact Survey of the Micro Irrigation (MI) Scheme Implemented by GGRC in Gujarat

Micro Irrigation - Sprinklers and Drip Irrigation

Observations from the Ground

Drip Irrigation:

- Government subsidizes upto 90% on drip systems investments from farmers. However, the upfront expense required remains considerably high for a smallholder farmer.
- Soluble fertilizers should be used if fertigation is done using drip systems. This increases the fertilizer costs since the govt doesn't subsidise soluble fertilizers. However, this increased cost can be offset by the yield increase.
- All farmers were satisfied with their investment in drip irrigation which was majorly driven by yield increase. A farmer in Haryana observed a 100% increase in tomato yield; a farmer in Nandol (Gujarat) observed a 30-40% increase in yield, 20% water savings and applied ~40% lesser amount of fertilizers using fertigation; a farmer in Satara (Maharashtra) could grow vegetable crops after installing drip irrigation, and his maize yield increased by 50%.

Challenges in Adoption

- High initial investment even after subsidy.[1]
- Awareness and ease of getting government subsidy is a challenge for farmers.[1]
- In the case of drip irrigation, farmers psychologically feel sufficient water is not being applied to the crop since its not visible, making them hesitant to opt out of flood irrigation.[1]
- Due to a lack of available credit, small farmers face challenges in investing in the upfront costs to setup a micro irrigation systems.[1]
- Damage caused by wild animals and lack of fencing leads to significant maintenance costs.[1]
- Poor after-sales service and non-availability of spare parts and skilled labour makes maintenance difficult for farmers.[2]

1 - Conversations with experts
2 - Report on Socio-Economic Impact Survey of the Micro Irrigation (MI) Scheme Implemented by GGRC in Gujarat. Written by CIIE Initiative, IIM Ahmedabad.

Micro Irrigation - Sprinklers and Drip Irrigation

Potential Opportunity

Drip Irrigation is a proven technology to help conserve water and improve yields. Despite the subsidies provided by the government, its adoption still remains low among smallholder farmers because of the high upfront costs and issues in getting the subsidies. To solve for these challenges: (i) Agri tech financing companies can provide credit for such solutions (ii) Technology innovations such as low-cost drip solutions (as manufactured in India; suitable for 0.25 to 1 acre in the range of INR 10,000 - 25,000) can lower costs. There are also now efforts using data and technology to make the government subsidy schemes more accessible to farmers.

Farmers can avail government subsidies to install drip and get benefits of higher yields.

"I installed drip using subsidies from the government. My fertilizer cost went up by almost 40% due to unsubsidized fertilizers for drip, but the yield doubled, clearly offsetting the increased fertilizer cost and increasing my net income substantially."

Crop Protection

Integrated Pest Management

Farmers in India have been facing a lot of crop yield losses due to pests and diseases attack. According to our research, pests & diseases is the biggest challenge for irrigated farmers. Pest populations have also been increasing significantly in the last 5 years. Pesticides have been the mainstream way to deal with this issue. Integrated pest management (IPM) system uses various techniques: biological, mechanical, cultural, and chemical, in an appropriate manner to maintain pest populations at levels below those causing economically unacceptable losses. It is a cost-effective, environmentally sound & socially acceptable method of controlling pests, diseases & weeds.

Biological control involves the augmentation and conservation of natural enemies of pests such as insect predators, parasitoids, parasitic nematodes, fungi & bacteria. It also includes biopesticides like Azadirachta Indica - Neem based biopesticides.

Mechanical methods include using light traps (*as shown in the picture at right*), pheromone traps (*as shown in the picture on the next slide*), sticky pads, growing border crops (eg. maize with cowpea) & trap crops, handpicking & destruction of various insect stages.

Integrated Pest Management

Cultural methods include regular farm operations like crop rotation, fallowing, manipulation of planting and harvesting dates, etc. These help in killing the eggs of pests hence reducing their growth in the next season.

Chemical controls involve the usage of chemical pesticides as the last resort when all other methods to control pests fail, however, in reality, chemical pesticides are used in parallel to other control methods.

Farmers who practice IPM do a combination of the practices mentioned, and might not do all of these.

The key to effective IPM is good localized advisory (manual or AI-based) which is based on surveillance, and other inputs which help determine the types of methods required and the timing based on the severity and frequency of current and likely pest attacks.

A major challenge to adoption is the lack of confidence of farmers in IPM; they tend to spray chemicals at the first few incidences of pests rather than following the step-by-step advisory. Hence practically as of now biological, mechanical, and cultural methods are used as an add-on method of pest control, instead of being the main practice.

Integrated Pest Management

Benefits to the Environment

- IPM leads to improvement in soil health and reduction in emissions because of reduced application of chemical pesticides, use of biopesticides, and cultural control methods.[1]
- It ensures better outcomes for surface & groundwater quality and less contamination by pesticides: an investigation in Telangana showed that water bodies contained no residue after 3 years of IPM practiced by farmers.[1]
- Biodiversity is conserved through IPM as biological or cultural methods don't destroy the natural enemies of pests.[1]

Benefits to the Farmer

- Through IPM, pulses have seen a 15-20% yield increase; NCIPM research mentioned a 20% average yield increase.[1]
- Studies by DPPQ&S (Directorate of Plant Protection, Quarantine & Storage) show a reduction in chemical pesticide spraying due to IPM usage: 50-100% in rice and 30-50% in cotton, thus reducing costs significantly.[1]
- Buyers who focus on low-residue products are willing to pay a premium price for products produced using IPM methods.[2]

1 - Gupta, Niti et al. (2021). Sustainable Agriculture in India 2021.
2 - Primary Research done by TASF Team with Chilli Farmers in Telangana

Integrated Pest Management

Observations from the Ground

- A visit to Warangal, Telangana by the TASF team in April 2023 showed a reduction in pesticide usage for chili crop by IPM farmers, as well as a higher selling price of produce.[2]
- Farmers from Nanded and Bidar in Maharashtra mentioned using mechanical methods of pest control like pheromone traps or sticky pads, after which they use chemical pesticides as the last resort. They also saw a decline in pesticide cost by 20% and also an improvement in yields, due to lesser losses.[3]

Challenges in Adoption

- There are a number of players providing advisory for adopting IPM, but there hasn't been an in-depth assessment of its effectiveness.
- Farmers lack confidence in IPM methods and mostly use IPM as an additive instead of primary practice.
- IPM is a knowledge-intensive practice, so field demonstrations and trials are more difficult to do, which makes its adoption at scale harder. [1]

1 - Gupta, Niti et al. (2021). Sustainable Agriculture in India 2021.
2 - Primary Research done by TASF Team with Chilli Farmers in Telangana
3 - Primary Research done by TASF Team in Maharashtra

Integrated Pest Management

Potential Opportunity

IPM is a knowledge-intensive practice that requires advisory and training. Farmers feel it is risky as they have a lack of confidence in these methods. Hence, there is an opportunity for buyers who procure low-pesticide produce to provide farmers a premium for the IPM produce and also support with advisory.

These companies can also collaborate with input companies that provide tools like pheromone traps, light traps, sticky pads, etc. to support the practice. As IPM improves the quality of food and reduces chemical pesticide usage, philanthropies & CSRs interested in this space can help adoption by funding NGOs who work on its adoption.

Farmers who practice IPM do a combination of advised practices and then use pesticides when the pest attack increases.

> *I use pheromone traps and sticky pads to control the pests. But when I see that pests have gone up, I tend to use pesticides. Using IPM, I have reduced my pesticide usage and costs significantly.*

Path Forward on Adoption of Agri-IKIGAI Solutions

Identification of Agri-IKIGAI solutions was the first step in our journey. The Nudge Institute (TNI) will now focus on the adoption of these practices via pathways such as:

Business Partnerships

We would work with buyers who are interested in selling products grown using Agri-IKIGAI solutions and work with them to scale these practices.

As a first step in this journey, we are conducting some pilots in the 2023 Kharif season with partner organizations to validate the impact.

Direct to Farmer

We would like to share the knowledge about these beneficial yet practical practices with farmers:

- We would work with progressive and lead farmers and encourage them to adopt and spread these practices.
- We would spread awareness via media platforms like youtube, etc.

Government

We would like to work with the government and influence policy decisions and divert the government's budget effectively on these Agri-IKIGAI solutions.

TNI is engaging with the central and state governments through various initiatives like Indian Administrative Fellowship and End Ultra Poverty as of now.

Ecosystem

We would work with ecosystem players such as NGOs and Philanthropies working in this space.

We will share our learnings with them and help them include these practices in their work and help philanthropies fund projects on these solutions.

Path Forward on Adoption of Agri-IKIGAI Solutions

Business Partnerships: One of the pathways for adoption is partnership with businesses. We are working on the following pilots in the near term to demonstrate impact and to engage with buyers.

Direct Seeded Rice

We are participating in pilots in Kharif 2023 with:

- WRMS
- Sehgal Foundation

Integrated Pest Management

We are participating in pilots in Kharif 2023 for Minimum Residue Paddy Crop with

- WRMS
- Olam

Zero Tillage Machinery

We are planning to participate in pilots in Rabi 2023 for Wheat Crop.

THANK YOU